The present working document of the European Commission intends to sum up the results of the discussions held in 2014 by the Working Group on aerodynamics and safety, set up by DG MOVE to detail the technical elements corresponding to Article 9a of the Leichtfried-Lupi Directive. This directive is amending Directive 96/53/EC. The Article 9a considers granting a length extension to the cab to enable safer and greener tractors for heavy goods vehicles.

1. Requirements of the Leichtfried-Lupi Directive concerning cabs

Article 9a of the Leichtfried-Lupi directive applies to tractors towing a trailer or semi-trailer, to rigid trucks, buses and coaches (classes M2, M3, N2, N3). Points 1.2 to 1.8 of Annex 1 of Directive 96/53/EC remain unchanged. According to Article 9a point 2, the derogation in length is based on the following criteria, between is no priority:

- demonstrable improvement in aerodynamic performances,
- improved visibility of vulnerable road users for the truck drivers,
- reduction of blind spots,
- reduction of damage or injury to other road users in case of a collision,
- and safety and comfort of the drivers.

The working group was set up by DG MOVE to help it defining:

1. **requirements with regard to the improvement in aerodynamics** of the vehicle. The demonstration procedure will ultimately enter into the type approval procedures created by Regulation (EC) 661/2009 and Regulation (EU) 1230/2012.

- 2. With regard to **safety and driver comfort** : The revision of the Directive provides an opportunity to make important improvements to the safety of HGVs and to the health and comfort of drivers, by improved design and the introduction of new equipment. The working group on aerodynamics and safety has identified **relevant technical safety improvements that can be linked to the increased length of cabs**. The Commission is currently studying further updates of type-approval Regulation (EC) 661/2009, taking into account the changes to maximum dimensions resulting from the Leichtfried-Lupi Directive.

As a general rule, new vehicles shall comply with Regulation (EC) 661/2009 and Regulation (EU) 1230/2012 (and their updates) as well as the relevant UNECE
Regulations. Some UNECE Regulations need to be updated to fully correspond to the amended Directive 96/53/EC. The EU shall work to ensure those necessary updates.

2. Aerodynamics of the front of the truck

The first objective of the length derogation is to enable a demonstrable improvement of the aerodynamics of the tractor and entire vehicle combinations, with a view to improving fuel efficiency and to reducing polluting emissions. The length extension shall not be used to increase loading capacity.

The maximum dimensions of the extended vehicle front, the wheel-bases of the towing vehicles and the rear of the cabs are derived from the mandatory compliance of the possible vehicle combinations with Annex I point 1.5 of Directive 96/53/EC and Regulation (EU) 1230/2012 (maneuverability circle requirement).

An analysis performed by ACEA by using the worst case scenario with respect to vehicle combinations (a tractor towing a semi-trailer) indicates that an overall maximum extension of the Bumper to Back of Cab (BBC) of around 900 mm is possible without being in conflict with the turning circle requirement (Annex I point 1.5) and applicable type-approval requirements.

The compliance with applicable type-approval requirements and the need for major redesign are directly linked to the distribution of the possible extension between the front of the truck and the rear of the cab, where front extensions are the most critical in this respect. The FUP requirements would probably need to be modified in order to allow an extension of the front by more than 350 mm.

For the purpose of establishing the improvement of the aerodynamic performance, the following elements are required:

- 1. reference in comparison to which the future generations of vehicles will be measured to demonstrate the improvement: the proposal is a common reference for all manufacturers, representing the mean values between a selection of the 3 most aerodynamic long haul
vehicles of category N3 on the EU market on the date of adoption of the Directive Leichtfried-Lupi modifying 96/53/EC (first semester 2015), as defined by the VECTO HDV classification.

The values constituting the reference vehicles will be introduced in the updated type-approval legislation.

- 2. The parameter to be measured for the reference vehicles and for the tested vehicles is the aerodynamic drag coefficient Cd.

