



Support Preparation of Legislation on Trailers Certification

**Procedure no:
CLIMA.C.4/SER/2019/0003**

**Task 1. Determination of a
classification system for O3 and
O4 category vehicles and rigid
lorry bodyworks for their effect
on the CO₂ emissions / fuel
consumption of the towing
vehicle / base vehicle**

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Acronyms and abbreviations

Acronym	Meaning
ACEA	<i>European Automobile Manufacturers Association</i>
CLCCR	<i>International Association of the Body and Trailer Building Industry</i>
EMS	<i>European Modular System</i>
HDV	Heavy Duty Vehicles
ICCT	International Council on Clean Transportation
RRC	Rolling Resistance Coefficient
TPMLM	Technically permissible maximum laden mass
VECTO	Vehicle Energy Consumption calculation TOol

Definitions

Term	Definition
Chassis-cab	An incomplete vehicle with a cabin (complete or partial), chassis rails, power train, axles and tyres which is intended to be completed with bodywork, customised to the needs of the transport operator according to Regulation (EU) 2018/858 (revision of 2007/46/EC), Annex I, Part C, (4)
CO ₂ -Factor	Ratio of two CO ₂ -values as results from VECTO for vehicles with the final body and equipment in the nominator and the results for the generic body and equipment in the denominator.
CO ₂ -value	Result from the simulation tool for vehicles in the units [g/km], [g/pass.-km],[g/t-km] or [g/m ³ -km]
DA	Code for semi-trailer according to Regulation (EU) 2018/858 (revision of 2007/46/EC), Annex I, Part C, (5).
DB	Code for Drawbar trailer according to (EU) 2018/858 (revision of 2007/46/EC), Annex I, Part C, (5).
DC	Code for Centre-axle trailer according to (EU) 2018/858 (revision of 2007/46/EC), Annex I, Part C, (5).
HDV	Vehicles with type approval according to Regulation (EC) 595/2009 and its amending Regulations”
LDV	Vehicles with type approval according to Regulation (EC) 715/2007 and its amending Regulations”. These are officially called “Light Passenger and Commercial vehicles”
Lorry	A vehicle that is designed and constructed exclusively or principally for conveying goods which may also tow a trailer according to Regulation (EU) 2018/858 (revision of 2007/46/EC), Annex I, Part C, (4). Lorries cover chassis-cab HDVs, vans and tractors.
Rigid Lorry	A lorry that is not designed or constructed for the towing of a semi-trailer and that is not a van; according to point (17) in Article 3 of the upcoming amendment of regulation (EU) 2017/2400
Tractor	A towing vehicle that is designed and constructed exclusively or principally to tow semi-trailers according to Regulation (EU) 2018/858 (revision of 2007/46/EC), Annex I, Part C, (4)
Trailer	Any non-self-propelled vehicle on wheels designed and constructed to be towed by a motor vehicle, that can articulate at least around a horizontal axis perpendicular to the longitudinal median plane and around a vertical axis parallel to the longitudinal median plane of the towing motor vehicle
Semi-trailer	A towed vehicle in which the axle, or axles are positioned behind the centre of gravity of the vehicle (when uniformly loaded), and which is equipped with a connecting device

Term	Definition
	permitting horizontal and vertical forces to be transmitted to the towing vehicle
Light Lorry	N1 and N2 not exceeding 5 tons maximum mass with engine type approval according to Regulation (EU) 595/2009 and a reference mass exceeding 2610 kg
Medium Lorry	N2 exceeding 5 tons and not exceeding 7.4 tons maximum mass with engine type approval according to Regulation (EU) 595/2009 and a reference mass exceeding 2610 kg
Heavy Lorry	N2 exceeding 7.4 tons maximum mass and N3 with engine type approval according to Regulation (EU) 595/2009
Sleeper cab	Type of cabin that has a compartment behind the driver's seat intended to be used for sleeping
Primary Lorry	Lorry with complete chassis, engine, transmission, axles, tyres and auxiliaries but with standard body or semi-trailer for declaration of the vehicles CO ₂ -value
Complete(d) Lorry	Lorry with its final body and equipment for declaration of the CO ₂ -Factor
Final body and equipment	Body, auxiliaries and any other equipment mounted to a Primary Lorry or a Primary Bus until the final stage, which changes weight, aerodynamics or auxiliary power consumption in the input data of the simulation tool.
Standard body or trailer	Body, trailer or semi-trailer defined in Appendix 4 to Annex VIII with standardised dimensions for air drag testing of lorries and with generic mass as input for the CO ₂ calculation tool

Executive Summary

Context and objectives

This report is part of the work developed in the project *Support Preparation of Legislation on Trailers Certification*, for DG CLIMA under the contract CLIMA.C.4/SER/2019/0003.

The aim of this project is to develop a detailed certification methodology for determining heavy-duty vehicles (HDV) CO₂ emissions, fuel and energy consumption with regards of their bodies and trailers, on the basis of technical properties of their components, such as engine, transmission, tyres and also aerodynamic drag, together with an extension of VECTO (Vehicle Energy Consumption calculation Tool). To achieve this, the project aims to:

- **Define a classification system** for O4 category vehicles and rigid lorry bodyworks for their effect on the CO₂ emissions and fuel consumption of the towing vehicle / base vehicle.
- **Define a certification methodology** including the development of test requirements for determining the necessary inputs for the IT tool(s) used for CO₂ emissions / fuel consumption calculations and the definition of the algorithms, standard values and generic equations to be used for the CO₂ emissions / fuel consumption calculations.
- **Develop and validate the required IT tool.**
- **Provide legislative support** throughout the project concerning the content of the technical annexes of a draft regulation.

To this purposes, the main goal of Task 1 has been the development of a classification system for semi-trailers and trailers and a separate one for rigid lorry bodyworks to be used as a basis for future legislation that can be a CO₂ standard, labelling or other type of regulation aiming at exploiting the CO₂ reduction potential of those vehicles and bodyworks.

Considering that the classification system shall reflect a clear consensus and also take into account the position and feedback of stakeholders, including industry and Member States, and be approved by the Commission services, a consultation has been made in order to achieve this goal.

A matrix has also been developed for the classification of aerodynamic devices (rear flaps, side skirts, or other aero devices) that can be added to the semi-trailers, trailers and rigid lorry bodies.

Abstract of this deliverable

The report starts with a review of the data obtained from the project *Bodies and trailers – development of CO₂ emissions* project (CLIMA/C.4/SER/OC/2018/0005) in order to use it as an input for the work developed within the current task.

Following, the classification system for trailer and bodywork categories is developed. This is divided in two main parts, the survey analysis and results and the second part which is the classification matrices. Two different classification matrices have been made: one for semi-trailers and trailers of category O3 and O4 and another one for complete or completed rigid lorries with actual bodywork.

The classification matrix for semi-trailers and trailers of category O3 and O4 can be found in this report. With regards to complete or completed rigid lorries with actual bodywork, there has been prepared a separate report to cover specifically this kind of vehicles for the whole of the work performed within this project.

Also as part of the present report, an independent system for the classification of aerodynamic features has been created. In order to do so, the most relevant additions have been identified and, afterwards, they have been classified with a classification matrix.

Table of contents

Document information	2
Acronyms and abbreviations	3
Definitions.....	4
Executive Summary	6
Figures	9
Tables	10
1 Introduction	11
1.1 Identification of the vehicles produced in Europe	11
1.2 Methods for the determination of the CO ₂ emissions contributions of bodies and trailers	12
2 Classification system of trailer and bodywork categories	13
2.1 Survey preparation	13
2.2 Survey results	14
2.2.1 Results with relevance to Task 1	14
2.2.2 Results with relevance to subsequent tasks	18
2.3 Classification system.....	20
2.3.1 Classification matrix for trailers	21
3 Classification system for aerodynamic features	27
3.1 Identification of features and definitions	27
3.1.1 General prescriptions.....	27
3.1.2 Boat tail.....	27
3.1.3 Side skirts and inter-wheel panels	29
3.1.4 Leading edge and gap reducers	30
3.1.5 Under body deflectors and diffusers	31
3.1.6 Other dedicated add-on devices	31
3.1.7 Storage boxes and closed pallet boxes	31
3.1.8 Slider lifts	32
3.1.9 Refrigeration systems	32
3.1.10 Another functional add-on	32
3.1 Add-on classification matrix.....	32
4 Summary and conclusions	35
5 Bibliography	37
Annex 1 – Survey questions.....	38
Annex 2 – Study of boat tails.....	59
Annex 3 – Add-on matrix combinations.....	62

Figures

Figure 1. Pie chart of the nature of organisations participating in the survey (source: survey).....	14
Figure 2. Survey result to the question: “Do you foresee any difficulty for the vehicle manufacturers/multi-stage manufacturers to classify their vehicles according to variants based in the aspects previously defined” (source: survey)	17
Figure 3. Survey results on the importance of possible input parameters for semi-trailers and trailers (higher values mean more importance) (source: survey)	18
Figure 4. Survey results on the importance of possible input parameters for rigid lorries (higher values mean more importance) (source: survey).....	19

Tables

Table 1. Share of O4 vehicles and semi-trailers in Europe (source: survey and EEA).....	11
Table 2 Order of relevance of parameters affecting CO ₂ emissions (source: survey)	14
Table 3. List of different bodyworks from Annex I, Appendix 2 of Regulation (EU) 858/2018, grouped with colours (source: survey)	17
Table 4. Vehicle groups for semi-trailers	21
Table 5. Vehicle groups for link semi-trailers.....	22
Table 6. Vehicle groups for converted dollies.....	22
Table 7. Vehicle groups for drawbar trailers	23
Table 8. Vehicle groups for link trailers	24
Table 9. Vehicle groups for centre-axle trailers	24
Table 10. Legend for vehicle group number	25
Table 11. Add-ons classification.....	33
Table 12. First iteration matrix	34
Table 13. Second iteration matrix.....	35

1 Introduction

1.1 Identification of the vehicles produced in Europe

In order to develop a classification system for trailers, semi-trailers and rigid lorries, an analysis of the European fleet of commercial vehicles is needed. This analysis has been found in the *Bodies and trailers – development of CO₂ emissions* project (CLIMA/C.4/SER/OC/2018/0005).

The results from Task 1 of the abovementioned project were based on a manufacturer's dataset and a consultation with organizations representative of the industry. Although it is a very detailed analysis, it does not represent strictly the full market reality in Europe. In order to compare and update this data, also Monitoring and Reporting data on heavy-duty vehicles new registrations in Europe, published by the European Environment Agency (EEA), has also been considered. According to both the analysis and the monitoring, the following outputs have been identified and used as a base to obtain an initial classification of the vehicles produced in Europe and can be summarised in the following statements:

Table 1. Share of O4 vehicles and semi-trailers in Europe (source: survey and EEA)

	Output from <i>Bodies and trailers</i> project	According to EEA monitoring data
Share of O4 category vehicles in Europe (rest are O3)	99,5%	97,65 %
From the O4 category, share of semi-trailers	80%	86,7% (excluding the special purpose vehicles and DE rigid drawbar trailers)
Share of semi-trailers that are box-body type, which include: curtain-sided, dry box and reefer semi-trailers	66%	< 60%

- Among O4 semi-trailers, vehicles with three-axle configuration are the most common, covering up to 99 % of the market. The second most common are two-axle vehicles, with four-axle vehicles mostly non-existent.
- Box body type trailers have higher annual mileages than most non-box types. However, data on average mileage of semi-trailer is scarce.
- With regards to rigid lorries, the split between weight categories showed no significant differences one another. Representing N2 a 59,5% of the market and N3 the other 40.5%. The largest categories are flatbeds, dry box and tippers, each covering around 25% of the market.
- The contribution to the relative impact on CO₂ emissions of each body type is based on its share in the vehicle fleet. This means that semi-trailers contribute to 80% of the fleet emissions and trailers 20%.

As a result of the information obtained from the statements above, the vehicles which have been taken into account within the classification system in the current project are box body types of the O4 category vehicles (for trailers and semi-trailers classification) and box body types of N2-N3 category vehicles (for rigid lorries classification).

1.2 Methods for the determination of the CO₂ emissions contributions of bodies and trailers

With the purpose of developing a classification system that considers the different parameters which affect the CO₂ emissions evaluation, the job performed in Task 3 – “Detailed assessment and implementation plans for the most suitable and feasible methodology options” from the project *Bodies and trailers – development of CO₂ emissions* (CLIMA/C.4/SER/OC/2018/0005) has been considered.

