CEDR

Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

Conditions for efficient road transport in Europe

July 2017

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Executive summary

Freight transport needs are expected to grow significantly by 2030. In spite of ambitions to ensure that this growth is absorbed by rail, short sea shipping, and inland waterways, it is becoming increasingly clear that a significant proportion of freight transport growth *will* have to be absorbed by roads (EC 2008). Even if multimodality is optimised, the first and last leg of transport operations will take place on the road. Furthermore, in its current state, the rail network is either limited in capacity in some places (e.g. Sweden[1]) or does not offer the necessary reliability for time-sensitive transport operations (e.g. the transport of perishable goods). Moreover, the planning and construction of new rail infrastructure can take up to 20 years. In the light of all this, it makes sense to examine potential ways to make road transport operations as efficient as possible.

Directive 96/53/EC leaves room for individual countries to deviate on their own territory from agreed maximum weights and, to some extent, dimensions. Many member states have made use of, or are planning to make use of, this possibility, while others maintain that the limits laid down in the directive should not be exceeded. The result is that legislation on weights and dimensions varies greatly from country to country and from region to region within Europe. This is due partly to varying infrastructure prerequisites that naturally limit the possibility of permitting longer or heavier vehicles and partly to the on-going debate on the effects on the modal shift. The issue remains politically sensitive, involving many conflicting interests and agendas, as demonstrated by the controversy sparked by the recent introduction of longer vehicles in Germany[2].

Of the 26 countries represented in CEDR, 14 deviate from the maximum length and/or maximum gross weight for heavy duty vehicles agreed in Directive 96/53/EC. For these countries, the main reason for this deviation is that it allows them to accommodate the growth of road freight transport, to accommodate the needs of specific logistics tasks (e.g. the transport of vehicles or timber) and to reduce CO_2 emissions. Those opposed to increases in the maximum weights and dimensions fear competition with other modes and a negative impact on traffic safety and the life span of road and bridge structures. The differences in viewpoints among CEDR members led to the setting up of Task Group N4 (Heavy Vehicles) in CEDR's Strategic Plan 2013–2017.

The variety of viewpoints on weights and dimensions within CEDR makes it difficult to agree on how heavy vehicles' weights and dimensions can be adapted to maintain or increase the performance of the road network. In order to allow CEDR's members to identify common positions on these issues and to help create strong, professionally grounded positions on subjects relating to the weights and dimensions of heavy vehicles, the group was tasked with compiling an inventory of on-going developments and ways of thinking about the weights and dimensions of heavy vehicles within CEDR countries.

Task Group N4 (TG N4) has taken into account the broader perspective of the link between access policy (mainly weights and dimensions) and road freight transport. The group has tried to draw conclusions and make recommendations that will help CEDR members evaluate their access policies in order to meet the challenges of ageing infrastructure, accommodate the growth of road freight transport, and lower emissions.

In order to get an overview of the CEDR members' different ways of thinking about the weights and dimensions of heavy duty vehicles, TG N4 conducted a survey in the form of a

[1] http://portal.research.lu.se/portal/files/16727368/Systemanalys_HCT_Slutversion_okt2016.pdf

[2] See http://www.verkehrsrundschau.de/allianz-pro-schiene-wirft-dobrindt-fehlendes-engagement-vor-1861409.html but also point 2.2.3 of the system analysis of the High Capacity Transport project in Sweden http://portal.research.lu.se/portal/files/16727368/Systemanalys_HCT_Slutversion_okt2016.pdf

questionnaire (Part 1). Fifteen CEDR member countries and two non-CEDR countries responded.

The task group analysed the responses and drew conclusions. Although it was not possible to get a complete overview, it was possible to provide a good picture of the differences in access policies between countries/regions in Europe. From a scientific perspective, the results can only be viewed as indicative.

The results showed, among other things, that the demand for extra weights and dimensions and the extent to which countries made use of the possibility to deviate from the EU-standards (i.e. not to comply with Directive 96/53/EC, amended by Directive 2015/719) differs according to type of transport and region. If the growth in freight transport by 2030 has to be accommodated mainly by roads, it could be beneficial to focus on longer vehicle combinations such as the *Lang-Lkw* rather than on EMS.

The questionnaire and feedback from CEDR showed that many organisations represented in CEDR are interested in the development of harmonised performance-based standards (PBS) for infrastructure, which could be used for the objective assessment of the suitability of roads for vehicle combinations with weights and/or dimensions exceeding the specified limits in Directive 96/53/EC. Such an approach would be applicable to all heavy-duty vehicles above 3.5 tonnes.

