Annex 1: Maximum Gross weight vehicle in EU

PERMISSIBLE MAXIMUM WEIGHTS OF TRUCKS IN EUROPE (in tonnes)							
Country	Weight per non-drive axle	Weight per drive axle	Lorry 2 axles	Lorry 3 axles	Road Train 4 axles	Road Train 5 axles and +	Articulated Vehicle 5 axles and +
Albania	10	11.5 (3)	18	26 (2)	36	40	44
Armenia	10	10	18	22	36 (19)	36 (19)	36 (19)
Austria	10	11.5	18	26	36	40	40
Azerbaijan	10	10	18	24	36	42	44
Belarus	10	10 / 11.5	18 / 20	25	38 / 40	40 / 42	42 / 44
Belgium	10	12	19	26	39	44	44 (1)
Bosnia-Herzegovina	10	11.5	19	26	38	40	40
Bulgaria	10	11.5	18	26 (2)	36	40	40
Croatia	10	11.5	18	24	36	40	40
Czech Republic	10	11.5	18	26 (2)	36	44 (2)	42 / 48
Denmark	10	11.5 (3)	18	26 (2, 3)	38	42 / 48	42 / 48
Estonia	10	11.5	18	26 (2)	36 (4)	40 (5)	40
Finland (6)	10	11.5	18	26 (2)	36	44 / 60 (7)	42 / 48
France	13	13	19	26	38	40	40
FYROM	10	11.5	18	24	31	40	40
Georgia	10	11.5			44	44	44
Germany	10	11.5	18	26 (2)	36	40	40
Greece	7 / 10	13	19	26	33	40	40
Hungary	10	11.5	18	25	30	40	40 / 44 (8)
Iceland	10	11.5	18	26 (2)	36	40	44
Ireland	10	11.5 (9)	18	26 (2)	36	44 (2)	44 (2)
Italy	12	12	18	26 (2)	40	44	44
Latvia	10	11.5	18	26 (2)	40	40	40
Liechtenstein	10	11.5	18	26	36	40	40
Lithuania	10	11.5	18	26 (2)	36	40	40 / 44 (10)
Luxembourg	10	12 (11)	19	26	44	44	44
Malta	10	11.5	18	25	36	40	40 / 44 (8)
Moldova	10	10	18	24	36	40	40
Montenegro	10		16	24	36	40	40
Netherlands (12)	10	11.5	21.5	33	40	50	50
Norway	10	11.5	19	26	37	42	44
Poland	10	11.5	18	26 (2)	36	40	40
Portugal (4)	10	12	19	26	37	40	40
Romania	10	11.5	18	25	36	40	40
Russia	10	10	18	25 (2)	36	38	38
Serbia	10	11.5	18	26	32	40	40
Slovakia	10	11.5	18	26 (2)	36	40	40
Slovenia	10	11.5	18	26 (2)	36	40	40
Spain	10	11.5	18	26	36	40	44 (13) / 42 (14)
Sweden	10	11.5	18	26 (2)	38	48/60 (10)	48/60 (10)
Switzerland	10	11.5	18	26 (2)	36	40	40
Turkey	10	11.5	18	25/26 (16)	36	40	40/44 (10)
Ukraine	11	11	16 (17)	22 (17)	38 (17)	38 (17)	38 (17)
United Kingdom	10	11.5	18	26 (2)	36	40 (18)	40 / 44 (10, 18)

Source: *PERMISSIBLE MAXIMUM WEIGHTS OF TRUCKS IN EUROPE* [online]. [cit. 2019-07-10]. Available from: https://www.yumpu.com/en/document/view/3972076/permissible-maximum-weights-of-trucks-in-europe-in-