The conclusion in that project was that weighting is the most suitable option for the mass calculation, and the tyre label given by the tyre manufacturer the best option to assess the rolling resistance coefficient, and so this is how it has been considered in the current project. From the four methods evaluated (method A, B, C1 and C2), the main difference was the way the value of C_{DXA} is obtained.

Different methodology is used for trailers (and semi-trailers) and rigid bodies, as there are fundamental characteristics between the vehicles of these categories, hence it is not possible to apply one single method to cover whole typology of vehicles.

The impact on the CO₂ emissions due to the addition of aerodynamic features to semi-trailers, trailers and bodyworks also needs to be analysed. It has therefore been developed, within current Task 1, a classification system for aerodynamic features including functional add-ons and add-ons dedicated to reducing the aerodynamic coefficient.

Further details of the methods used can be found within Task 2 of this project.

2 Classification system of trailer and bodywork categories

The classification system for semi-trailers, trailers and rigid trucks has considered two main issues:

- A. The classification strategy must comprise all relevant parameters that are needed for component certification and simulation of the CO₂ values.
- B. The classification must support customer demands for information and limitations in applying fuel saving technologies (e.g. differentiation according to body styles)

In order to develop a classification system that would take into account the issues mentioned above, communication with the main stakeholders has been ongoing throughout the whole progression of Task 1. Furthermore, a survey has been conducted among the stakeholders with the aim of obtaining feedback on the evolution of the classification system in order to include the stakeholders' concerns.

With the knowledge of IDIADA's experts and using the information gathered from *Bodies and trailers – development of CO₂ emissions* (CLIMA/C.4/SER/OC/2018/0005) project, which is briefly summarised in the introduction section of the current task, a preliminary classification matrix has been developed. This initial classification has been sent to the stakeholders within the survey, along with other relevant questions which could contribute to the development of the current and also subsequent tasks.

2.1 Survey preparation

The survey, which can be found in “Annex 1 – Survey questions” has been divided into different parts, according to the information obtained from each part.

Part I has as a main objective the collection of information in order to develop a well-defined purpose-built classification system for semi-trailers, trailers and rigid lorry bodyworks in different groups, which will be the basis of a future CO₂ legislation for real bodyworks and trailers. This part contains the preliminary classification system that consists in two classification matrices, one for rigid lorries and one for semi-trailers and trailers. It also includes questions regarding the classification matrices in order to identify any missing topic that might have not been taken into account initially.

Part II and III of the survey have been dedicated to the compilation of data with regards to vehicle specifications and technology features that need consideration in the time of developing a methodology for the determination of the CO₂ emissions and for the definition of generic 3D towing vehicles for trailers and semi-trailers needed for the simulation tool.

In addition, with the aim of determining the current use and availability of aerodynamic features, questions respecting these devices have been also included in the survey (Part IV). This fourth part of the survey has been used for the development of the classification system for aerodynamic features in section 3 of this task.

Finally, Part V of the survey has only been asked to trailer, body or aerodynamic device manufacturers in order to establish the level of knowledge and possible difficulties when using certain methodologies to measure aerodynamic performance. Due to limited

number of replies received on this part, the results have not been included in this task as they have not led to any clear conclusion.

The survey has been sent to 22 participants with different nature organisations which include, professional organisations and private enterprises in majority but also public authorities, academic/research institutions, international organisation, etc. Figure 1 shows the percentage of participation for each type of organisation. The questions of the survey have been chosen in order to cover all the aspects that can affect not only vehicle manufacturers, but all type of organisations involved in the process.

Nature of organisations

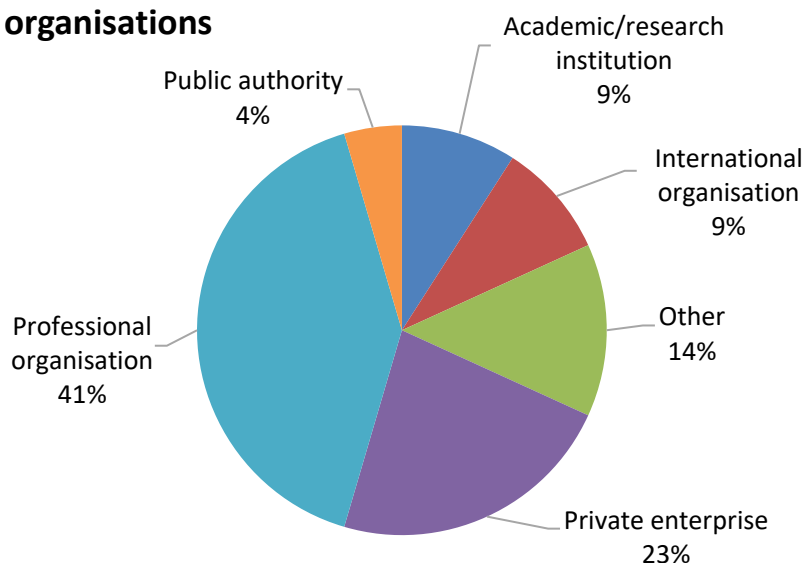


Figure 1. Pie chart of the nature of organisations participating in the survey (source: survey)

2.2 Survey results

2.2.1 Results with relevance to Task 1

The first issue to be addressed is related to which relevant parameters could affect the CO₂ emissions and thus shall be included in the classification matrix. The conclusion has been that the type of trailer and its body type, the number of axels and tyres per axle, the total permissible mass and the possibility of being a volume-oriented cargo area are all relevant parameters and should be included in the classification. The order of relevance and the main reason of each parameter's importance can be seen in Table 2.

Table 2 Order of relevance of parameters affecting CO₂ emissions (source: survey)

Classification parameter	Conclusion
Body type	Very important for Air-drag
Number of axles	Important for rolling-resistance

Type of trailer (DA, DB, DC)	Important for choosing the generic towing vehicle and for Air-drag
Number of tyres per axle	Important for choice of tyres (and rolling-resistance)
Volume oriented cargo area	Important for dimensions
Total permissible mass	Influence already covered by parameter "Number of axles"

According to the opinion of the respondents and further discussions (especially with CLCCR), the type of trailer and the body type are such important concepts due to their high relevance on terms of Air-drag, and for choice of the generic towing vehicle.

The discussions have raised that in the case of volume-oriented towed vehicles the reference load in VECTO simulations has to be lower than that of standard vehicles, which normally results in lower CO₂ emission in CO₂g/km, higher value in CO₂g/tkm and lower value in CO₂g/m³km.

In this regard, most of respondents coincided in the fact that volume-oriented vehicles are defined by an internal height $\geq 2,900\text{mm}$ with an external height of $\leq 4,000\text{mm}$ (reference is made to White book for (Semi-) trailers, December 2018), which have high relevance for aerodynamic result due to the space underneath the vehicle for air-flow. It is important to highlight that the efficiency of trailers shall not only defined by mass of payload, but also in available internal space. Especially in availability of amount of load carriers.

Most of the respondents raised the fact that kinetic/potential energy is related to actual mass and not to permissible mass, however, it is clear that there is a relationship between the number of axles and total permissible mass. For this reason, after the consultation there have been several discussions with the stakeholders and the European Commission and finally it has been considered appropriate to keep the total permissible mass on the axle assembly as a relevant classification parameter for the vehicles.

The number of axles is related to the specific cargo mass and is relevant for rolling-resistance, as well as number of tyres per axle and choice of these tyres. Tyres heavily influence energy losses in drivetrains. Friction in tyres can be reduced with tyre pressure regulation systems. Up to 2.5% according to ICCT for complete tractor-trailer (source: p.48 of https://theicct.org/sites/default/files/publications/EU-HDV-Tech-Potential_ICCT-white-paper_14072017_vF.pdf).

In addition, it was also a discussion topic that there is a significant energy loss at the axles because of the wheel bearings, however it is not being considered as an input parameter for the current project due to the complexity of determination and the lack of a fully-defined and agreed test procedure.

Despite this initial classification matrix has been received positively by vast majority of the respondents, there were concerns about using this classification system with longer and heavier vehicle combinations (e.g. EMS), which may be difficult, and also considering national weight and dimension restrictions. Furthermore, topics on additional parameters, which may be relevant to a greater or lesser extent, have been introduced into the discussions during and after the consultation:

- To include differentiation between standard trailers and volume-oriented trailers.
- To cover the use of EMS.
- To consider the energy consumption of body equipment and the positive effect of an electric axle (reuse of recuperated energy).
- To include pallet-box configuration (especially the existence of a front box in front of the trailer wheels, which has impact on the aerodynamics).
- To extend the bodywork type options (the Air-drag of the goods transported on a flat bed or drop side determines the real Air-drag of the combination in practice. When loading equipment is mounted on a flat bed or drop side, like loading cranes, this influences the Air-drag considerably).

The inclusion of differentiation between standard trailers and volume-oriented trailers has been considered a good improvement on the classification matrix, as it has high relevance on efficiency of load carriers and also its internal body height in combination with tyre sizes.

On the other hand, the inclusion of specific devices (as a pallet-box) and equipment in the classification matrix does not provide additional information and only increases the complexity of an already complex classification system. These parameters are considered as input parameters for the VECTO when defining the vehicle but are not relevant in order to classify it.

Other bodyworks types out of the box-body type are not being considered in this project due to infinite possibilities of different goods to be transported. This could be further analysed in a future extension of the project.

The large number of different EMS configurations and the lack of a common regulatory framework within European countries, where each country establishes different requirements based on national laws, have been the main reason to determine the use of the vehicle into an EMS not being yet part of the classification.

As it is common that the vehicles covered in this project can be subject to multi-stage manufacturing, it is important to consider the difficulties that could show up when sorting out the vehicles with the proposed parameters. It can be seen in Figure 2. Survey result to the question: "Do you foresee any difficulty for the vehicle manufacturers/multi-stage manufacturers to classify their vehicles according to variants based in the aspects previously defined" (source: survey), that in general terms respondents do not foresee big difficulties, neither for complete vehicle manufacturers nor multi-stage manufacturers, on classifying the vehicles according to the initially proposed parameters. In addition, when asked about the need of a different classification system for complete and multi-stage vehicles the 95% of the respondents answered no. However, they stated that responsibility for classification should not fully be carried over to the last multi-stage manufacturer, but every stage builder should stay responsible for the stage he will supply in the completion of a vehicle.

Anticipation of difficulties on classifying the vehicles according to the parameters proposed:

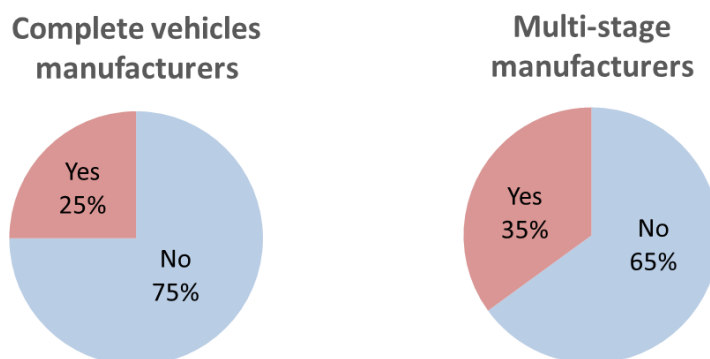


Figure 2. Survey result to the question: “Do you foresee any difficulty for the vehicle manufacturers/multi-stage manufacturers to classify their vehicles according to variants based in the aspects previously defined” (source: survey)

Notwithstanding this, several discussions appeared related to the difficulties that the multi-stage manufacturers may face when information from the incomplete vehicle’s manufacturer is required. For example, to add additional axles to the chassis of a vehicle would request a new calculation of the chassis/axle configuration where input parameters from the first stage manufacturer are necessary, and the reality is that it might be difficult to obtain this data, as some of these manufacturers are not willing to exchange their relevant data. Additional concern is that most multi-stage builders are small enterprises with focus on coach building or bodyworks, and this branch has little knowledge of air-drag and environmental effects, as well as less possibility to invest in this field.

It has also been asked to the respondents to group the different bodyworks listed in the Regulation (EU) 2018/858 (Annex I, Appendix 2) as per their general construction, shape and dimensions according to their possible contribution to CO₂ emissions.

In Table 3, a visual representation of the different groups resulting from the survey can be seen. The different colours show the bodyworks that belong to the same group of classification. It can be concluded that grouping together box body (03), refrigerated (04), conditioned (05) and curtain sided (06) type vehicles appears to be the most agreed way of grouping.