The group commissioned The Swedish National Road and Transport Research Institute (VTI) to conduct a study and literature review of the above topic. In 2015, VTI published the results in the **report '*Performance-based standards for vehicle combinations with weight and/or dimensions exceeding the specified limits in the Directive 96/53/EC* ' (Part 2)**.

The pre-study showed that vehicle-related topics are thoroughly regulated by EU legislation and are, therefore, very difficult to alter, as well as already being well described in existing literature. Road infrastructure factors, on the other hand, are to a much greater degree subject to national variations.

The results of the VTI study led to the formulation of **a DoRN (Description of Research Needs) for Part C of the 2015 Call Freight and Logistics in a Multimodal Context (Part 3)**. The FALCON group was selected for part C: Fit for purpose road vehicles to influence modal choice (performance-based standards) and for final dissemination. The project is set to finish in April 2018 with final dissemination in the autumn of the same year.

The result of the FALCON project will be a proposal for a Smart Infrastructure Access Policy (SIAP) that is performance based as a one-solution tool, which can be developed even more widely in future. The project will reflect on the capabilities and design criteria of the current infrastructure network including roads, bridges, and tunnels. It could help road owners to handle the growth of heavy duty transport in a better and more unified way.

The results of the two research projects (parts 1 + 2) and the description of the current FALCON project (part 3) can be found in this report. The conclusions and recommendations in this report can also be used as suggestions for the FALCON project, which is currently underway. To be able to implement these recommendations and the results of the FALCON project, a working group should continue work on these criteria to ensure that the results of the project are implemented through PBS criteria and to facilitate the use of these criteria in CEDR countries. Such a group should preferably be organised by CEDR.

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List of Abbreviations

PBS	performance-based standards
LHV	longer and/or heavier vehicle combination, exceeding the current permitted weights and dimensions in Directive 96/53/EC
R	Regulations
Dir	Directives
ISO	International Organization for Standardization
EBS	Electronic Braking System
ESC	Electronic Stability Control
EMS	European Modular System
DoRN	Description of Research Needs

General introduction

The European Commission has set ambitious emission targets for the transport sector in order to reduce global warming, slow climate change, and improve air quality. In 2013, the transport sector contributed about one-quarter of the EU's GHG emissions[3]. Moreover, this is the only sector whose contribution to GHG emissions is growing. The growing demand for freight transport caused by globalisation is one of the driving forces behind this trend. The European Commission Directorate-General for Energy and Transport (EC 2008) projects that road freight transport activity will increase, accounting for 75.4% of total freight transport by 2030. It is clear that intrinsically more efficient logistics are needed. Furthermore, according to the EU, a modal shift from road to rail, short sea shipping, and inland waterways— i.e. optimum multimodality—is necessary. But as indicated in Figure 1, it is also clear that European roads will have to absorb the lion's share of the increasing transport demand.