Annex 2: Impact of new aero technologies

TECHNOLOGY	FUEL SAVINGS			Source
	% Reduction (Liters/100 km)		Annual Savings [2] (Liters)	
	Original Estimate	Adjusted to 70 kph [1]		
Single Technology Aerodynamic Improvements				
Front Trailer Skirt	10.9% at 105 kph	4.9%	2,797	Cooper 2003[3] [25]
Front/Back Trailer Skirt	14.7% at 105 kph	6.6%	3,752	Cooper 2003[3] [25]
Side Skirt	4.8% at 105 kph	2.1%	1,219	EPA 2004 [26]
Gap Seal	4.0% at 105 kph	1.8%	1,027	Cooper 2003[3] [25]
Underbody Fairings (Aerodynamic Underbody)	6.4% at 100 kph	3.1%	1,791	SmartTruck Products 2010 [27]
	3.2% at 97 kph	1.7%	959	RMI 2005 [28]
Boat Tail	4.8% at 97 kph	2.5%	1,430	RMI 2005 [28]
	5.7% at 103 kph	2.6%	1,494	Slipstreem 2007
	6.1% at 105 kph	2.7%	1,557	Cooper 2003[3] [25]
Pneumatic Blower Device	7.4 - 8.3% at 105 kph	3.3% - 3.7%	1,895 – 2,113	Englar 2005 [10]
	1.2% at 97 kph	0.6%	356	RMI 2005 [28]
Cross Vortex Trap Device	4.8% at 97 kph	2.5%	1,430	RMI 2005 [28]
Electronic Vision System (No Mirrors)	1.0% at 97 kph	0.5%	297	RMI 2005 [28]
Multiple Technology Aerodynamic Improvements				
Cab Deflectors, Sloping Hood, Cab Side Flares	2.0% at 97 kph	1.0%	589	RMI 2005 [28]
Tractor-Trailer Gap, Wheel Wells, Baffles, Bumper	0.5% at 97 kph	0.3%	149	RMI 2005 [28]
Leading/Trailing Edge, Vortex Strake Device	2.0% at 97 kph	1.0%	589	RMI 2005 [28]
Aerodynamic Underbody + Nose/Side Fairings	9.9% at 100 kph	4.9%	2,787	SmartTruck Products 2010 [27]
Aerodynamic Tractor	13% at 105 kph	5.8%	3,338	EPA 2004 [26]
Design				
Front/Rear Trailer Skirts, Gap Seal, Boat Tail	25.4% at 105 kph	11.4%	6,493	Cooper 2003[3] [25]

[1] *$\%\ Reduction_{V=70kph} = \%\ Reduction_{VT} * (70^2 \div VT^2)$; VT = average velocity of actual test (kph)*

[2] *Based on: 120,000 km annually, average speed 70 kph; baseline fuel consumption 47.6 Liters per 100 km. Baseline fuel consumption assumes regularly overloaded trucks. Based on the difference in weight between U.S. and Chinese trucks, the improvements from Aerodynamic technologies may be slightly overstated because % improvement is based on U.S. tests at a lower truck weight.*

[3] *Cooper 2003: Wind tunnel model results; % reduction relative to truck with a standard aerodynamic package including: cab shaping, cab-mounted deflectors, trailer front-end fairings, cab side extenders, body front-edge rounding, tractor-trailer gap seals, trailer side skirts, and rear boat tailings. Wind tunnel models tend to overestimate the actual savings from some aerodynamic improvement, but are effective in determining the appropriate design of equipment.*

Source: *M.J.Bradley &Associates LLC: Summary of Available Technologies to Reduce Aerodynamic Drag & Rolling Resistance from Heavy Trucks* [online]. , 33 [cit. 2019-07-09]. Available from: https://theicct.org/sites/default/files/publications/AERO_RR_Technologies_Whitepaper_FINAL_Oct2012.pdf

Annex 3: Legislation

ECE Addendum 12: Regulation No. 13, Revision 8

First, I would like to clarify the difference between Endurance braking system and Service braking system. All detailed informations about testing of Endurance braking systems of motor vehicles and towed vehicles are described in standard: ***ISO 12161:2006(en)***

"5.1.2.1. ***Service braking system***

The service braking system shall make it possible to control the movement of the vehicle and to halt it safely, speedily and effectively, whatever its speed and load, on any up or down gradient. It shall be possible to graduate this braking action. The driver shall be able to achieve this braking action from his driving seat without removing his hands from the steering control.

2.15. ***"Endurance braking system"*** *means an additional braking system having the capability to provide and to maintain a braking effect over a long period of time without a significant reduction in performance. The term "endurance braking system" covers the complete system including the control device.*

2.15.1. The endurance braking system may comprise a single device or a combination of several devices. Each device may have its own control.

2.15.2. Control configurations for endurance braking systems:

2.15.2.1. ***"Independent endurance braking system"*** *means an endurance braking system whose control device is separated from that of the service and other braking systems; 2.15.2.2. "****Integrated endurance braking system****" means an endurance braking system whose control device is integrated with that of the service braking system in such a way that both endurance and service braking systems are applied simultaneously or suitably phased by operation of the combined control device;*

*2.15.2.3. "****Combined endurance braking system****" means an integrated endurance braking system, which in addition has a cut-out device, which allows the combined control to apply the service braking system alone.*

Type-IIA test (endurance braking performance)

1.8.1. Vehicles of the following categories shall be subject to the Type-IIA test:

1.8.1.1. Vehicles of category M_3, belonging to Classes II, III or B as defined in the Consolidated Resolution on the Construction of Vehicles (R.E.3).