Table 3. List of different bodyworks from Annex I, Appendix 2 of Regulation (EU) 858/2018, grouped with colours (source: survey)

01 Flat bed	12 Tanker for dangerous goods	22 Glider carrier
02 Drop side	13 Livestock carrier	23 Retail or display purposes
03 Box body	14 Vehicle transporter	24 Recovery vehicle
04 Refrigerated	15 Concrete mixer	25 Ladder vehicle
05 Conditioned	16 Concrete pump	26 Crane lorry (not a mobile crane)

06 Curtain sided	17 Timber	27 Aerial work platform vehicle
07 Swap body	18 Refuse collection	28 Digger derrick vehicle
08 Container carrier	19 Street sweeper	29 Low floor trailer
09 Vehicle fitted with hook lift	20 Compressor	30 Glazing transporter
10 Tipper	21 Boat carrier	31 Fire engine
11 Tanker		

Lastly, questions regarding aerodynamic features have been asked within the survey in order to help develop a classification system for aerodynamic devices that includes all the relevant ones. The conclusion is that the aerodynamic appendices studied in task 3.6 of the *Bodies and trailers – development of CO₂ emissions* (CLIMA/C.4/SER/OC/2018/0005) project are already, or will be, available on the market, however, their use in the current European fleet is uncommon.

2.2.2 Results with relevance to subsequent tasks

To make the most out of the survey, other questions related to different parts of this project have been included. Because of the determination of the CO₂ features of a certain specific semi-trailer, trailer or rigid body shall be based on a set of relevant vehicle specifications and technology features, the second part of the survey has addressed this topic.

The results to the survey (Figure 3 and Figure 4) show that the most important parameters are mass, rolling-resistance (semi-trailers/trailers), air-drag ($C_D \times A$) and outer dimensions of the vehicle. On the other hand, it is agreed that air-drag ($C_D \times A$) is a difficult input parameter to calculate.

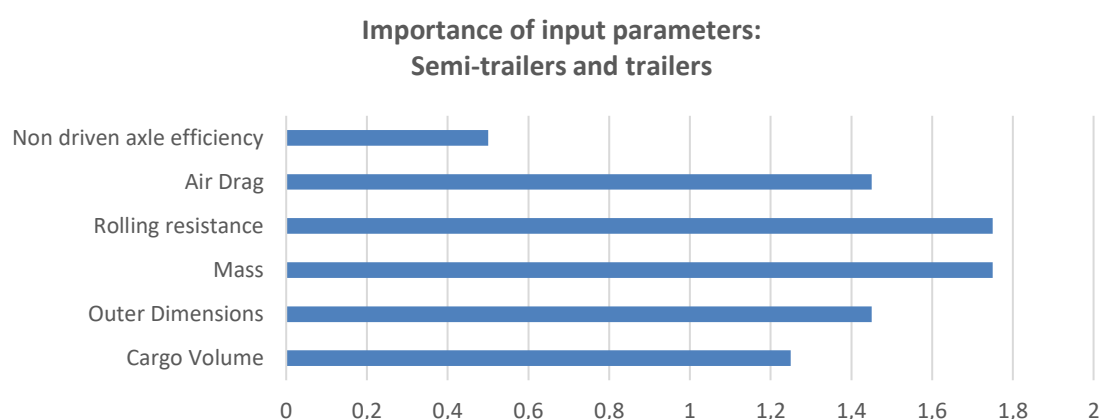


Figure 3. Survey results on the importance of possible input parameters for semi-trailers and trailers (higher values mean more importance) (source: survey)

Importance of input parameters: Rigid lorries

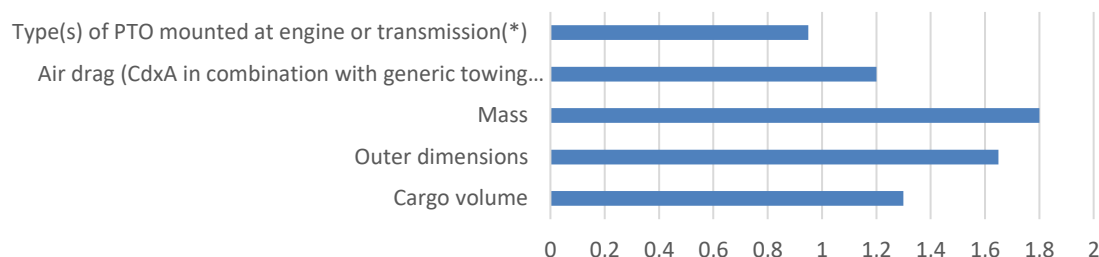


Figure 4. Survey results on the importance of possible input parameters for rigid lorries (higher values mean more importance) (source: survey)

Since trailers and semi-trailers are interchangeable and the determination of the air drag shall be based on simulation, generic 3D vehicles need to be defined to ensure the level playing field. There are some necessary inputs, which have to be taken into consideration when defining the generic vehicles, including average dimensions and emerging new technologies. Part III of the survey has proposed questions with regards this issue in order to obtain the most common configurations of tractors and rigid lorries.

The necessary inputs to be studied are the type of cabin roof, the type of cabin and the wheelbase configuration and their most common configurations are summarised below:

- **Cabin roof:**
 - **High roof** – for Tractors and Rigid lorries on Long Haul, Tractors for Distribution transport
 - **Low roof with air deflector** – for Rigid lorries on Distribution transport
- **Cabin type:**
 - **Sleeper cab** – for Long Haul
 - **Day cab** – for Distribution transport
- **Wheelbase configuration:**
 - **Tractors** – 4x2, 6x2 and 6x4 for both Long Haul and Distribution transport)
 - **Rigid lorries** – 4x2, 6x2, 6x4 and 8x4 for both Long Haul and Distribution transport)

Even though the most common configurations are the ones mentioned, the use of new technologies and additional features is expected to increase so they need to be taken into account within this project. The respondents agreed that the technology using cameras instead of side-mirrors is already available. In addition, elongated cabins, active roof spoilers and active side deflectors are expected to be available soon and widely used. About the use of panels in the rear wheels and active grill shutters there is no defined information available.

The specific results and the values obtained from the survey which resulted in the information summarised in this section (2.2.2 Results with relevance to subsequent tasks), will be specified and studied in deep subsequently in Task 2.

2.3 Classification system

Once the results of the first part of the survey have been studied, they have been implemented into the preliminary proposed classification matrix so as to update it accordingly. Also, the continuous discussions within the stakeholders during the progress meetings of the project led to the creation, by part of the European Commission, of a dedicated group of experts that would share their proposals and contributions within a Task Force: Trailer certification Task Force.

Task Force meetings started in March 2021 and re-opened the classification matrix for semi-trailers and trailers to newer considerations, which finally concluded that some O3 vehicles shall also be included in the new regulation, with the definitive most relevant parameters that are shown in section 2.3.1 and described in section 2.3.1.1.

As a result of the job done it is possible to elaborate two different classification matrices, one for semi-trailers and trailers of categories O3 and O4 and another one for rigid lorries with bodywork. The classification matrix for semi-trailers and trailers has been, at the same time, further split in 3 tables, one for each trailer type: semi-trailers, drawbar trailers and centre-axle trailers.

Both classification matrices define which groups of vehicles are subject to CO₂ determination and, with the use of different parameters, apply segmentation with boundary conditions for CO₂ emissions.

Whilst the classification matrix for semi-trailers and trailers of category O3 and O4 can be found in this report, the classification matrix for complete or completed rigid lorries with actual bodywork is described in report *Bodies&Trailers_Report_Bodies*, which is specifically dedicated to the job done within this project with regards to this kind of vehicles.

Focusing on trailers and semi-trailers, the classification matrices are currently only taking into account box body type vehicles due to their higher presence on the European roads as mentioned in the introduction section of this task. However, the assignation of a group code for each vehicle allows the future introduction of additional vehicles with different bodyworks.

In sections 2.3.1 the classification matrices for semi-trailers and trailers of category O3 and O4 can be found, together with a brief explanation of how they are composed.

2.3.1 Classification matrix for trailers

Table 4
Vehicle groups for semi-trailers

Table 4. Vehicle groups for semi-trailers

Description of elements relevant to the classification in vehicle groups				Vehicle group	Allocation of mission profile and vehicle configuration				
Number of axles	Bodywork type	TPMLM(**) axle assembly [t]	Volume orientation		Long haul	Long haul (EMS*)	Regional delivery	Regional delivery (EMS*)	Urban delivery
DA semi-trailers									
1	soft shell box body	≥ 8,0 t	No	111	5RD		5RD		5RD
			Yes	111V	5RD		5RD		5RD
	hard shell box body	≥ 8,0 t	No	112	5RD		5RD		5RD
			Yes	112V	5RD		5RD		5RD
	refrigerated box body	≥ 8,0 t	No	113	5RD		5RD		5RD
			Yes	113V	5RD		5RD		5RD
2	soft shell box body	≥ 8,0 t ≤ 18 t	No	121	5LH		5LH		5LH
			Yes	121V	5LH		5LH		5LH
		> 18 t	No	122	5LH		5LH		5LH
			Yes	122V	5LH		5LH		5LH
	hard shell box body	≥ 8,0 t ≤ 18 t	No	123	5LH		5LH		5LH
			Yes	123V	5LH		5LH		5LH
		> 18 t	No	124	5LH		5LH		5LH
			Yes	124V	5LH		5LH		5LH
	refrigerated box body	≥ 8,0 t ≤ 18 t	No	125	5LH		5LH		5LH
			Yes	125V	5LH		5LH		5LH
		> 18 t	No	126	5LH		5LH		5LH
			Yes	126V	5LH		5LH		5LH
3	soft shell box body	---	No	131	5LH		5LH		5LH
			Yes	131V	5LH		5LH		5LH
	hard shell box body	---	No	132	5LH		5LH		5LH
			Yes	132V	5LH		5LH		5LH
	refrigerated box body	---	No	133	5LH		5LH		5LH
			Yes	133V	5LH		5LH		5LH
4	soft shell box body	---	No	(141)					
			Yes	(141V)					
	hard shell box body	---	No	(142)					
			Yes	(142V)					
	refrigerated box body	---	No	(143)					
			Yes	(143V)					

(*) EMS – European Modular System

(**) TPMLM – Technically permissible maximum laden mass

RD = Regional delivery
LH = Long haul

Table 5
Vehicle groups for link semi-trailers

Table 5. Vehicle groups for link semi-trailers

Description of elements relevant to the classification in vehicle groups				Vehicle group	Allocation of mission profile and vehicle configuration				
Number of axles	Bodywork type	TPMLM(**) axle assembly [t]	Volume orientation		Long haul	Long haul (EMS*)	Regional delivery	Regional delivery (EMS*)	Urban delivery
Link semi-trailers									
2	soft shell box body	---	No	(221)					
	hard shell box body	---	No	(222)					
	refrigerated box body	---	No	(223)					
3	soft shell box body	---	No	(231)					
	hard shell box body	---	No	(232)					
	refrigerated box body	---	No	(233)					

(*) EMS – European Modular System

(**) TPMLM – Technically permissible maximum laden mass

Table 6
Vehicle groups for converted dollies

Table 6. Vehicle groups for converted dollies

Description of elements relevant to the classification in vehicle groups				Vehicle group	Allocation of mission profile and vehicle configuration				
Number of axles	Bodywork type	TPMLM(**) axle assembly [t]	Volume orientation		Long haul	Long haul (EMS*)	Regional delivery	Regional delivery (EMS*)	Urban delivery
SJ converter dollies									
2	fifth wheel unit	---	No	(321)					
			Yes	(321V)					

(*) EMS – European Modular System

(**) TPMLM – Technically permissible maximum laden mass

Table 7
Vehicle groups for drawbar trailers

Table 7. Vehicle groups for drawbar trailers

Description of elements relevant to the classification in vehicle groups				Vehicle group	Allocation of mission profile and vehicle configuration				
Number of axles	Bodywork type	TPMLM(**) axle assembly [t]	Volume orientation		Long haul	Long haul (EMS*)	Regional delivery	Regional delivery (EMS*)	Urban delivery
DB drawbar trailers									
2	soft shell box body	---	No	421	9LH		9LH		9LH
			Yes	421V	9LH		9LH		9LH
	hard shell box body	---	No	422	9LH		9LH		9LH
			Yes	422V	9LH		9LH		9LH
	refrigerated box body	---	No	423	9LH		9LH		9LH
			Yes	423V	9LH		9LH		9LH
3	soft shell box body	---	No	431	4LH		4LH		4LH
			Yes	431V	4LH		4LH		4LH
	hard shell box body	---	No	432	4LH		4LH		4LH
			Yes	432V	4LH		4LH		4LH
	refrigerated box body	---	No	433	4LH		4LH		4LH
			Yes	433V	4LH		4LH		4LH
4	soft shell box body	---	No	(441)					
			Yes	(441V)					
	hard shell box body	---	No	(442)					
			Yes	(442V)					
	refrigerated box body	---	No	(443)					
			Yes	(443V)					