- 3. The test procedure shall define the test conditions, and the conditions of simulation or measurement. The tested vehicles will be evaluated in the same conditions as the ones used to measure the reference vehicles : equipped with identical reference equipment (tyres, …), similar weather conditions, and attached to the same trailer or semi-trailer.

The procedure will be the one currently used for the measurement of the drag coefficient inside the VECTO system (VECTO-Constant Speed Evaluation) developed for the European Commission in cooperation with the vehicle manufacturers.

- 4. Alternative to constant speed test procedure within VECTO: Manufacturers may choose instead of the use of VECTO the following alternative methods:

  - wind tunnel tests (either on full or reduced scale between 1/1 and 1/5). The demonstration shall be according to the US standard SAEJ 1252. The comparison with the reference vehicles will be made in the same tunnel.

  - use of computer simulation models, once a standardized computer simulation methodology has been developed, validated and agreed for the aerodynamic measurement.

- 5. The results of the test procedure shall be assessed by the technical services designated for type approval tests in the EU, in order to ensure a pan-European validity of the certificate.

- 6. This test procedure will be included in the type-approval legislation.

ACEA has proposed an alternative to this demonstration process for extensions of the BBC up to 500 mm. This alternative proposal is described here under:

For this limited extension a simplified procedure would use an “envelope” agreed to represent the area within which an extension can be allowed without being in conflict with Directive 2007/46/EC as amended, and with the Annex I point 1.5 of Directive 96/53/EC and Regulation (EU) 1230/2012 (manoeuvrability circle requirement). The critical type-approval requirement with respect to the front extension is the max allowed 400 mm deflection of the Front Underrun Protection (FUP) from the most forward part of the vehicle. The max 500 mm extension will only be possible if an exemption is granted from this 400 mm requirement for soft zones intended to reduce impacts for Vulnerable Road Users (VRU).
The reference against which the “envelope” should be compared is defined by the parameters applicable without the length derogation - Maximum height of 4.0 m, maximum width of 2.55 m and max BBC 2.35 m

1. This “envelope” is characterised by:
   A. Maximum rear width of 2.55 m
   B. The tapering on each of its sides reflecting the worst case tapering (degrees) necessary to keep the extended front within the outer circle of the turning circle requirement.
   C. A BBC of maximum 2.85 m
   D. A front radius which is determined by the minimum radius that can be applied without being in conflict with existing TA requirements
   E. The maximum height of 4.0 m.

\[1\] The parameters that define the extended envelope have yet to be agreed and should include parameters that have been shown to improve the aerodynamic performance. The resulting envelope needs to be validated before application.
- 2. Extensions of the BBC of maximum 500 mm are allowed under the conditions\(^2\) that these extensions are within the identified area of the extended envelope, and provide an improvement of the aerodynamic drag of at least [1] % by a virtual test.

![Possible Usage of Front Extension](image)

(View 3)

(the green areas represent the possible extended cabs, inside the envelope presented in blue)

The elements mentioned with (*to be agreed) should be defined later (including the utilization of the envelope) with respect to the top view as well as the side view, during the definition of the final requirements. In view 2, the degrees to the left and right are related to the worst case tapering necessary to keep the extended front within the outer circle of the turning circle requirement. The front radius is determined by the minimum radius that can be applied without being in conflict with existing type-approval requirements, mainly the FUP requirements but also related to any new passive safety requirements that might be introduced with respect to VRUs. The side and top radius are linked to the importance, with respect to air drag, of keeping the air stream following the vehicle shape. It should be noted that is does not exist one single value for each of these characteristics that is the best from an aerodynamic perspective but many different combinations can achieve the same result.

Furthermore, some parameters can at the same time have impacts on other important vehicle characteristics. Larger corner radius and tapering reduces the volume in the cab and can reduce the available area for driver and passenger seats which might need to be compensated by moving these backwards, that in turn impacts the driver’s direct fields of vision.