1.8.1.2. Vehicles of category ***N_3*** *which are authorized to tow a trailer of category O_4. If the maximum mass exceeds 26 tonnes, the test mass is limited to 26 tonnes or, in the case where the unladen mass exceeds 26 tonnes, this mass is to be taken into account by calculation.*

1.8.1.3. Certain vehicles subject to ***ADR***

Test conditions and performance requirements

1.8.2.1. The performance of the endurance braking system shall be tested at the maximum mass of the vehicle or of the vehicle combination.

1.8.2.2. Laden vehicles shall be tested in such a manner that the energy input is equivalent to that recorded in the same period of time with a laden vehicle driven at an average speed of ***30 km/h*** *on a* ***7 per cent*** *down-gradient for a distance of* ***6 km****. During the test, the service, secondary and parking braking systems* ***shall not be engaged****. The gear engaged shall be such that the speed of the engine does not exceed the maximum value prescribed by the manufacturer. An integrated endurance braking system may be used, provided that it is suitably phased such that the service braking system is not applied; this may be verified by checking that its brakes remain cold, as defined in paragraph 1.4.1.1. of this annex.*

1.8.2.3. For vehicles in which the energy is absorbed by the braking action of the engine alone, a tolerance of ***±5 km/h*** *on the average speed shall be permitted, and the gear enabling the speed to be stabilized at a value closest to* ***30 km/h*** *on a* ***7 per cent*** *down-gradient shall be engaged. If the performance of the braking action of the engine alone is determined by measuring the deceleration, it shall be sufficient if the mean deceleration measured is at least* ***0.6 m/s2*** *.*

ADR

This annex applies to certain vehicles which are subject to section 9.2.3. of Annex B to the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR).

2. Requirements

2.1. General provisions Power-driven vehicles and trailers intended for use as transport units for dangerous goods shall fulfil all relevant technical requirements of this Regulation. In addition, the following technical provisions shall apply as appropriate.

2.2. Anti-lock braking system of trailers

2.2.1. Trailers of category O4 shall be equipped with category A anti-lock systems as defined in Annex 13 to this Regulation.

2.3. Endurance braking system

2.3.1. Power-driven vehicles having a maximum mass exceeding 16 tonnes, or authorized to tow a trailer of category O4 shall be fitted with an ***endurance braking system*** *according to paragraph*

2.15. of this Regulation which complies with the following requirements:

2.3.1.1. The endurance braking control configurations shall be from a type described in paragraphs 2.15.2.1. to 2.15.2.3. of this Regulation. 2.3.1.2. In the case of an electrical failure of the anti-lock system, integrated or combined endurance braking systems shall be switched off automatically.

2.3.1.3. The effectiveness of the endurance braking system shall be controlled by the anti-lock braking system such that the axle(s) braked by the endurance braking system cannot be locked by that system at speeds above 15 km/h. However, this requirement shall not apply to that part of the braking system constituted by the natural engine braking.

2.3.1.4. The endurance braking system shall comprise several stages of effectiveness, including a low stage appropriate for the unladen condition. Where the endurance braking system of a power-driven vehicle is constituted by its engine, the different gear ratios shall be considered to provide the different stages of effectiveness.

*2.3.1.5. The performance of the endurance braking system shall be such that it fulfils the requirements of paragraph 1.8. of Annex 4 to this Regulation (****Type-IIA test****), with a laden vehicle mass comprising the laden mass of the motor vehicle and its authorized maximum towed mass but not exceeding a total of 44 tonnes." []*

[31] *ECE R.13: PROPOSAL FOR DRAFT AMENDMENTS TO REGULATION No. 13*. In: . 2004. Available also from: https://www.unece.org/fileadmin/DAM/trans/doc/2004/wp29grrf/TRANS-WP29-GRRF-56-inf03e.pdf

Directive 96/53/EC

Article 9a

1. With the aim of improving energy efficiency, in particular as regards the aerodynamic performance of cabs, as well as road safety, vehicles or vehicle combinations which fulfil the requirements laid down in paragraph 2 and which comply with Directive 2007/46/EC may exceed the maximum lengths laid down in point 1.1 of Annex I to this Directive provided that their cabs deliver improved aerodynamic performance, energy efficiency and safety performance. Vehicles or vehicle combinations equipped with such cabs shall comply with point 1.5 of Annex I to this Directive and any exceeding of the maximum lengths shall not result in an increase in the load capacity of those vehicles.