(*) EMS – European Modular System

(**) TPMLM – Technically permissible maximum laden mass

LH = Long haul

Table 8
Vehicle groups for link trailers

Table 8. Vehicle groups for link trailers

Description of elements relevant to the classification in vehicle groups				Vehicle group	Allocation of mission profile and vehicle configuration				
Number of axles	Bodywork type	TPMLM ^(**) axle assembly [t]	Volume orientation		Long haul	Long haul (EMS ^(*))	Regional delivery	Regional delivery (EMS ^(*))	Urban delivery
Link trailer									
4	soft shell box body	---	No	(541)					
	hard shell box body	---	No	(542)					
	refrigerated box body	---	No	(543)					

(*) EMS – European Modular System

(**) TPMLM – Technically permissible maximum laden mass

Table 9
Vehicle groups for centre-axle trailers

Table 9. Vehicle groups for centre-axle trailers

Description of elements relevant to the classification in vehicle groups				Vehicle group	Allocation of mission profile and vehicle configuration				
Number of axles	Bodywork type	TPMLM axle assembly [t]	Volume orientation		Long haul	Long haul (EMS ^(*))	Regional delivery	Regional delivery (EMS ^(*))	Urban delivery
DC centre-axle trailers									
1	soft shell box body	---	No	611	2RD		2RD		2RD
		---	Yes	611V	2RD		2RD		2RD
	hard shell box body	---	No	612	2RD		2RD		2RD
		---	Yes	612V	2RD		2RD		2RD
2	soft shell box body	8.0 t <= 13.5 t	No	621	2RD		2RD		2RD
			Yes	621V	2RD		2RD		2RD
		> 13.5 t	No	622	9LH		9LH		9LH
			Yes	622V	9LH		9LH		9LH
	hard shell box body	8.0 t <= 13.5 t	No	623	2RD		2RD		2RD
			Yes	623V	2RD		2RD		2RD
		> 13.5 t	No	624	9LH		9LH		9LH
			Yes	624V	9LH		9LH		9LH
	refrigerated box body	> 13.5 to	No	625	9LH		9LH		9LH
3	soft shell box body	---	No	631	4LH		4LH		4LH
		---	Yes	631V	4LH		4LH		4LH

	hard shell box body	---	No	632	4LH		4LH		4LH
		---	Yes	632V	4LH		4LH		4LH
	refrigerated box body	---	No	633	4LH		4LH		4LH

(*) EMS – European Modular System

(**) TPMLM – Technically permissible maximum laden mass

RD = Regional delivery

LH = Long haul

Table 10. Legend for vehicle group number

Legend for vehicle group number			
<u>Nxx</u>	<u>Digit for bodywork type (type of trailer)</u>	<u>xNx</u>	<u>Digit for number of axles</u>
1xx	DA semi-trailers	x1x	1 axle
2xx	DA link trailer	x2x	2 axles
4xx	DB drawbar trailers	x3x	3 axles
5xx	DB link trailer	x4x	4 axles
6xx	DC centre-axle trailer		
<u>xxN</u>	<u>Digit for each sub-group</u>	<u>xxxV</u>	<u>Additional character for Volume-oriented</u>
	Serial number starting from 1 in each sub-group	xxx	No (standard)
		xxxV	Yes (volume-oriented)

2.3.1.1 Classification matrix for trailers description

As explained in the first paragraph of this section, the classification matrix for semi-trailers and trailers has been divided into three separate tables to make it more user-friendly. Each separate table corresponds to a specific trailer type: semi-trailers, drawbar trailers and centre-axle trailers. Apart from that, the parameters that are considered within the classification tables are axle configuration (first column), bodywork type (second column), Technically Permissible Maximum Laden Mass (TPMLM) on axle assembly (third column) and indication of the volume-orientation (fourth column). Then there is a column dedicated to the vehicle group code (fifth column) and the allocation of mission profile and vehicle configuration (sixth column).

The number of axles considered in a first approach was one to three axles as it is the most common configuration on the European fleet. However, due to their high relevance in some European countries, four axle vehicles have been included in the classification matrix.

A similar situation happens with regards to the type of trailer. After consultation with different stakeholders, it has been decided to broaden the classification matrix including also link-trailer vehicles due to their extended use in some European countries. Nonetheless, as they still not represent a majority in the European vehicle fleet, they

have not been considered for the development of other tasks of the current project.

The decision on which type of vehicles are considered volume-oriented or not has been obtained based on meetings done with the stakeholders after the realisation of the survey. It is prominent that the classification matrix considers the possibility of having different standard or volume-oriented vehicles other than the proposed ones; thus, coding of the vehicle group covers this situation by including an additional character for standard or volume-oriented vehicles.

Lastly, the classification matrix includes the different mission profiles and configurations possible for the vehicles studied which are long haul and regional delivery, as well the specification of the generic towing vehicle that can be used, in order to have a complete classification matrix for trailers and semi-trailers which is totally aligned with the classification included in Annex I of Regulation (EU) 2017/2400.

3 Classification system for aerodynamic features

3.1 Identification of features and definitions

Based on the standard add-ons catalogue defined in the CLIMA/C.4/SER/OC/2018/0005 [1] Task 3.6, the world-wide market offer, paying special attention to the European market in particular and the results of the survey on this task sent to the main stakeholders of this project; the most relevant add-ons have been identified and classified.

Those aero enablers included in all the European dealers such as the boat tail or the side-skirt have been categorized in accordance with the regulation applying now a days in Europe. Furthermore, some brief guidelines on the minimum requirements these devices would be recommended to include have been proposed.

3.1.1 General prescriptions

From the Annex I part C and D of the Regulation (EU) 2019/1892, amending the Regulation (EU) 1230/2012, [2] referring to the masses and dimensions of the vehicles of category N2, N3 and O, any aero device shall:

- not disturb the visibility, lamps, marking nor ventilation both when folded and deployed
- not increase the usable length of the loading area
- be lockable in both deployed and folded positions
- will not be considered for the determination of the outermost dimensions of the vehicle
- not disturb docking operations (loading/unloading at the rear)

3.1.2 Boat tail

A boat tail is a device installed on the end of the vehicle, composed by at least three panels; two of them located at the side of the vehicle at an angle to the lateral walls and one on the top, at an angle to the roof, elongating this way the total length. In configurations EMS, those elongations installed at the end of the first vehicle are not considered boat tails and will have their own classification as gap reducers.

The technical prescriptions for the boat tail and the considerations that have been taken for their classification comes from the abovementioned Regulation of masses and dimensions:

- The device should be built with materials able to resist the outdoor conditions.
- The manoeuvrability requirements specified in for trailers and semi-trailers must be fulfilled with the boat tail in the deployed position: trajectories of 360° in both direction within two concentric circles of 12,50m and 5,30m without any of the vehicle's outermost points of the towing vehicle protruding beyond the outer circle or any of the outermost points of the

trailer or semi-trailer intruding inside the inner circle (according to paragraph 3.1 of Part D, Annex I, of R(EU)2019/1892 [3])

There are special prescriptions if the boat tail is longer than 500 mm, so the considerations have been split in two groups. For those boat tails shorter than 500 mm the following considerations should be applied:

- If the trailer with the deployed boat tail does not exceed 12 meters length, the boat tail does not need to be foldable
- If the trailer with the deployed boat tail does exceed 12 meters length, the boat tail needs to be foldable at standstill situation. In this case, when folded,
 - o The maximum vehicle width can't be exceeded more than 25mm on each side of the vehicle
 - o The maximum vehicle length (12 meters) can't be exceeded more than 200mm
 - o The lowest part of the device shall be at least 1050mm above the ground level
 - o The folding and deploying operation shall be manual and not exceeding the 400N force. In addition, the operation may be done automatically

For those boat tails which exceed the 500mm,

- It must be foldable at standstill despite the total length of the trailer with the deployed boat tail. In this case, as before, when folded:
 - o The maximum vehicle width can't be exceeded more than 25mm on each side of the vehicle
 - o The maximum vehicle length (12 meters) can't be exceeded more than 200mm
 - o The lowest part of the device shall be at least 1050mm above the ground level
 - o The folding and deploying operation shall be manual and not exceeding the 400N force. In addition, the operation may be done automatically

Not only length defines the performance of these devices, but also the angle of the panels. As it is shown in "Annex 2 – Study of boat tails" and the "Aerodynamic Performance of Flat-Panel Boat-Tails and Their Interactive Benefits with Side-Skirts" SAE paper [4], different combinations of length and angles lead to different results. For this classification, the optimal combination among the several simulated ones will be defined as standard and any other combinations will be left opened as a possible improvement for aero-device manufacturers to prove.

When classifying the boat tails, the longitudinal dimension of the boat tail will provide the legal constraints as we have seen in the previous section. Nonetheless, the height of the lateral panels can also have an impact on the performance of this device and in Europe it is possible to see more than one configuration. For the sake of simplicity, one possible heights have been considered, leaving the "low" boat tail with 2 meters of height and the "tall" boat tail with 2.7 meters or the full height of the rear end of the vehicle. The reason of

installing “low” boat tails is to ensure the handler to open the rear door, when it is mounted on the same door, can be reached with the boat tail folded.

Some boat tail designs present a decreasing longitudinal length as they reach its bottom end. It has been seen in some simulations performed in this project that the effect of the panels composing these angles that start at bottom end of the “low” boat tails have almost the same effect as if they were complete “long” boat tails (see Annex 2 – Study of boat tails).

Apart from the length of the panels, boat tails can include a fourth horizontal panel below the top panel which can be located either at the bottom or in the middle of the rear end of the vehicle. These four-panel boat tails are more frequent in the USA than in Europe and tend to measure between 1 and 1.2 meters.

3.1.3 Side skirts and inter-wheel panels

A side skirt is a device installed at the lateral of the vehicle, reducing the gap between the lateral wall of the lorry or the trailer and the floor that can be composed of one or several panels which can be mounted continuously or with some gaps in between (segmented configuration, seen in some models sold in the USA). The position of these panels can be in parallel with the longitudinal axis of the vehicle or with some slight inclination of 5° seen in some American models. Depending on the length of these panels and its location, it is possible to classify the side skirts in the following groups:

- Short side skirt: in trailers, the panels are located only between kingpin and first trailer axle covering around 3-4 meters. For rigid lorries, this side skirt would cover the distance between the first and the second axle.
- Full side skirt: in trailers, the panels reach from the kingpin and rear end and leaving the wheel space open, coving about 8-9 meters. In rigid lorries, the side skirt would cover from the first axis to the rear end leaving the space of the rear axles free.
- Full side skirt with covered wheels: same configuration as the previous one but also covering the rear axle zone with panels.
- Full wrap: this variant includes an undercover deflector that connects the panels of both sides of the vehicle both at the front of the first panel and at the end of the last panel.
- Segmented side skirt: This version includes separated panels tilted few degrees with regard the longitudinal axis allowing some air flow to run under the vehicle. The reason of this separation is to ensure the brakes have some refrigeration flow.

Those geometries in which the wheels are fully covered or in which the air flow underneath the body is restricted, such as the full side skirt or the full wrap, might need some extra consideration. The reduction of air flow throughout the braking components (axles, drums/discs, callipers, brake pads, etc.) might impact negatively in its performance if its temperature increases too much. It has to be checked whether the approval of the vehicle’s braking system, according to UN

Regulation 13R11, is still valid and compatible with the installation of such devices. The current version of the regulation does not foresee any aerodynamic device nor additional feature on the bodywork (at this moment, an approval regarding the braking system of a trailer/semi-trailer does not take into account if the vehicle type is fitted with aerodynamic appendices or not). Maximum temperature for the UN Regulation 13R11 approval tests is indicated in the regulation, therefore it would need to be checked that those add-ons not installed during the approval tests (and also the after-market components) do not affect negatively to the point of invalidating the braking system approval. In order to do so, specific provisions could be introduced in the requirements of Type-III test (fade test for laden vehicles of category O4 or alternatively of category O3) included in the regulation.

Those models that leave the wheels uncovered have the option to add inter-wheel panels to cover the gap between the different axles. These panels can be part of the same side skirt or individual panels installed for this purpose.

No ground clearance is specified in any regulation, but a value between 350 and 500 mm is recommended for a better manoeuvrability and capability of driving over steep ramps (at least the free height under the skirt cannot exceed the 40% of the total wheel diameter). Large side skirts can be also a problem in northern countries where ice can be stacked on the panel [5].