\(^2\) These conditions need to be agreed and should specify which extensions are allowed
During the discussions, it appeared that many stakeholders rejected this proposal for the following reasons:

- (a) the envelope concept does not guarantee that new vehicles are more aerodynamic than the reference vehicles, a situation which would contradict the first criterion set by Article 9a point 2 of the Leichtfried-Lupi Directive;

- (b) this proposal might tend to limit the willingness of manufacturers to use the full capability of length extension up to the 900 mm allowed by the maneuvering circle requirement, and thus limit the potential to fully increase safety with the new designs.

Discussions on this proposal might continue during the update process for the type-approval regulations, but at the present stage, this proposal is not retained.

3. Safety

The following paragraphs are based on the fact that Article 9a point 2 of the Leichtfried-Lupi Directive indicates the improvement of safety as a criterion for granting length extension of the cab, with the following aspects: protection of vulnerable road users, their visibility for the driver, reduction of blind spots, reduction of damage and injury caused to other road users in the event of a collision. This paragraph will provide the recommendations of this working group for the update of the type-approval legislation on how to best use the extra space in the cabs for the purpose of safety. The following paragraphs have consequently been organized around such recommendations.

- a. vulnerable road user (VRU) protection:

1. general approach: Between 50 and 75% of vulnerable road users fatalities in accidents with trucks occur during a collision with the front of the vehicle. A pedestrian or cyclist involved in a frontal collision with a truck has a very high probability (70%) of being overrun by the lorry. Pedestrians involved in such collisions can be injured in several different ways:

- The initial impact with the front of the vehicle
- A secondary impact with the ground
- Being run-over by the wheels.

Permitting additional length would to improve this situation by two distinct mechanisms:

a) Improve packaging and use of deformable materials such that a few centimeters of controlled crush could occur in the initial impact, to reduce forces and accelerations on the pedestrian. This could be achieved with sheet of metal or plastic of appropriate stiffness combined with the removal of “hard points” in the zone immediately behind.
b) Introduce a curved profile, that would improve the kinematics of the pedestrian such that they are not pushed to the floor so directly (reducing the probability of injury in the secondary collision with the ground), and deflecting them to the side such that they fall outside of the path of the wheels, reducing the risk of being run-over.

It should be noted that though many of the vehicles that would apply for an extended front may complete most of their journey outside urban areas, many of these vehicles will also enter urban areas.

It should also be noted that the effect of the deflection depends on speed. Many accidents involving VRUs and HDVs in urban areas occur at a relative low speed – especially when starting (from stand still) or when turning.

The following recommendations have been proposed by the participants.

2. **Recommendation 1**: For vehicles taking full advantage of a length extension around 90 cm to the front, a more effective deflection effect will happen if the structure at the centerline of the vehicle is at least 80 cm forward of the front corners of the structure.

Note: It should be further verified that this recommendation is not in conflict with the Front Underrun Protection (FUP) requirements.

3. **Recommendation 2**: Manufacturers should optimize the deflection effect of their elongated cabs to minimize the chances of vulnerable users going under the vehicle or its wheels. They should also include deformable structures in these rounded shapes, as well as a soft zone to reduce head impacts for adults and children.

To reduce the severity of injuries to vulnerable road users, the front structure should be divided into horizontal bands representing zones where lower limb contacts, child head contacts, adult chest contacts and adult head contacts will occur. See an example in the figure below (the vehicle shown is a theoretical design used for the purpose of the example).

![IMPACTOR ZONES](image)

Each zone defined as above could be tested with the impactors specified in Regulation (EC)
631/2009 (annex), or an equivalent regulation to be adapted from this one. These impactors measure forces, accelerations and other parameters. They represent the low speed urban environment where the great majority of VRU collisions occur. The limit values for the impact tests for the different impactors should be those provided in point 3 of Annex I to Regulation (EC) No 78/2009.