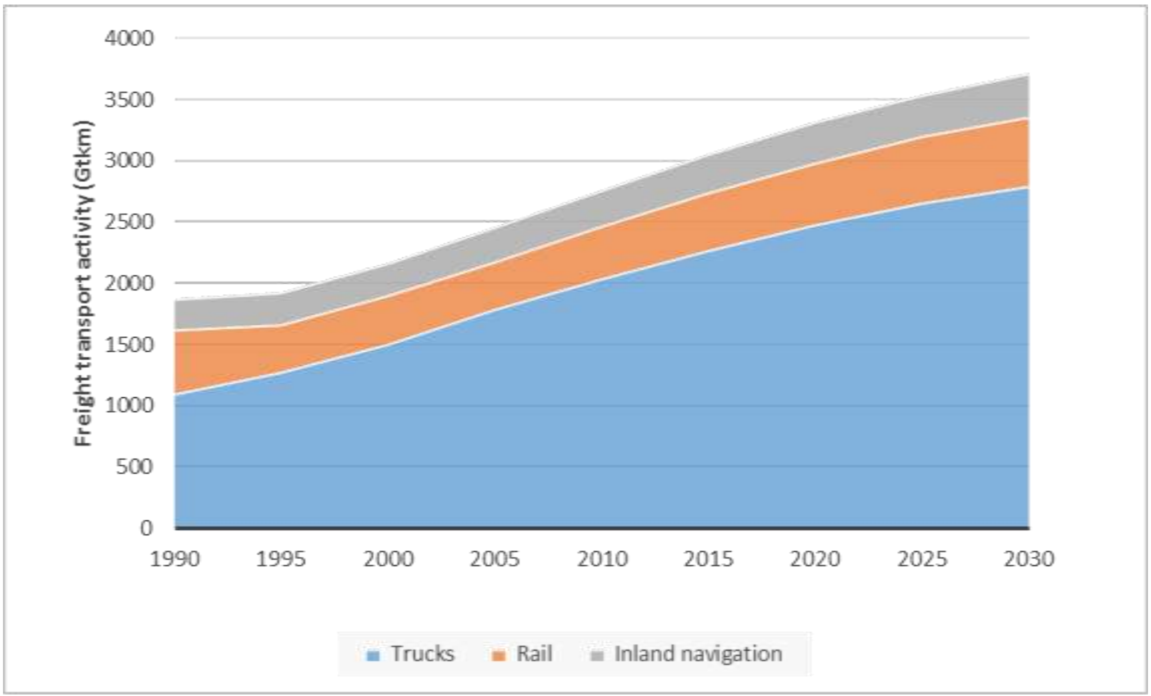

Figure 1: Freight transport activity, 1990–2030[4] (EC 2008)

There are several reasons why goods are carried by road and why a modal shift is not possible, e.g. the shipper or receiver of goods is not located on an inland waterway or at a railway line, short distances, small amount of goods, or time pressure. Moreover, even if money/resources are invested in rail infrastructure, it can take 20 years for new infrastructure to be ready for use. In order to be able to absorb the growth of freight transport by road and to meet societal needs (health, safety, congestion) and ambitious emission targets, freight transport by road should be made more efficient. One way of dealing with this problem is to look at the differences in the access policies of European countries. There is a direct connection between restrictions on weights and dimensions and on the free circulation of heavy goods vehicles on the one hand, and the efficiency of road freight transport on the

[3] https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-5

[4] European Commission Directorate-General for Energy and Transport; TRENDS TO 2030 - UPDATE 2007

other. Restrictions are imposed on heavy goods vehicles for very reasonable reasons: to protect the infrastructure, to increase traffic safety, to improve air quality, for reasons related to road design etc. Nevertheless, the results of all these local, regional, and national measures could be inefficient road freight transport because they lead to more heavy goods vehicles on the roads and extra kilometres driven.

In Europe, vehicle weights and dimensions are regulated both with respect to type approval and to the circulation on European roads, each in a different piece of legislation. There is a wide range of European regulations and directives that regulate performance levels for vehicles, but only a small number of European directives that regulate performance levels for infrastructure. The common approach is to set maximum limits on vehicle (combinations) weights and dimensions to ensure safety and to protect the infrastructure. Furthermore, restrictions on access to the road network are imposed on heavy vehicles. Such restrictions include driving bans, dedicated routes, and environmental zones. These traffic restrictions are not harmonised for Europe and can be regulated at national, regional, or local level.

Directive 96/53/EC sets out the maximum authorised weights and dimensions for heavy goods vehicles, buses, and coaches in international transport and certain dimensions for such vehicles in national transport. It also requires member states to allow vehicles with weights and dimensions that comply with the limit values specified in Annex I of the directive in both international and national traffic. This ensures these vehicles' access to the road network in each member state and equal competition in the road transport industry.

During the lifetime of TG N4, Directive 96/53/EC was under revision with a view to taking account of new technologies and needs, facilitating intermodal transport, and reducing energy consumption and emissions. The result of this revision was the new Directive 2015/719/EC, which amends the former Directive 96/53/EC. These amendments are taken into account in this report.

Several of CEDR's member organisations have expressed an interest in the development of standards for determining whether a type or section of road is suitable for heavy vehicles with weights and/or dimensions exceeding the limits specified in Directive 96/53/EC. However, the application of such standards is not limited to determining whether a road is suitable, for example, for European Modular System (EMS) combinations with a length of 25.25 m and a total weight of up to 60 tonnes. Road administrations and legislators could also use the standards to decide which roads to open to which types of heavy vehicle. The aim is to facilitate the use of the right heavy vehicle on the right road. A further step could, for example, be to take into account traffic density at certain times of the day or in certain weather/seasonal conditions.

This report is divided into three different parts.