The technical prescriptions for the side skirt also come from the existing regulations:

- The device should be built with materials able to resist the outdoor conditions Regulation (EU) 2019/1892 [3]
- Must not interfere with the already installed side underrun protection defined in the UN Regulation 73R01 [6]. Alternatively, the side skirt can fulfil the function of the side underrun protection if complies all requirements specified in the regulation.
- Despite this device is not considered when defining the total dimensions of the vehicle, it can add up to 100mm to the total width without exceeding the maximum allowed width and cannot exceed the rear end of the vehicle unless they are foldable, following the rules described in the previous section of boat tails.
- In case of the full side skirts, the skirt after the rear axle shall consider trailer docking operations (approach/departure) by increasing the ground clearance or with a sliding mechanism to shorten the last skirt part

3.1.4 Leading edge and gap reducers

The objective of this add-on is to minimise the distance between the tractor and the semitrailer or the first and the second vehicle in an EMS configuration by bridging it with a panel, reducing the turbulence generated in that gap.

The main concern with these devices is the interactions that may occur during the turning of the vehicle. In order to prevent this, these devices, especially the gap reducers, can have automatic systems to deploy and fold the gap reducers based on the speed of the vehicle.

The criteria to be met by this add-on in order to be valid for its certification could be:

- These add-ons both folded and deployed shall not exceed the limit of 4 meters established in the regulation.
- The width of the leading edge cannot exceed the maximum dimensions for the vehicle defined by the regulation. (2.55 meters for regular trailer/semitrailers and 2.60 meters for refrigerated trailers).
- The device should be built with materials able to resist the outdoor conditions.

3.1.5 Under body deflectors and diffusers

These add-ons are located at the under body of the trailer or truck, whether before or behind the axles, covering a great part of the under body of the vehicle or just redirecting the flow. The aim of these add-ons may vary but it can include the redirection of the airflow to prevent turbulences at the axles or compress and accelerate the airflow through the under body, so the wake generates less drag resistance.

Due to its location, the applying regulation does not have any prescription apart from the general ones.

3.1.6 Other dedicated add-on devices

Vortex generators and wheel covers were also included in the standard add-ons catalogue. Regarding the requirements, both shall fulfil the minimum requirements that have been described in the point 3.1.1. However, the effect of these devices is expected to be less impactful than the rest of the aero devices analysed before.

3.1.7 Storage boxes and closed pallet boxes

Storage boxes can be installed in trailers and semitrailers to transport a wide variety of items such as repair tools, machinery or first-aid kits. These boxes are usually installed under the chassis; either between the fifth wheel and the first axle or behind the last axle, facing the sides of the vehicle and their sizes depends on their purpose.

When considering closed pallet boxes, they may fall under this classification with the exception that they are commonly located under between the fifth wheel and the first axle and seldom under the rear overhang.

The effect of the boxes, depending on its size and whether or not they are located close to the outer edge of the under body, might be similar to the effect of a side skirt. It has to be taken into account that the volume occupied by the box on the

under body is larger than the space a side skirt might occupy and thus, the flow will present a greater alteration in an under body with boxes than in another without boxes.

3.1.8 Slider lifts

These devices are aimed to load and unload goods to the vehicle. The engine of these lifters is usually mounted under the rear overhang, taking the space that otherwise it would be used for boxes or diffusers. The platform can be either folded against the rear wall or also under the rear overhang.

3.1.9 Refrigeration systems

Reefer trailers need a refrigeration system to maintain the temperature low of the goods inside. On trailers, these refrigeration systems are located between the truck and trailer, fulfilling somehow the function of a gap reducer. On rigid trucks, the refrigeration systems are typically attached to the front of the body, in a position above the cabin.

3.1.10 Another functional add-on

In the standard add-ons catalogue other functional add-ons such as the fire extinguisher attached to the landing gear or the open pallet box were considered. Nonetheless, the aerodynamic effect of such devices is expected to be negligible compared to other items in this section and have not been developed any further.

3.1 Add-on classification matrix

In this section all the relevant add-ons have been included in a combination matrix.

The add-on matrix classification has been developed with the aim of cover as many cases as possible and, at the same time, have a reasonable number of use cases so the most relevant can be included. To this end, a series of assumptions have been taken in several iterations in order to discard those configurations that have been estimated to be unrealistic or could be less used.

The initial list contains all the above-mentioned add-ons. As it has been developed before, some of these add-ons can have several classifications but they have not been expanded in this first table:

Table 11. Add-ons classification

High impact	Boat tail	● Short low (300-500 mm; 2 m)
		● Short tall (300-500 mm; 2,7 m)
		● Long low (>500 mm; 2 m)
		● Long tall (>500 mm; 2,7 m)
	Side skirt	● Short
		● Short with inter-wheel panels
		● Full with open wheels
		● Full with open wheels and inter-wheel panels
		● Full with covered wheels
Medium impact	Storage box	● Small between kingpin and rear axle
		● Small between kingpin and rear axle both sides
		● Big between kingpin and rear axle
		● Big between kingpin and rear axle both sides
		● Small behind rear axle
		● Small behind rear axle both sides
		● Big behind rear axle
		● Big behind rear axle both sides
	Pallet box	● Closed (between kingpin and rear axle)
		● Open (between kingpin and rear axle)
Miscellaneous impact	● Refrigeration system	
	● Slider lift	
	● Leading edge and gap reducers	
	● Underbody deflector	
	● Diffuser	
Miscellaneous impact	● Other functional add-ons	

- >2% CdxA expected improvement
- < 2% CdxA expected improvement
- < 1% CdxA expected improvement
- Undefined improvement (very singular)

In a first iteration, when including the boxes in the classification matrix, the combination of shapes and sizes these boxes present would make the combinations to rise exponentially. To keep the numbers in a manageable amount, it was considered the worst case for each position being the closed pallet box between the fifth wheel and the first axle. In the rear overhang, a large box able to be installed in the standard trailer (leaving space for the spare wheels) would be enough.

A set of 25 double combinations, 40 triple combinations, 31 for four elements combinations, 12 for five elements combinations and 2 six element combinations appear after doing all the possible combinations of these devices. In total, 110 cases fully developed in “Annex 3 – Add-on matrix combinations” plus the initial 9 single items.

Table 12. First iteration matrix

	Two add-ons combinations	Three add-ons combinations	Four add-ons combinations	Five add-ons combinations	Six add-ons combinations	Total number of combinations
● Pallet box closed	7	20	21	11	2	61
● Storage box big behind rear axle	7	18	21	11	2	59
● Refrigeration system	7	18	21	11	2	59
● Side skirt full with open wheels	6	14	16	9	2	47
● Boat tail short low (300-500 mm; 2 m)	6	15	13	6	1	41
● Boat tail short tall (300-500 mm; 2,7 m)	6	14	13	6	1	40
● Inter wheel panels	1	5	9	7	2	24
● Side skirt short with inter-wheel panels	5	9	7	2	0	23
● Side skirt full with covered wheels	5	9	7	2	0	23

- >2% C_{dx}A expected improvement
- <2% C_{dx}A expected improvement

It is expected that the main impact of the boxes to the overall C_{DXA} comes from the “side skirt” effect instead of the “under body” deflector effect. Taking this into account, it is expected to see a greater impact of these devices on the polar-yaw curve instead than in the C_{DXA} at 0°. Since the polar-yaw is calculated only considering one half of the vehicle up to 10° [7], the effect of having a box on the side which is not being considered could be ignored.

Regarding the boat tails, despite long boat tails exist in the American market, they are not sold in Europe. Furthermore, the homologation of this long variant is longer and implies more steps than the shorter version. Due to these two points, it is suggested to remove them.

Under body deflectors and diffusers along with wrap skirts are not as extended in the European market as they are in the USA and they have not been considered either in the final matrix classification.

As a final consideration, leading edges have been removed from the matrix as they might appear redundant when a proper alignment is achieved between the roof deflector and the trailer. On the functional add-on side, the slider lift has been discarded from the matrix because the market offers a wide variety of models and it can be difficult to standardize one.

Considering the above-mentioned add-ons, the interaction matrix looks like this:

Table 13. Second iteration matrix

	Two add-ons combinations	Three add-ons combinations	Four add-ons combinations	Five add-ons combinations	Six add-ons combinations	Total number of combinations
● Boat tail short low (300-500 mm; 2 m)	1	-	-	-	-	1
● Boat tail short tall (300-500 mm; 2,7 m)	1	-	-	-	-	1
● Side skirt short	1	-	-	-	-	1
● Side skirt full with covered wheels	1	-	-	-	-	1

● >2% CdxA expected improvement

● <2% CdxA expected improvement

This leaves a set of 8 single combinations, being the following ones:

1. Long side skirt
2. Short side skirt
3. Short boat tail
4. Tall boat tail
5. Long side skirt and short boat tail
6. Long side skirt and tall boat tail
7. Short side skirt and short boat tail
8. Short side skirt and tall boat tail

4 Summary and conclusions

Resulting from the survey made to the main stakeholders, the following conclusions, with influence in Task 1 of the project, are drawn:

- In order of relevance, the main parameters that affect CO₂ emissions are body type, number of axles, type of trailer (DA, DB, DC), number of tyres per axle, volume oriented cargo area and total permissible mass.
- No difficulties are anticipated on classifying vehicles according to the parameters above, nor with using the same classification system for complete and multi-stage vehicles.
- The most common group of bodyworks includes box body, refrigerated, conditioned and curtain sided vehicles.

- With regards to aerodynamic appendices, they are already available on the market, however their use in the European fleet is uncommon.

Three different classification matrices have been made in this first task of the *Support Preparation of Legislation on Trailers Certification* project, for DG CLIMA under the contract CLIMA.C.4/SER/2019/0003.

Whilst the current report is containing the two classification matrices for, on one hand, semi-trailers and trailers and, on the other hand, the classification and combination of aerodynamic features that can be added to the different trailers and body-works; a third matrix for rigid lorries with bodywork is contained in the dedicated report *BodiesTrailers_Report_Bodies*.

5 Bibliography

- [1] DG CLIMA, Bodies and trailers – development of CO2 emissions determination procedure. Procedure Number CLIMA/C.4/SER/OC/2018/0005, 2019.
- [2] European Commission, COMMISSION REGULATION (EU) No 1230/2012 of 12 December 2012, 2012.
- [3] European Commission, COMMISSION REGULATION (EU) 2019/1892 of 31 October 2019, 2019.
- [4] B. R. McAuliffe and A. S. Wall, *Aerodynamic Performance of Flat-Panel Boat-Tails and Their Interactive Benefits with Side Skirts*, SAE International Journal of Commercial Vehicles, 2016.
- [5] J. M. Ortega and K. Salari, "Investigation of a Trailer Underbody Fairing for Heavy Vehicle Aerodynamic Drag Reduction," in *Commercial Vehicle Engineering Congress & Exhibition*, 2008.
- [6] UN/ECE, Regulation No 73 Revision1, 2004.
- [7] European Commission, COMMISSION REGULATION (EU) 2017/2400 implementing Regulation (EC) No 595/2009 of the European Parliament, 12 December 2017.

Annex 1 – Survey questions

General information about respondents

1.1. In what capacity are you completing this questionnaire?

☐ Public authority
☐ Academic/research institution
☐ International organisation
☐ Civil society organisation
☐ Professional organisation
☐ Private enterprise
☐ Other

1.2. If private enterprise

1.2.1. Business sector

Drop-down list of sectors

1.2.2. Is your comp any an SME? (see link to Commission SME definition in footnote¹)

☐ Yes — micro enterprise (i.e. having staff below 10, and/or turnover below €2m, and/or a balance sheet below €2m)
☐ Yes — small enterprise (i.e. having staff below 50, and/or turnover below €10m, and/or a balance sheet below €10m)
☐ Yes — medium sized enterprise (i.e. having staff below 250, and/or turnover below €50m, and/or a balance sheet below €43m)
☐ No
☐ I don't know

1.3. If professional organisation

1.3.1. Please indicate the sector(s) your organisation represents

(drop down list of sectors)

1.3.2. Where are your member companies located?

Whole EU
Drop-down list of MS + EEA countries
Drop-down list of non-EU countries

1.4. If civil society organisation

Please indicate your main area of focus (environment, energy, etc. – drop down list)

Free text (200 characters)

1.5. Please give the name of your organisation / company

Free text (200 characters)

¹ http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition/index_en.htm

1.6. If your organisation is registered in the Transparency Register, please give your Register ID number.

Free text (20 characters)

If your organisation is not registered, you can register now. Please note that contributions from respondents whose choose not to register will be processed as a separate category "non-registered organisations/business".