2. Before being placed on the market, the vehicles referred to in paragraph 1 shall be approved in accordance with the rules on type-approval within the framework of Directive 2007/46/EC.

3. Paragraph 1 shall apply from 3 years after the date of transposition or application of the necessary amendments to the instruments referred to in paragraph 2, as appropriate.'

Current situation

The current Article 9a(3) includes a 3 years moratorium for the introduction of aerodynamic cabs after the date of transposition or application of the necessary amendments as regards technical type-approval requirements. It is proposed to adjust Article 9a(3) so as to suppress the 3 years moratorium and to come to a shorter, but proportionate time limit. [30]

However, the moratorium included in the current legislation deters manufacturers from improving aerodynamics of cabs as a way to achieve compliance with the upcoming CO2 standards for heavy goods vehicles. Moreover, the moratorium also goes against the innovation principle and the principles of better regulation as it hinders the development of new technologies and concepts. [30]

Therefore, the Commission is proposing to shorten the time limit for the transposition of Article 9a(1) of Directive 95/53/EC. The proposed new text of Article 9a(3) would still leave sufficient time for Member States to take the necessary steps.[30]

[30] ERBACH, Gregor. *CO2 emission standards for heavy-duty vehicles* [online]. April 2019, 10 [cit. 2019-07-10]. Available from: http://www.europarl.europa.eu/RegData/etudes/BRIE/2018/628268/EPRS_BRI%282018%29628268_EN.pdf

STOPPING DISTANCE EHK-R13, ES 71/320 notice 102/1995

For vehicles category N3 m>12t N3 is maximum stopping distance s_0 from initial speed v_0 =40km/h for:

- Service braking: s_0=19,9m; a_{ms}= 4,4 m/s^2
- Emergency braking: s_0=33,8m

The service brakes of vehicles of categories M_1, M_2, M_3, N_1, N_2 and N_3 shall be tested under the conditions shown in the following table:

	M_1	M_2	M_3	N_1	N_2	N_3
Type of test	0—I	0—I	0—I—II	0—I	0—I	0—I—II
v	80 km/h	60 km/h	60 km/h	70 km/h	50 km/h	40 km/h
s ≤	$0{\cdot}1\ v + \frac{v^2}{150}$	$0{\cdot}15\ v + \frac{v^2}{130}$		$0{\cdot}15\ v + \frac{v^2}{115}$		
dm ≥	5·8 m/s²	5 m/s²		4·4 m/s²		
f ≤	50 kgf	70 kgf	70 kgf	70 kgf	70 kgf	70 kgf

where:

v = test speed
s = stopping distance
dm = mean braking deceleration at normal engine speed
f = force applied to foot control

Annex 4: Braking strategy

Events | Inputs | Outputs | Plots

Attri...	Event Descriptions	Event Exit Criterion	Next Event No.	Output 1	Output 2	Output 3	Output 4	Output 5
0								
1	accelerate to target ...	delta_v>0	2-3	0	0	0	0	acc_pedal
2	is neccessary to fuel...	acc_pedal>0	4	0	0	0	0	0
3	is not neccessary to...	acc_pedal=0	5	0	0	0	0	0
4	fueling	delta_v>0.5	5	0	0	0	0	acc_pedal
5	no fueling	delta_v>1.5	6	0	0	0	0	0
6	LEVEL 1	delta_v<-2 \\ delta_...	7-8	1	0	0	0	0
7	-	acc>0.1	12	0	0	0	0	0
8	-	acc<=0.1	9	0	0	0	0	0
9	keep level 1	delta_v<-5 \\ delta_...	10-11	1	0	0	0	0
10	-	delta_v<-5	25	0	0	0	0	0
11	-	delta_v>0	12	0	0	0	0	0
12	LEVEL 2	delta_v<-2 \\ delta_...	13-14	0	1	0	0	0
13	-	acc>0.1	18	0	0	0	0	0
14	-	acc<=0.1	15	0	0	0	0	0
15	keep level 2	delta_v<-4 \\ delta_...	16-17	0	1	0	0	0
16	-	delta_v<-4	9	0	0	0	0	0
17	-	delta_v>0	18	0	0	0	0	0
18	LEVEL 3	delta_v<-2 \\ delta_...	19-20	0	0	1	0	0
19	-	acc>0.1	24	0	0	0	0	0
20	-	acc<=0.1	21	0	0	0	0	0
21	keep level 3	delta_v<-3 \\ delta_...	22-23	0	0	1	0	0
22	-	delta_v<-3	15	0	0	0	0	0
23	-	delta_v>3	24	0	0	0	0	0
24	FRICTION BRAKES ...	delta_v<-1	21	0	0	1	brk_pedal	0
25	DEACTIVATE LEVEL 1	delta_v<-10 \\ delta...	26-27	0	0	0	0	0
26	-	delta_v<-10	1	0	0	0	0	0
27	-	delta_v>0	9	0	0	0	0	0