CEDR's members have very different views on the weights and dimensions of heavy vehicles. It was, therefore, interesting to try to get an overview of how these views vary and how they translate into member countries' regulations on weights and dimensions and on other types of regulations applying to heavy vehicles. To this end, Task Group N4 (TG N4 on Heavy Vehicles) was set up in 2013. The group conducted a questionnaire-based survey (see Part 1 of this report) and distributed it to all CEDR members and to a few other European countries that are not CEDR members. The responses to the questionnaire showed clearly that the regulations relating to where and how heavy vehicles are allowed to circulate vary considerably from country to country. Based on the results of the questionnaire, TG N4 deemed it necessary to commission an overview of regulations in the EU and some CEDR countries relating to heavy vehicles and infrastructure. The study described in Part 2 of this report is a more detailed version of what was originally carried out as a pre-study for a Call under the CEDR Transnational Road Research Programme. The pre-study then led to the formulation of a DoRN (Description of Research Needs) for the 2015 Call 'Freight and Logistics in a Multimodal Context'. This project is currently underway. Part 3 of this report describes the background and status of TG N4's activities within CEDR's Strategic Plan 2013–2017 and makes some suggestions regarding potential future use of the results.

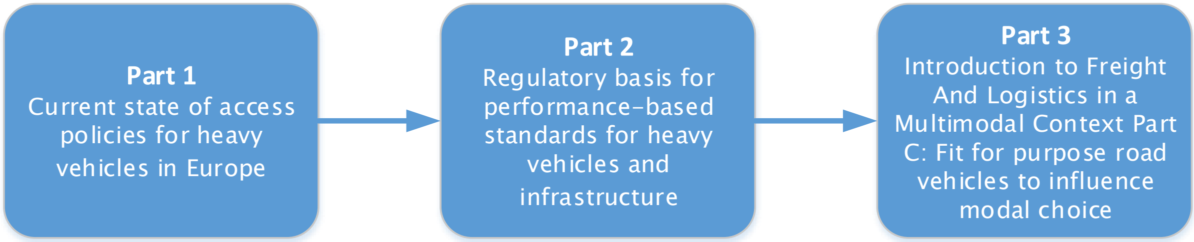

Figure 2: Structure of this report

Part 1 of this report summarises the results of the questionnaire-based survey that was conducted with a view to getting an overview of on-going developments and ways of thinking about the weights and dimensions of heavy vehicles. The questionnaire was divided into different focus areas covering the revision of Directive 96/53/EC, derogations in national legislation regarding to Directive 96/53/EC, other national regulations on issues such as traffic restrictions, heavy vehicle inspections, and weight checks, heavy vehicles safety, and accessibility for heavy vehicles in winter conditions.

Part 2 of this report (written by The Swedish National Road and Transport Research Institute) reviews and compares existing pieces of legislation in Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden that restrict the weights and dimensions of heavy vehicles. Other relevant legislation relating to safety and the environmental effects of heavy vehicles are also presented. Performance measures for the safety and manoeuvrability of longer and/or heavier vehicles (LHVs) as well as relevant infrastructure and environmental aspects are also discussed. Areas requiring further investigation have been identified.

Part 3 of this report gives a short introduction to the CEDR Transnational Research Programme Call 2015 'Freight and Logistics in a Multimodal Context', where the research areas identified in Part 2 are one of several research topics. The DoRN was drawn up by the members of TG N4 (Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden). Germany, the Netherlands, Norway, Sweden, and MAN Truck and Bus are funding the call; the intention is to use the results of this research to draft CEDR guidelines on assessing infrastructure. The conclusions and recommendations based on the results of the questionnaire (Part 1) and literature review (Part 2) can also be seen as suggestions for the FALCON project[5]. The results of this project are also intended to be utilised in CEDR guidelines on assessing infrastructure. The FALCON project will finish in 2018. The results will be presented at a 'dissemination workshop', after which a working group to continue the work on the PBS criteria for heavy vehicles and infrastructure could be set up.

[5] **F**reight **A**nd **L**ogistics in a Multimodal **Con**text, which covers part the part of the 2015 CEDR call based on the DoRN

Part 1 Current[6] access policies for heavy vehicles in Europe

Summary

In order to get an overview of how European countries have made use of the opportunities for having different national regulations on the weights and dimensions of heavy vehicles provided by Directive 96/53/EC, amended by Directive 2015/719/EC, TG N4 devised a questionnaire. The aim was to obtain information about on-going and planned projects involving longer and/or heavier vehicles and vehicle combinations and national regulations that affect transport efficiency.