1.7. Please give your country of residence/establishment

Drop down list

1.8. Please indicate your preference for the publication of your response on the Commission's website:

(Please note that regardless of the option chosen, your contribution may be subject to a request for access to documents under [Regulation 1049/2001](#) on public access to European Parliament, Council and Commission documents. In this case the request will be assessed against the conditions set out in the Regulation and in accordance with applicable [data protection rules](#).)

- | |
|--|
| ☐ Under the name given:
<i>I consent to publication of all information in my contribution and I declare that none of it is subject to copyright restrictions that prevent publication</i> |
| ☐ Anonymously:
<i>I consent to publication of all information in my contribution and I declare that none of it is subject to copyright restrictions that prevent publication. No personal data, such as names, will be published.</i> |

PART 1.- CLASSIFICATION

The classification matrix shall have the purpose of:

- Cover all semi-trailers, trailers types, which are candidates for CO₂ determination.
- Apply segmentation into groups where boundary conditions for CO₂ emissions or customer information are homogenous.
- Support a clear allocation of the generic towing vehicles to be used in the IT Tool (and CFD).

For **classification of bodywork of rigid lorries** it is proposed to use the same classification matrix as basis as already defined in Annex I of Regulation (EU) 2017/2400 (see table below).

Description of elements relevant to the classification in vehicle groups			Vehicle group	Allocation of mission profile and vehicle configuration						
Axle configuration	Chassis configuration	P (tons)		Long haul	Long haul (EMS)	Regional delivery	Regional delivery (EMS)	Urban delivery	Municipal utility	Construction
4x2										
	Rigid lorry (or tractor) **	> 7.4 – 7.5	1s			R		R		
	Rigid lorry (or tractor) **	> 7.5 – 10	1			R		R		
	Rigid lorry (or tractor) **	> 10 – 12	2	R+T1		R		R		
	Rigid lorry (or tractor) **	> 12 – 16	3			R		R		
	Rigid lorry	> 16	4	R+T2		R		R	R	
	Tractor	> 16	5	T+ST	T+ST+T2	T+ST	T+ST+T2	T+ST		
	Rigid lorry	> 16	4v***						R	R
	Tractor	> 16	5v***							T+ST
4x4	Rigid lorry	> 7,5 – 16	(6)							
	Rigid lorry	> 16	(7)							
	Tractor	> 16	(8)							
6x2	Rigid lorry	all weights	9	R+T2	R+D+ST	R	R+D+ST		R	
	Tractor	all weights	10	T+ST	T+ST+T2	T+ST	T+ST+T2			

	Rigid lorry	all weights	9v***						R	R
	Tractor	all weights	10v***							T+ST
6x4	Rigid lorry	all weights	11	R+T2	R+D+ST	R	R+D+ST		R	R
	Tractor	all weights	12	T+ST	T+ST+T2	T+ST	T+ST+T2			T+ST
6x6	Rigid lorry	all weights	(13)							
	Tractor	all weights	(14)							
8x2	Rigid lorry	all weights	(15)							
8x4	Rigid lorry	all weights	16							R
8x6 8x8	Rigid lorry	all weights	(17)							

* EMS - European Modular System

** in these vehicle groups tractors are treated like rigid lorries but with specific curb weight of tractor

*** sub-group "v" of vehicle groups 4, 5, 9 and 10: these mission profiles are exclusively applicable to vocational vehicles

T = Tractor
R = Rigid lorry & standard body
T1, T2 = Standard trailers
ST = Standard semitrailer
D = Standard dolly".

For the **classification of semi-trailers and trailers**, similar philosophy will be used; however, the table might include other information that are relevant in this regard.

As a starting point, the following table has been drafted.

Type of trailer Regulation (EU) 2018/858, Annex I, Part C (1)	Axle/tyres configuration (2)		TPMLM (3)	Group code (4)	Box body (5)	Box type/code (6)	Standard / Volume orientation (only for box vehicles) (7)	Sub-group code (8)	Allocation of mission profile and vehicle configuration (9)					
									Long haul	Long haul (EMS)	Regional delivery	Regional delivery (EMS)	Urban delivery	Construction
DA (Semi-trailer)	1 axle	2 tyres per axle		1	box	DX-03 - Box body (Drybody)		a						
DB (Drawbar trailer)		4 tyres per axle		2		DX-04 - Conditioned body with insulated walls and equipment to maintain		b						
DC (Center-axle trailer)	2 axle	2 tyres per axle		3				c						
		4 tyres per axle		4				d						
	3	2 tyres per axle		5										

[illegible]

Explanations on the columns in the table above:

- (2) It might be an option to include separation between 2 and 4 tyres for each axle configurations. It is considered relevant to the CO₂ emission as it is linked with the rolling-resistance of the vehicle.
- (3) Maybe it will provide the same information as column (3). It is to be evaluated after the analysis of the responses whether (3) or (4) may be removed from the classification matrix.
- (4) Group codes combining the characteristics as set by columns (1) and (2) or (3) to be defined after definition of previous columns.
- (5) To divide the type of bodywork of the semi-trailer/trailer in box bodies or non-box bodies. At a first level classification, only box bodies are considered as they are more relevant to CO₂ emissions.
- (6) According to Regulation (EU) 2018/858. These four body codes are the ones considered in the box bodies. The rest of the body codes are considered as non-box bodies at a first level classification; however it has to be considered to include non-box bodies in the future (as open boxes and tippers).
- (7) This information may be needed for the definition of payload. It is to be evaluated after the analysis of the responses.
- (8) This subgroup identifier could be defined do summaries the characteristics as defined by the information from (5) to (7). Thus in any (semi-)trailer could be allocated to a combination of group and sub-group, e.g. 3c.
- (9) Same allocation of vehicle groups to mission profiles and payloads as per rigid lorries and tractors table above. Additionally the allocation needs to define the towing vehicle for each combination of group and sub-group.

- 1.1. Please indicate how relevant the parameters according to your expert judgement are.

Please include and comment other parameters that you consider as relevant to the classification and the CO₂ emissions.

Please provide any experimental data or other evidence you have in the comment fields to support your answer.

	Relevant	Not relevant	Comment Free text
Type of trailer (1)	☐	☐	
Number of axles (2a)	☐	☐	
Number of tyres per axles (2b)	☐	☐	
Total permissible mass (3)	☐	☐	
Body type (5)	☐	☐	
Volume oriented cargo area (7)	☐	☐	
Mission profile (9)	☐	☐	
Other, please specify Free text			

Do you foresee any difficulty for the vehicle manufacturers to classify their vehicles according to variants based in the aspects previously defined?

yes	no	please comment
☐	☐	

- 1.2. In case of multi-stage manufacturing, do you foresee any difficulty for the second stage manufacturers to classify their vehicles according to variants based in the aspects previously defined?

yes	no	please comment
☐	☐	

- 1.3. Do you foresee the need to define a different classification for multi-stage vehicles than for complete vehicles?

yes	no	please comment
☐	☐	

- 1.4. Taking into account the different kinds of bodywork listed in the Regulation (EU) 2018/858, Annex I, Appendix 2.), please group the following bodyworks as per their general construction, shape and dimensions according to their possible contribution to CO₂ emissions (as per your own experience). Do as many types in a group as necessary, considering that one type can also be relevant in terms of the classification if justified by their large number, and possibly some of them are not relevant at all to CO₂ emissions or does not exist in the market.

	Group 1	Group 2	Group 3	Group 4	Relevant but does not belong to any group	Not relevant / negligible
01 Flat bed	☐	☐	☐	☐	☐	☐
02 Drop-side	☐	☐	☐	☐	☐	☐
03 Box body	☐	☐	☐	☐	☐	☐
04 Refrigerated	☐	☐	☐	☐	☐	☐
05 Conditioned	☐	☐	☐	☐	☐	☐
06 Curtain-sided	☐	☐	☐	☐	☐	☐
07 Swap body	☐	☐	☐	☐	☐	☐
08 Container carrier	☐	☐	☐	☐	☐	☐
09 Vehicles fitted with hook lift	☐	☐	☐	☐	☐	☐
10 Tipper	☐	☐	☐	☐	☐	☐
11 Tanker	☐	☐	☐	☐	☐	☐
12 Tanker for dangerous goods	☐	☐	☐	☐	☐	☐
13 Livestock carrier	☐	☐	☐	☐	☐	☐
14 Vehicle transporter	☐	☐	☐	☐	☐	☐
15 Concrete mixer	☐	☐	☐	☐	☐	☐
16 Concrete pump	☐	☐	☐	☐	☐	☐
17 Timber	☐	☐	☐	☐	☐	☐
18 Refuse collection	☐	☐	☐	☐	☐	☐
19 Street sweeper	☐	☐	☐	☐	☐	☐
20 Compressor	☐	☐	☐	☐	☐	☐
21 Boat carrier	☐	☐	☐	☐	☐	☐

22 Glider carrier	☐	☐	☐	☐	☐	☐
23 Retail or display purposes	☐	☐	☐	☐	☐	☐
24 Recovery vehicle	☐	☐	☐	☐	☐	☐
25 Ladder vehicle	☐	☐	☐	☐	☐	☐
26 Crane lorry (not a mobile crane)	☐	☐	☐	☐	☐	☐
27 Aerial work platform vehicle	☐	☐	☐	☐	☐	☐
28 Digger derrick vehicle	☐	☐	☐	☐	☐	☐
29 Low floor trailer	☐	☐	☐	☐	☐	☐
30 Glazing transporter	☐	☐	☐	☐	☐	☐
31 Fire engine	☐	☐	☐	☐	☐	☐

PART 2.- INPUT DATA TO A CO₂ DETERMINATION

The determination of the CO₂ features of a certain specific semi-trailer, trailer or rigid body shall be based on a set of relevant vehicle specifications and technology features. Those parameters need to be declared or certified for each vehicle and then be provided as input data to the simulation tool.

Semi-trailers and trailers

- 2.1.1. Please review the non-exhaustive list of possible input parameters and indicate the importance of each parameter according to your expert judgement.

Please add any other relevant input parameter that you miss in the list.

Please provide any experimental data or other evidence you have in the comment fields to support your answer.

Importance of parameter on CO ₂ related real world performance				
Input parameter	Least important	Important	Most important	Comments Free text max 100 characters
Cargo volume	☐	☐	☐	
Dimensions	☐	☐	☐	
Masses	☐	☐	☐	
Rolling resistance	☐	☐	☐	
Air drag (CdxA in combination with generic towing vehicle)	☐	☐	☐	
Axle efficiency	☐	☐	☐	
Other relevant inputs Please specify (Free text)				

2.1.2. Please review the non-exhaustive list of possible input parameters and indicate how much effort you foresee to determine them.

Please add any other relevant input parameter that you miss in the list.

Please provide any experimental data or other evidence you have in the comment fields to support your answer.

Determination of input parameters				
Input parameter	Difficult to determine	Need to invest to determine	Easy to determine	Comments Free text max 100 characters
Cargo volume				
Length of cargo area	☐	☐	☐	
Height of cargo area	☐	☐	☐	
Width of cargo area	☐	☐	☐	
Other, please specify (Free text)				
Dimensions				
Length of vehicle	☐	☐	☐	
Height of vehicle	☐	☐	☐	
Width of vehicle	☐	☐	☐	
Other, please specify (Free text)				
Masses				
Actual mass of the vehicle	☐	☐	☐	
Technically permissible maximum laden mass of the vehicle	☐	☐	☐	
Other, please specify (Free text)				
Rolling resistance				
Tyre RRC	☐	☐	☐	
Other, please specify (Free text)				
Air drag (CdxA in combination with generic towing vehicle)				
CdxA calculated by generic functions based on (semi-)trailer type, dimensions and standard Δ CdxA values for a list of combinations of generic aero-features	☐	☐	☐	
CdxA calculated by generic functions and, as an option, by certified Δ CdxA values determined via CFD for a specific component	☐	☐	☐	
CdxA calculated by generic functions and, as an option, by certified Δ CdxA values determined via CFD based on simulation of the entire (semi-)trailer	☐	☐	☐	
Other, please specify (Free text)				
Axle efficiency				
Lift axle or retractable axle [yes or no]	☐	☐	☐	
Steered axles [yes or no]	☐	☐	☐	

Optimised wheel bearings	☐	☐	☐	
Electric energy recovery systems	☐	☐	☐	
Other, please specify (Free text)				
Other relevant inputs				
Please specify (Free text)				

2.2. Rigid lorries

For rigid lorries, information on chassis (e.g. powertrain and axles) as well as tyres are already available from the base vehicle CO₂ determination with VECTO. The list below only refers to the input data to be provided at the complete(d) stage of manufacturing.