Actions | Inputs | Outputs | Plots

Attri...	Action Descriptions	Actions	Conditions	Output 1	Output 2	Output 3
0						
1	Low Brake Peal	If	BrakePedal>0 && B...	BrakePedal*5	0	0
2	High Brake Pedal	Elseif	BrakePedal>=20	100	1.25*(BrakePedal)-25	0
3	No Brake Pedal	Elseif	delta_v<-3 && Brak...	BrakePedal	0	0
4	accelerate	Else		0	0	AccPedal

Annex 5: GT-SUITE Introducion

Engine, powertrain, and vehicle engineering simulation software

GT-SUITE is a single software package for modeling and simulation of systems in automotive and transportation engineering and beyond. It is based on a multi-physics platform, but offers higher-level, added-value toolboxes specifically tailored to a continually broadening set of applications.

Highlights

- GT-SUITE is a comprehensive set of simulation tools for engine and vehicle systems.
- Industry-standard engine simulation (GT-POWER library)
- Used by all major engine manufacturers, and their suppliers, worldwide
- Models boosting systems, EGR concepts, VVT, variable geometry systems, and after treatment systems
- Includes built-in 3D CAD, DOE, optimization, and neural network training tools
- Coupled to MATLAB and Simulink technical computing software for control system analysis

Description

The GT-SUITE simulation consists of a set of simulation modeling libraries - tools for analyzing engine breathing, combustion, and acoustics, vehicle powertrains, engine cooling systems, engine fuel injection systems, valvetrains, crankshafts, and lubrication systems. The code can be used to investigate a wide range of issues, such as component design, vehicle emissions, and system interaction. Each simulation consists of a library of component models that you can add to an existing model and edit using a point-and-click interface. Each of the modeling areas mentioned above can be modeled in isolation or as a single, integrated system using GT-SUITE's unique model building architecture.

Design optimizer

The GT-SUITE Design Optimizer can be activated for any model in GT-ISE, and clicking the Run Simulation button will run an optimization study instead of a normal simulation. The Direct Optimizer runs the simulation iteratively, each time changing the parameter values which represent the factors, until a stopping criteria is met. Optimized simulation results may then be viewed in GT-POST.

Genetic algorithm

This genetic algorithm performs a broad search of the design space is the recommended choice for problems with any medium to high complexity: when using three or more factors, for multi-modal problems, and/or when working with very non-linear problems.

The two key inputs required from the user are the population size and the number of generations to run. Multiplying these two inputs yields the total number of designs that the optimizer will run. There are no automatic stopping criteria when using the genetic algorithm; the optimizer will stop after completing all designs according to the number of generations. After the optimizer automatically stops, the user can extend the optimization study for additional generations by using the Extend button in the Integrated Design Optimizer's toolbar. This button will become active only after the optimizer automatically stops.The population size should generally increase as the number of factors increases, where the counting of factors, *n*, should be as follows:

n = (number of "Independent" factors)(number of active cases)+(number of "Sweep" factors)

Although the best choice of population size will depend on the particular problem and should be considered in conjunction with the number of generations, the following table can serve as an initial recommendation.

n	Population Size
3	10
4	16
5	20
6	26
7	30
8	40
9+	50

The genetic algorithm has five parameter settings: population size, crossover rate, crossover rate distribution index, mutation rate, and mutation rate distribution index. It is generally true that a set of optimal parameter values can be found to work best for different problem classes. For example, specific values are recommended for predictive combustion calibration, as detailed in the Engine Performance manual. If a user expects to use the genetic algorithm multiple times for similar problems, it might be worthwhile to experiment with different parameter settings to see what works best. Otherwise, using the default parameter settings should be sufficient.

Source: User's manual in GT-SUITE