Revision of Directive 96/53/EC

The European Commission put forward a proposal for a directive amending Directive 96/53/EC in the spring of 2013. The proposal included among other things limited increases in the permitted total weight of certain motor vehicles that use alternative fuels, limited increases in the permitted length of vehicles and vehicle combinations equipped with aerodynamic devices and cabs, and new provisions for transporting 45-foot containers. CEDR members had different opinions on whether the proposed increases would affect their infrastructure and the accessibility of vehicles.

Longer and/or heavier vehicles

In addition to not regulating the maximum permitted weights in national transport, the Directive makes two derogations for length: one for special vehicles that operate under special conditions and one for European Modular System vehicle combinations. CEDR countries have to varying degrees taken advantage of the possibility to permit weights and dimensions that exceed the limits set in the Directive. The Nordic countries have made extensive use of these derogations. Other CEDR countries have made use of the derogations to varying degrees. Among those who have, derogations most frequently relate to timber and vehicle transport operations. There have been quite a few developments since the survey was carried out, and new countries have introduced vehicles that do not comply with the directive.

Other national regulations

In addition to permitted lengths and total weights, several other types of regulations also affect the efficiency of road transport. Although traffic restrictions and spring thaw restrictions are common in many CEDR countries, the type and extent of such restrictions vary.

Checks and enforcement

Overloaded vehicles contribute more to the deterioration of infrastructure and therefore generate higher maintenance costs than vehicles loaded in accordance with regulations. EU statistics indicate that the proportion of overloaded vehicles is as high as 30%. CEDR countries report varying proportions of overloaded vehicles, ranging from 2% to 18%, with higher numbers where targeted checks are used. Effective regimes for weight checks are therefore an important factor in preventing damage to the road infrastructure. New provisions in Directive 96/53/EC require EU member states to pre-select vehicles for weight checks

[6] 2013/2014

either by communication with on-board unit systems (OBU) or Weigh-in-motion systems (WIM). As of spring 2014, CEDR members to varying degrees use WIM; only Lithuania reports using on-board systems as well. Many still use manual weighing only.

Winter accessibility

Climatic conditions vary greatly between CEDR countries. In the northern and the mountainous parts of Europe, winter conditions are an additional impediment to the efficiency of road transport. Some CEDR countries have strict requirements for tyres and snow chains and permit the use of equipment that increases traction in difficult conditions but are detrimental to the pavement, such as snow chains, studded tyres, and retractable axles.

1 Introduction

The mandate for TG N4 was set out in CEDR's Strategic Plan 3 (SP3, 2013–2017). The description of the task states that:

'CEDR's members have very different ways of thinking about the weights and dimensions. This diversity makes it difficult to agree on how heavy vehicles' weights and dimensions can be adapted to maintain or increase the performance of the road network. An inventory of ways of thinking about the weights and dimensions of heavy vehicles could form the basis for a more unified position on these issues.'

Accordingly, one of the goals outlined in the group's mandate was to compile an 'an inventory of the on-going developments and ways of thinking about weights and dimensions of heavy vehicles of the different CEDR members.' The purpose of the inventory was to 'allow CEDR's members to identify common positions on these issues, identify topics of which further studies will be of value to many of CEDR's members, and help to create strong, professionally grounded positions on subjects relating to the weights and dimensions of heavy vehicles.'

TG N4 had members from six countries in different European regions: Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden. The members all came from different professional and/or scientific backgrounds. Denmark and Italy were also in the group at the time the questionnaire was formulated; the Netherlands joined the group in 2015.

For the purpose of the task described above, a questionnaire was sent out to all CEDR members and some non-member countries. Rather than asking for in-depth information on a few selected topics, the questionnaire covered a wide range of topics. In the case of several topics, respondents were also asked to provide links or references to studies on the subject in order to allow the group to determine which areas are already covered in literature and which areas could potentially be explored further either by the group or by CEDR.

The main ambition of the questionnaire was to get an overview of how European countries have made use of the opportunities to have different national regulations on the weights and dimensions of heavy vehicles given in Directive 96/53/EC, amended by Directive 2015/719/EC. In particular, the objective was to obtain information about on-going and planned projects involving longer and/or heavier vehicles and vehicle combinations. Furthermore, the questionnaire sought to collect links or references to reports on the experiences from these trials/projects and other issues relating to the long and/or heavy vehicles and their impact on road infrastructure, road safety, and the environment. The questionnaire also included questions on other national regulations such as traffic restrictions, heavy vehicle inspections and weight checks, heavy vehicle safety, and the accessibility for heavy vehicles in winter conditions.