2.2.1. Please review the non-exhaustive list of possible input parameters and indicate the importance of each parameter according to your expert judgement.

Please add any other relevant input parameter that you miss in the list.

Please provide any experimental data or other evidence you have in the comment fields to support your answer.

Importance of parameter on CO ₂ related real world performance				
Input parameter	Least important	Important	Most important	Comments Free text max 100 characters
Cargo volume	☐	☐	☐	
Dimensions	☐	☐	☐	
Masses	☐	☐	☐	
Air drag (C _{dx} A in combination with generic towing vehicle)	☐	☐	☐	
Type(s) of PTO mounted at engine or transmission(*)	☐	☐	☐	
Other relevant inputs Please specify (Free text)				

(*): Value to be declared based on technology definitions as set in Annex IX of Regulation (EU) 2017/2400, e.g.:

"none"; "drive shaft and/or up to 2 engaged gearwheels, multi-disc clutch"

Explanations:

'Power take-off (PTO)' means a device on a transmission or an engine to which an auxiliary driven device, e.g., a hydraulic pump, can be connected. The simulation tool adds standard drag losses from the PTO (not considering the auxiliary driven device) as a function of the declared technology.

2.2.2. Please review the non-exhaustive list of possible input parameter and indicate how much effort you foresee to determine them.

Please add any other relevant input parameter that you miss in the list.

Please provide any experimental data or other evidence you have in the comment fields to support your answer.

Input parameter	Difficult to determine	Need to invest to determine	Easy to determine	Comments Free text max 100 characters
Cargo volume				
Length of cargo area	☐	☐	☐	
Height of cargo area	☐	☐	☐	
Width of cargo area	☐	☐	☐	
Other, please specify (Free text)				
Dimensions				
Length of vehicle body	☐	☐	☐	
Height of vehicle body	☐	☐	☐	
Width of vehicle body	☐	☐	☐	
Other, please specify (Free text)				
Masses				
Actual mass of the vehicle	☐	☐	☐	
Technically permissible maximum laden mass of the vehicle	☐	☐	☐	
Other, please specify (Free text)				
Air drag (Cd_xA in combination with generic towing vehicle)				
Cd _x A calculated by generic functions based on (semi-)trailer type, dimensions and standard ΔCd _x A values for a list of combinations of	☐	☐	☐	

generic aero-features				
CdxA calculated by generic functions and, as an option, by certified $\Delta CdxA$ values determined via CFD for a specific component	☐	☐	☐	
CdxA calculated by generic functions and, as an option, by certified $\Delta CdxA$ values determined via CFD based on simulation of the entire (semi-)trailer	☐	☐	☐	
Other, please specify (Free text)				
Type(s) of PTO mounted at engine or transmission				
Value to be declared based on technology definitions as set in Annex IX of Regulation (EU) 2017/2400	☐	☐	☐	
Other relevant inputs				
Please specify (Free text)				

PART 3.- INPUTS TO DEFINE GENERIC 3D VEHICLES

Since trailers and semi-trailers are interchangeable and the determination of the air drag shall be based on simulation, generic 3D vehicles need to be defined to ensure the level playing field. There are some necessary inputs, which have to be taken into consideration when defining the generic vehicles, including average dimensions and emerging new technologies.

- 3.1. **Wheelbase(*)**: What is the most common wheelbase (in mm) in your product portfolio/vehicle fleet or as per your own experience for rigid lorries and tractors in the following configurations:

	Rigid		Tractor	
4x2				
	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
6x2				
	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
6x4				
	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
8x4			N/A	
	Long-haul transport:	Distribution transport:		

(*) NOTE:

Definition of *wheelbase* according to Commission Regulation (EU) 2019/1892 of 31 October 2019 amending Regulation (EU) No 1230/2012 as regards type-approval requirements for certain motor vehicles fitted with elongated cabs and for aerodynamic devices and equipment for motor vehicles and their trailers:

“wheelbase” means the horizontal distance between the centre of the first and the last axle;

3.2. Cabin height:

3.2.1. What is the most common cabin type(*) in your product portfolio/vehicle fleet or as per your own experience for rigid lorries and tractors in the following configurations:

Axle configuration	Rigid						Tractor					
	Long-haul transport			Distribution transport			Long-haul transport			Distribution transport		
4x2	Low roof	Low roof with air	High roof	Low roof	Low roof with air deflector	High roof	Low roof	Low roof with air deflector	High roof	Low roof	Low roof with air deflector	High roof
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6x2	Low roof	Low roof with air	High roof	Low roof	Low roof with air	High roof	Low roof	Low roof with air	High roof	Low roof	Low roof with air	High roof
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6x4	Low roof	Low roof with air deflector	High roof	Low roof	Low roof with air deflector	High roof	Low roof	Low roof with air deflector	High roof	Low roof	Low roof with air deflector	High roof
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3.2.2. What is the height of the most common cabin type (in mm) in your product portfolio/vehicle fleet or as per your own experience for rigid lorries and tractors in the following configurations?

Axle configuration	Rigid		Tractor	
4x2	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
6x2	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
6x4	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:

3.3. Cabin length:

3.3.1. What is the most common cabin type(*) and length (in mm) in your product portfolio/vehicle fleet or as per your own experience for rigid lorries and tractors in the following configurations:

Axle configuration	Rigid						Tractor					
	Long-haul transport			Distribution transport			Long-haul transport			Distribution transport		
4x2	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6x2	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6x4	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab	Short cab	Day cab	Sleeper cab
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

3.3.2. What is the length of the most common cabin type (in mm) in your product portfolio/vehicle fleet or as per your own experience for rigid lorries and tractors in the following configurations:

	Rigid		Tractor	
4x2	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
6x2	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:
6x4	Long-haul transport:	Distribution transport:	Long-haul transport:	Distribution transport:

(*) NOTE:

Explanatory notes on cabin types, in terms of length:

- Short cab: smallest cab, with no room behind the driver's seat.
- Day cab: there is room behind the driver's seat but not enough to accommodate a sleeping compartment.
- Sleeper cab: there is a compartment with a bed behind the driver's seat intended to use for sleeping.

3.4. Additional features on the market

3.4.1. What is your experience, plans or expectations with new technologies and additional features for rigid lorries and tractors? Please provide your comments for the following topics.

Cameras instead of side-mirrors:	Use of cameras instead of side-mirrors and a display inside the cabin (similar as for rear-view cameras).
Elongated cabins:	Non-standard cabins with elongated front-end, designed to deliver improved aerodynamic performance, energy efficiency and safety performance.

	Already available	Will be available and widely used	Expected to be available	Comment Free text
Cameras instead of side-mirrors for long haul vehicles	☐	☐	☐	
Cameras instead of side-mirrors for distribution vehicles	☐	☐	☐	
Elongated cabins for long haul vehicles	☐	☐	☐	
Elongated cabins for distribution vehicles	☐	☐	☐	
Others, please specify Free text				

3.4.2. What is your experience with additional features that are available / will be available / expected to be available on the market for rigid lorries and tractors?
Please provide your comments for the following topics:

	Already available	Will be available and widely used	Expected to be available	Comment Free text
Active roof spoiler	☐	☐	☐	
Active side deflector (cabin extension for tractors)	☐	☐	☐	
Side panelling to cover rear wheels	☐	☐	☐	
Active grill shutter	☐	☐	☐	
Others, please specify Free text				

PART 4.- AERODYNAMIC APPENDICES

The aerodynamic appendices (add-ons) aim to reduce the air drag resistance of the vehicle.

The detailed description of the add-ons can be found at the DG CLIMA website:
https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/heavy/docs/report_bodies_trailers_en.pdf

Non-exhaustive list of dedicated air-drag reduction aerodynamic devices(*):

- Boat tails
- Side skirts
 - Covered-wheel full side skirts
 - Open-wheel full side skirts
- Inter-wheel panels
- Leading edge
- Underbody deflectors
- Diffusers

4.1. What are, according to your knowledge, the most common aerodynamic devices on a **trailer**? Please feel free to add devices and comment the list below.

	Uncommon	Common	Very common	Comment Free text
Boat tails	☐	☐	☐	
Covered-wheel full side skirts	☐	☐	☐	
Open-wheel full side skirts	☐	☐	☐	
Inter-wheel panels	☐	☐	☐	
Leading edge	☐	☐	☐	
Underbody deflectors	☐	☐	☐	
Other, please specify <i>Free text</i>				

- 4.2. What are, according to your knowledge, the most common aerodynamic devices to on a **rigid lorry**, neglecting the cab roof spoiler? Please feel free to add devices and comment the list below.

	Uncommon	Common	Very common	Comment Free text
Boat tails	☐	☐	☐	
Covered-wheel full side skirts	☐	☐	☐	
Open-wheel full side skirts	☐	☐	☐	
Inter-wheel panels	☐	☐	☐	
Leading edge	☐	☐	☐	
Underbody deflectors	☐	☐	☐	
Other, please specify <i>Free text</i>				

- 4.3. What is your experience on the availability of the aerodynamic devices for trailers and semi-trailers? Please feel free to provide your comments below.

	Already available	Will be available	Expected to be available	Comment Free text
Boat tails	☐	☐	☐	
Covered-wheel full side skirts	☐	☐	☐	
Open-wheel full side skirts	☐	☐	☐	
Inter-wheel panels	☐	☐	☐	
Leading edge	☐	☐	☐	
Underbody deflectors	☐	☐	☐	
Other, please specify <i>Free text</i>				

PART 5.- AERODYNAMIC DEVELOPMENT (only for trailer, body or aero add-ons manufacturers)

- 5.1. Is your company aware of any of the following methodologies to measure aerodynamic performance?

	Yes	No	Comment Free text
Constant Speed Tests (CST)	☐	☐	
Coast-down tests	☐	☐	
Wind tunnel test	☐	☐	
Computational Fluid Dynamics (CFD)	☐	☐	
Others. Which one? <i>Free text</i>			

- 5.2. Do you foresee the possibility to do any of the above methods (in-house or outsourced) in aerodynamic development of any of the aerodynamic appendices listed in Part 4?

	Yes	Maybe	No
Constant Speed Tests (CST)	☐	☐	☐
Coast-down tests	☐	☐	☐
Wind tunnel test	☐	☐	☐
CFD simulation (Computational Fluid Dynamics)	☐	☐	☐
Others. Which one? <i>Free text</i>			

- 5.3. If you are a body, trailer or aerodynamic device manufacturer, are you currently using Computational Fluid Dynamics (CFD) software in your development process?

Yes, as an in-house activity	Yes, as an outsourced activity	No
☐	☐	☐
If yes, which software? <i>Free text</i>		

Annex 2 – Study of boat tails

With the aim of understanding better the behaviour of the boat tails and classifying them in a smart way, a set of simulations have been performed in which the general geometry of the truck and trailer have been kept unmodified while different combinations of length, angle and geometry were tried.

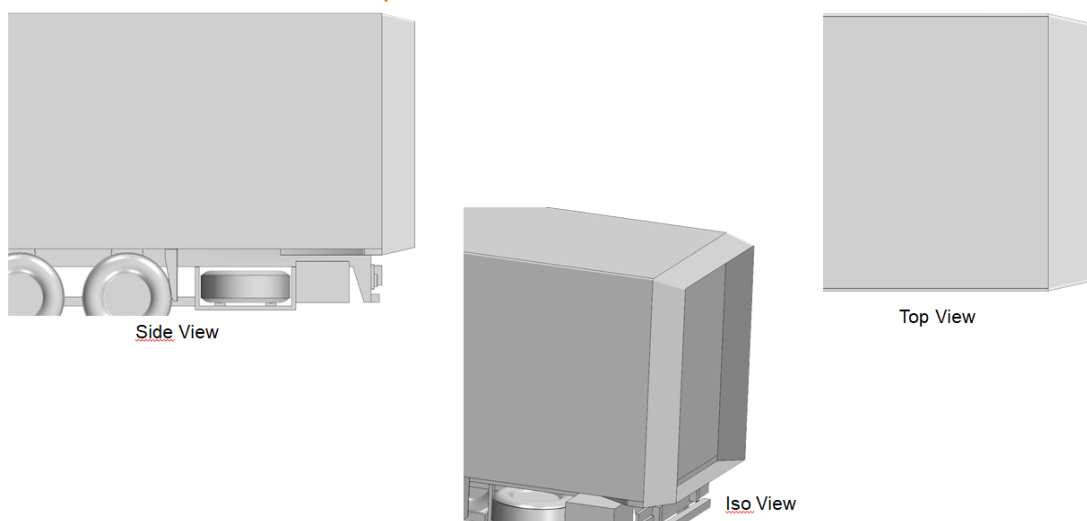
The first part of the study was focused on the effect of the combined effect of the length of the panels and its inclination. This study was based on the “Aerodynamic Performance of Flat-Panel Boat-Tails and Their Interactive Benefits with Side-Skirts” SAE paper in which similar simulations both by CFD and wind tunnel were performed.