These requirements can be met by providing appropriate deformation distances (2 to 3 cm ?) through appropriate sheet metal surfaces or plastic structures which will deform and attenuate the forces to acceptable levels. Major structural changes and additional weight is not necessary.

Furthermore, a FKA study shows that a surrounding plateau (as shown in red on the photo below) has an important effect in deflecting the vulnerable road users, avoiding overrun and roll over of these users, as well as dampening the impact in accidents with cars. The curvature of the plateau along the width of the truck has also an important advantage in right-cornering scenarios.

![Example of a plateau structure](image)

To ensure that truck fronts are optimized for vulnerable users protection without prescribing a pre-defined design, a test procedure should be developed in the type-approval legislation to test/simulate whether new designs would avoid overruns and overroll as well as whether they improve the structural interaction between lorry fronts and VRUs in case of frontal collisions.

Regulation (EC) 661/2009 already requires side underrun protection systems (UNECE Regulation N°73) for heavy goods vehicles. However a number of derogations are allowed when such systems are not compatible with the use of the vehicle (e.g. off-road vehicles). These derogations should be revised during the update of Regulation (EC) 661/2009.

This recommendation will have to be tested against Regulation (EU) 1005/2010 which says that “All motor vehicles must have a towing device fitted at the front”.

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- b. **improvement of the field of vision of the driver.**

1. General approach:

The position of the driver and the dimensions of the current window apertures to the front and the sides mean that there are large blind areas in the driver's field of vision (direct and through mirrors). More than half of fatal accidents in the blind spot occur in close proximity of the lorry cab. Especially in urban areas, it is particularly difficult for the driver to see pedestrians, cyclists and powered two-wheelers during near side turning manoeuvres.

For urban vehicles, existing examples demonstrate that a lower visibility window in the door and extended windows in the front can be introduced independently or as part of a front extension.

The EU Vehicle Type Approval process does not include any harmonized requirements on forward vision, but the existing German requirements (StVZO §35) could represent a suitable baseline for identifying the forward vision performance of European trucks, and to develop a direct vision requirement for these European trucks.

2. **Recommendation 3**: A length extension allowing redesigning the cab could improve direct vision and eliminate most of the blind spots through the development of larger windscreens (taking however into consideration the requirements on the cab structure and the impactor zones presented above in 3.a), and the inclusion of low window apertures (or transparent doors) on the side doors of the cabs. It might also facilitate lowering the driver's eye height.

This solution is preferred by the drivers (represented by ETF) against a multiplication of mirrors or screens which may provide distorted images and lead to cognitive overload distracting drivers and reducing their effectiveness. At night, these screens cause also disturbing light in the cab.

Some studies consider that the direct vision of N3 vehicles could be significantly improved by increasing and adding windscreens and slightly lowering the driver eye height (230 mm) as illustrated below (a situation which is more and more used for urban trucks). In the example below, the driver's field of vision would be improved by up to 50 % compared to a reference cab.

![Examples of larger window apertures on a theoretical model](image-url)
However, as mentioned in the recommendation here above, it is recalled that cab designs have to comply with UNECE regulation No 29 on cab strength, which might limit the possibilities for windows extensions, unless it is revised (Large glass areas reduce the structural integrity of the cab).

3. **Recommendation 4** : due to the reasons put forward above, it is recommended that further direct vision requirements be developed for vehicles with extended cabs.

An amendment to UNECE Regulation No 46 was recently adopted to enhance the indirect field of vision on the passenger side of trucks. This amendment should improve the driver's field of vision in case of a turning manoeuver and will be mandatory for all trucks sold from 30 June 2015.

4. **Recommendation 5** : A complementary solution to improve safety is **active safety measures** which can identify hazards by using radar, cameras and sensors that will warn the driver of a possible hazard. If no action is taken by the driver in due time such actions can be activated by the system. This solution can reduce the impact of human errors for which modern technical solutions can provide an effective driver support.