The results of this paper show that the same boat tail geometry, applied to different scale models, show a similar drag reduction performance, with an increasing level of drag reduction at higher yaw angles of wind. Regarding the length of the panels, in general, the longer the panels, the better the performance until the 1.2 metres. After this point, the performance either stays equal or decreases. The study also reveals that it seems there is a trend relating the effect of panel angles and their length. Higher angles seem to benefit shorter panels while lower angles see their effect improved with longer panels. Regarding the inclusion of a fourth panel, it is proven that the overall performance of the boat tail improves, but not all the configurations show the same improvement. There is a major drawback when mounting this four panel though, and it is the loss of operational effectiveness when reaching the rear doors handles.

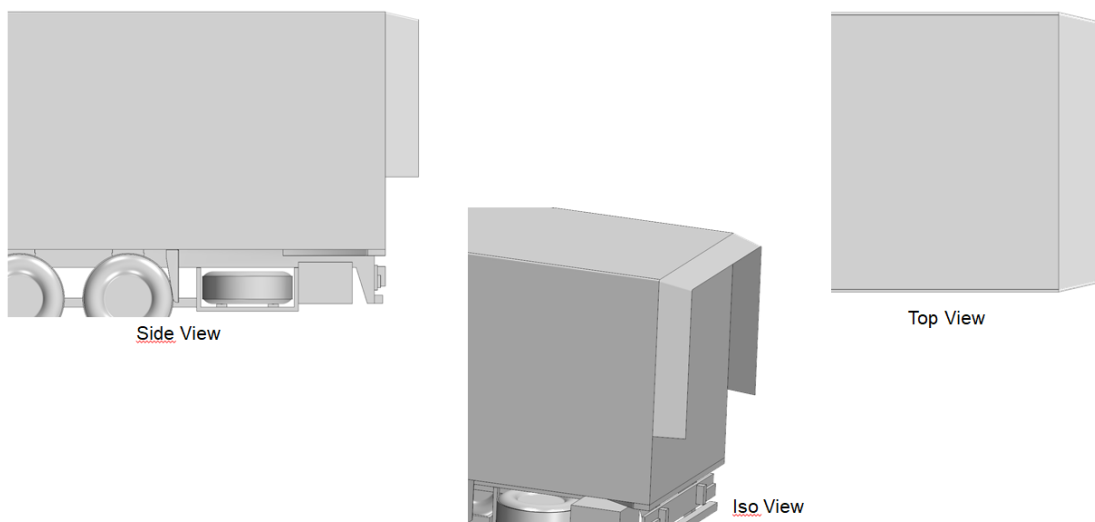
The second part of this study focused on the effect of the different geometries observed in the market. Three models were selected while leaving the angle and the length of the panels in what was found as the optimal position in the first part of the study. These three cases were compared to the initial geometry without any add-on at 0° of yaw.

The selected geometries are:

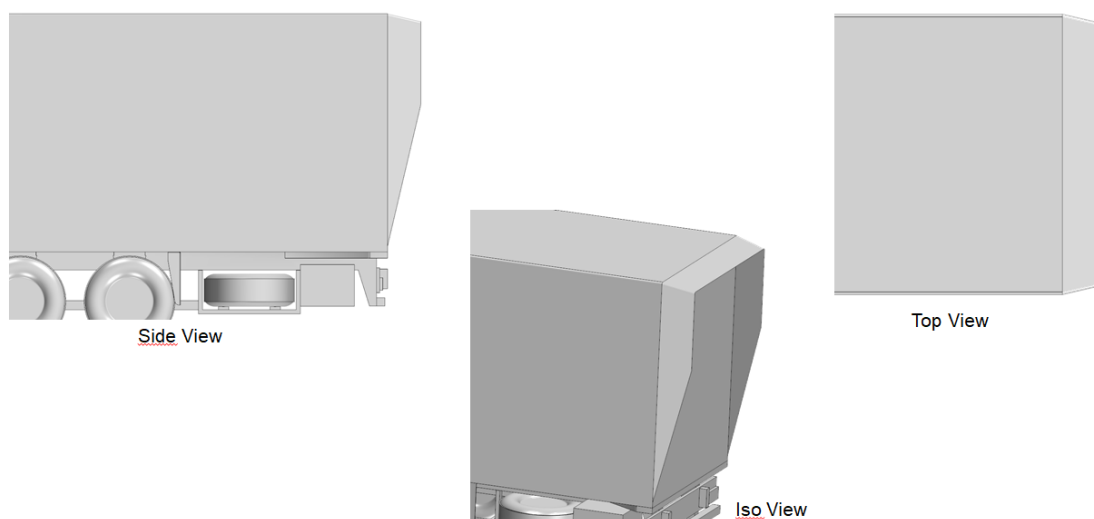
- Tall boat tail: A boat tail which lateral panels cover the whole wall flange, from the ceiling to the floor



- Short boat tail: A boat tail which lateral panels are 2 m long starting from the ceiling of the vehicle



- Decreasing boat tail: In this case, the geometry is the same as the tall boat tail but at a certain point, the length of the panel decreases, creating an angle. This kind of geometries is widely used among tall boat tails since boat tail doesn't usually leave sharp edges. The effect of this lack of material when compared to the complete version would vary depending on the amount of material subtracted from the panel. To study this effect, an extreme case with just one meter tall at the rear end of the boat tail was considered.



The results are shown in the following table:

	Standard Trailer	Boat Tail 2.8m / 2.6m	Boat Tail 2.0m / 1.9m	Boat Tail 2.8m / 1.0m
				
L_1 [m]	-	2,60	1,90	1,00
L_{avg} [m]	-	2,70	1,95	1,90
ΔC_{DxA} [m ²] (w.r.t ST1)	-	-0,31	-0,22	-0,28
ΔC_{DxA} [%] (w.r.t ST1)	-	-7,0 %	-4,9 %	-6,3 %

It is clear that the effect of the short boat tail is smaller than the tall boat tail. However, when compared the tall boat tail with the one with the angle, a 10% of difference was spotted. Again, this last case is an extreme geometry since the outer length of the boat tail tends to be more similar to the earlier one. After seeing this effect and considering that the majority of boat tails present a softened edge at the lower corner, it would be safe to assume that these softer edges has little effect on the final boat tail.

Annex 3 – Add-on matrix combinations

Combination of two add-ons

TWO ADDONS COMBINATIONS	Pallet box closed between	Storage box big behind	Refrigeration system	Boat tail short low (300-500mm; 2m)	Boat tail short tall (300-500mm; 2,7m)	Side skirt short	Side skirt full with open wheels	Side skirt full with covered wheels	Inter wheel panels
Combination 1	X	X							
Combination 2	X		X						
Combination 3	X			X					
Combination 4	X				X				
Combination 5	X					X			
Combination 6	X						X		
Combination 7	X							X	
Combination 8		X	X						
Combination 9		X		X					
Combination 10		X			X				
Combination 11		X				X			
Combination 12		X					X		
Combination 13		X						X	
Combination 14			X	X					
Combination 15			X		X				
Combination 16			X			X			
Combination 17			X				X		
Combination 18			X					X	
Combination 19				X		X			
Combination 20				X			X		
Combination 21				X				X	
Combination 22					X	X			
Combination 23					X		X		
Combination 24					X			X	
Combination 25							X		X
	7	7	7	6	6	5	6	5	1

Combination of three add-ons

THREE ADDONS COMBINATIONS	Pallet box closed between	Storage box big behind	Refrigeration system	Boat tail short low (300-500mm; 2m)	Boat tail short tall (300-500mm; 2,7m)	Side skirt short	Side skirt full with open wheels	Side skirt full with covered wheels	Inter wheel panels
Combination 25	X	X	X						
Combination 26	X	X		X					
Combination 27	X	X			X				
Combination 28	X	X				X			
Combination 29	X	X					X		
Combination 30	X	X						X	
Combination 31	X		X	X					
Combination 32	X		X		X				
Combination 33	X		X			X			
Combination 34	X		X				X		
Combination 35	X		X					X	
Combination 36	X			X	X				
Combination 37	X			X		X			
Combination 38	X			X			X		
Combination 39	X			X				X	
Combination 40	X			X					
Combination 41	X				X	X			
Combination 42	X				X		X		
Combination 43	X				X			X	
Combination 44	X						X		X
Combination 45		X	X	X					
Combination 46		X	X		X				
Combination 47		X	X			X			
Combination 48		X	X				X		
Combination 49		X	X					X	
Combination 50		X		X		X			
Combination 51		X		X			X		
Combination 52		X		X				X	
Combination 53		X			X	X			
Combination 54		X			X		X		
Combination 55		X			X			X	
Combination 56		X					X		X
Combination 57			X	X		X			

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Procedure no: CLIMA.C.4/SER/2019/0003

Combination 58			X	X			X		
Combination 59			X	X				X	
Combination 60			X		X	X			
Combination 61			X		X		X		
Combination 62			X		X			X	
Combination 63			X				X		X
Combination 64				X			X		X
Combination 65					X		X		X
	20	18	18	15	14	9	14	9	5

Combination of four add-ons

FOUR ADDONS COMBINATIONS	Pallet box closed between	Storage box big behind	Refrigeration system	Boat tail short low (300-500mm; 2m)	Boat tail short tall (300-500mm; 2,7m)	Side skirt short	Side skirt full with open wheels	Side skirt full with covered wheels	Inter wheel panels
Combination 65	X	X	X	X					
Combination 66	X	X	X		X				
Combination 67	X	X	X			X			
Combination 68	X	X	X				X		
Combination 69	X	X	X					X	
Combination 70	X	X		X		X			
Combination 71	X	X		X			X		
Combination 72	X	X		X				X	
Combination 73	X	X			X	X			
Combination 74	X	X			X		X		
Combination 75	X	X			X			X	
Combination 76	X	X					X		X
Combination 77	X		X	X		X			
Combination 78	X		X	X			X		
Combination 79	X		X	X				X	
Combination 80	X		X		X	X			
Combination 81	X		X		X		X		
Combination 82	X		X		X			X	
Combination 83	X		X				X		X
Combination 84	X			X			X		X
Combination 85	X				X		X		X
Combination 86		X	X	X		X			
Combination 87		X	X	X			X		
Combination 88		X	X	X				X	
Combination 89		X	X		X	X			
Combination 90		X	X		X		X		
Combination 91		X	X		X			X	
Combination 92		X	X				X		X
Combination 93		X		X			X		X
Combination 94		X			X		X		X
Combination 95			X	X			X		X
Combination 96			X		X		X		X
	21	21	21	13	13	7	16	7	9

Combination of five add-ons

FIVE ADDONS COMBINATIONS	Pallet box closed between	Storage box big behind	Refrigeration system	Boat tail short low (300-500mm; 2m)	Boat tail short tall (300-500mm; 2, 7m)	Side skirt short	Side skirt full with open wheels	Side skirt full with covered wheels	Inter wheel panels
Combination 96	X	X	X	X		X			
Combination 97	X	X	X	X			X		
Combination 98	X	X	X	X				X	
Combination 99	X	X	X		X	X			
Combination 100	X	X	X		X		X		
Combination 101	X	X	X		X			X	
Combination 102	X	X	X				X		X
Combination 103	X	X		X			X		X
Combination 104	X	X			X		X		X
Combination 105	X		X	X			X		X
Combination 106	X		X		X		X		X
Combination 107		X	X	X			X		X
Combination 108		X	X		X		X		X
	11	11	11	6	6	2	9	2	7

Combination of six add-ons

SIX ADDONS COMBINATIONS	Pallet box closed between	Storage box big behind	Refrigeration system	Boat tail short low (300-500mm; 2m)	Boat tail short tall (300-500mm; 2, 7m)	Side skirt short	Side skirt full with open wheels	Side skirt full with covered wheels	Inter wheel panels
Combination 109	X	X	X	X			X		X
Combination 110	X	X	X		X		X		X
	2	2	2	1	1	0	2	0	2