The use of cameras to reduce or eliminate blind spots has already been identified by UN ECE as important future safety measures. Beside its positive safety impact it also provides important improvement of aerodynamics (if existing mirrors would be replaced by cameras).

Both these positive effects can be achieved without major redesigns of cabs and have in some cases the additional benefits of also being possible to be applied on existing trucks.

- c. **energy absorption in case of frontal collision with another vehicle**:

1. **General approach** : Including energy-absorption in the front underrun protection system would improve the survivability of road users during frontal collisions, up to relative speeds of 75km/h.4

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4 ECE/TRANS/WP.29/GRSG/2011/23/Rev.1
An optimized approach to energy absorption might require extending cabs approaching the 90 cm. Some minor amendments to UNECE regulation on Front Underrun Protection (R93) and possibly of the UNECE regulation on lighting and light-signaling devices (R48), or of Regulation (EC) 661/2009, may facilitate an extension of the cabs beyond 35 cm with a curved design. Some participants in the group however consider that a majority of FUP products on the market are currently stiff enough to allow an extension by 80 cm with the existing regulations.

Currently, manufacturers’ requirements like the minimum approach angle (in red in the picture below) that can be accepted for different vehicle applications, also limit the length extension. This angle varies between application with construction vehicles (requiring the largest angle), and vehicles operating on a smooth area such on an airfield requiring the smallest.

Extending the front of a long haul truck by around 80 cm requires the front axle to be moved forward due the approach angle requirement and will likely give as an effect that the instep to the truck cab needs to be located behind the front axle (instead of in front as is the standard today) which in turn will require a major redesign of the chassis/cab.

Furthermore, the current FUP regulation requires the FUP to be fitted so that it is located at max. 400mm from the foremost part of the vehicle after deformation as illustrated below.

2. Recommendation 6: A substantive amendment to UNECE R93 could seek to improve the effectiveness of FUP and allow the integration of energy absorbing devices (crash boxes),
providing increased protection (possibly equivalent to 4*NCAP) for the occupants of colliding cars.

This amendment could also define a **common interaction zone** at the front of the truck: "only structures essential to the function of the front underrun protection are permitted to have a stiffness in the x-axis in excess of 200 kg/m in a zone extending across the full width of the vehicle to a height of 2 m above the ground and covering the length from the front of the vehicle to a point 40 cm rearward of the front face of the FUP". To ensure the maximum effectiveness it should also be ensured that structural interaction between cars and trucks is optimized.

The front structure should also have a maximum height of 360 mm in order to limit the damage to adult pedestrians’ legs, reduce the chances of VRUs being run over and provide compatibility with the bumper heights of car.

- d. **truck occupant protection (driver safety):**

  1. **General approach**: 12 % of fatalities with trucks involve truck occupants. Most cases occur when trucks strike other trucks or roadside objects, or when a truck rolls over. Such situations usually involve substantial intrusion into the interior space. Hence, cab strength is important as well as occupant restraint. This issue is addressed by UNECE Regulation 29 on cab strength. As requested by Regulation (EC) N°661/2009, the Commission has made mandatory this UNECE Regulation with Regulation (EU) N°166/2015 (for type-approval of new types by 30.01.2017 and all new vehicles of category N by 30.01.2021).

  2. **Recommendation 7**: The safety of the truck occupants should be increased by an improved absorption zone at a suitable height.

- e. **active safety:**

  1. **General approach**: In addition to the issues set out under points 3. a – d above, the development of active safety technologies can help improving the safety of all road users, especially vulnerable road users, as already mentioned above, and should be encouraged. Vulnerable Road Users can be identified by using radars, cameras and sensors that will warn the driver of a possible hazard. If no action is taken by the driver in due time, such actions can be activated by the system. This technology can consequently provide effective driver support and reduce the consequences of human errors.

    The additional space granted with the extra length of the cabs gives the opportunity to integrate more easily the necessary equipment for active safety systems.

    2. **Recommendation 8**: New Regulations should address active safety under the EU type-approval framework and at UNECE level.
It is recalled that there is an on-going revision of the type-approval safety requirements (Regulation (EU) N° 661/2009) and Regulation (EC) N° 78/2009. This revision should cover active systems, truck safety and vulnerable road user safety.

The opinion of many members of the group is however that active safety measures cannot replace sound passive safety designs. For instance, the Autonomous Emergency Braking System represents an interesting new approach at speeds above 40 km/h, but may be less effective in urban areas than an improved direct vision, due to the fact that the time available in typical pedestrian crashes is very small.

4. Driver comfort

Article 9.2 of Directive Leichtfried-Lupi sets driver comfort as one criterion upon which the length extension is granted. As a consequence, this paragraph will provide the recommendations of this working group for the update of the type-approval legislation on how to best use the extra space in the cabs for the purpose of driver comfort. The following paragraphs have consequently also been organized around such recommendations.

The following Directives are currently relevant for driver comfort and safety:

Directive 2002/44/EC – vibration
Directive 2003/10/EC – noise
Directive 2006/42/EC - machinery directive

As a preliminary, it should be noted that the extension of around 900 mm enables also an extension to the rear of the cab of about 400 mm due to the possibility to extend the wheelbase of the tractor without being in conflict with the turning circle requirements (inner circle). With a 400 mm extension to the rear of the cab the BBC will increase to 3250 mm

Following the discussions of the working group, the issues proposed to be addressed and which are facilitated by an extension of the cab length are the following.

- a. improved quality of sitting and resting:

1. General approach: the increased space allows manufacturers to better adapt the seats to the size of the driver, to allow him to get promptly into correct driving position, include lumbar support, arm rest, to allow adjustability of the steering wheel, and eliminate bulkheads
around the seat, to provide the possibility of a swivel seat for use while resting and an increased width of the sleeper bunk including the madras. Extra space to the rear of the cab also provides space for increased insulation for better cab climate. It could also allow the driver to exit more easily from the cab in case of emergency.

2. **Recommendation 9**: The width of the couchettes could be increased by 20 cm thus also leading to the elimination of the dent in the lower couchette.

3. **Recommendation 10**: At the front of the vehicle, the cab extension could be used to increase the total existing length between the couchette and the driver’s work station; driver’s seat should be adjustable (rearward and forward for the full length).

4. **Recommendation 11**: The gain in volume – of about 0.9m³ could also be used to increase the storage space with a safe storage, for driver’s personal belongings.

If lowering the cab floor (cab position, windshield) may result in more cab volume being taken up by the engine, driver's opinion is that it is not desirable from the point of view of their comfort.

**- b. vibration reduction:**

**Recommendation 12**: The reduction of vibrations in the cab could possibly be achieved by a cab suspension in 4 points.

Further studies are however necessary to completely define the solutions.

**- c. noise reduction**: Drivers are exposed to constant noise and vibration from their own vehicles generated by the machinery and their working environment (traffic noise). Noise can damage hearing. Continuous exposure to high noise levels of 85 dB(A) and above for a number of years can lead to a loss of hearing. Noise can also contribute to stress. Reducing cabin noise improves driver comfort, but also his productivity and his safety.

**Recommendation 13**: noise level in cabs should be reduced below 70 dB(A).

Such a reduction of the noise level seems to be a challenge and might require additional space for insulation material. Thus, further studies are required, also on test methods and the conditions under which this level should be achieved.

**- d. Miscellaneous**

The group also draws the attention of the vehicles designers on the following issues, but recognizes that increase in the cab size is also constrained by the maneuverability criteria set by Directive 96/53/EC and Regulation (EU) 1230/2012:

- improved access in and out of the cab with anti-skid steps, large and deep enough to ensure adequate room for safe access,
- safely coupling / decoupling features between tractor and trailer
- placing of control devices in driver's visual field.

The Commission thanks all participants of the group for their participation, their cooperative spirit and the quality of the results achieved.