The group's aim in drawing up a questionnaire was to collect information about CEDR member countries' views on heavy vehicles, in particular longer and/or heavier vehicles. The questionnaire originally focused on seven main areas:

1. General information
2. The revision of Directive 96/53/EC
3. Directive 96/53/EC and derogations in national legislation
4. Other national regulations, including traffic restrictions
5. Heavy vehicle inspections and weight checks
6. Heavy vehicles safety
7. Accessibility for heavy vehicles in winter conditions

The questionnaire was distributed to CEDR member organisations and the relevant authorities in EU member states that are not members of CEDR in mid-October 2013. By April 2014, 15 CEDR member countries (Austria, Estonia, Finland, Germany, Iceland, Italy, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Slovenia, Sweden, and the UK), as well as Bulgaria and Slovakia had responded.

Some of the responses were fairly extensive and detailed, while others were only partially completed. Some countries also reported that questions had to be distributed to a number of different departments and agencies, which probably explains why some questionnaires are only partially completed. To obtain the information missing from the original responses, telephone interviews were performed with several of the respondents.

This report describes the responses to a selection of the questions. Part 1 (General information) has been left out as it mainly asked for background information such as the length of the road networks in the responding countries and the number of heavy vehicles registered in the different vehicle categories. Part 6 (Traffic Safety) has also been left out as a lack of uniform data made formulating any kind of summary or conclusions difficult. Furthermore, some of the questions in other parts of the questionnaire are not described in this report, due, for example, to a low response rate or inconclusive data. The questionnaire and an overview of all responses are included in Appendices 1 and 2.

TG N4 analysed the responses and drew conclusions. Although the resulting overview is not complete, it provides quite a good picture of the differences in access policies between countries/regions in Europe. From a scientific perspective, the results can only be viewed as indicative.

2 Results

2.1 The revision of Directive 96/53/EC

After a public consultation in 2011/2012, the European Commission launched its proposal for an amending directive in April 2013. The purpose of the announced revision was to get on track with new technologies and needs, to facilitate intermodal transport, and to reduce energy consumption and emissions. The questionnaire contains a section on the countries' position on some of the proposed amendments.

The amending directive was adopted in (May) 2015. While the information given in this section of the questionnaire relates to the [countries'] position on the proposal, it serves as a backdrop to the answers given in the other chapters, particularly Chapter 3, as the answers highlight some of the issues related to permitting longer and/or heavier vehicles on roads. The proposed increases in length and weight were fairly conservative. It showed how politically sensitive the issue of weights and dimensions of heavy vehicles is in Europe. Even increases of 1 tonne or 1 metre provoke a lot of discussion. The main reasons for this are that competition is expected with other modes such as rail and inland waterways and that many European countries are struggling with ageing infrastructure.

Two aspects of the proposed revisions of the Directive 96/53/EC were addressed in the questionnaire: the increased length of vehicles fitted with aerodynamic devices and cabs and increased weights for alternative fuelled motor vehicles.

2.1.1 Increased length of vehicles fitted with aerodynamic devices and cabs

The proposal granted derogations from the maximum dimensions of vehicles for the addition of aerodynamic devices to the rear of vehicles or for the redefinition of the geometry of cabs for tractors to improve the driver's field of vision, safety, and comfort. Respondents were asked if the proposed derogations would pose a problem for the accessibility of heavy vehicles on their roads.

Of the 16 countries that responded to this question, seven (AT, IS, EE, DE, SK, NL, UK) viewed the increase as problematic; nine (SI, LU, PL, IT, BG, MT, LT, SE, NO) did not. It should be kept in mind that the fact that countries indicated the extra length as problematic does not mean that there are no available solutions. Car parks, roundabouts, and narrow secondary roads were mentioned as being potentially problematic. The answers are most likely indicative of the remaining CEDR member countries. However, it was probably difficult for the respondents to estimate the impact as the Commission proposal did not specify any increase in length, just that vehicles equipped with aerodynamic devices and cabs would be allowed to exceed the length limitations given in Annex I of the directive.

Like the proposal from 2013, the adopted directive does not state by how much the permitted lengths may be exceeded. For cabs, a natural limit derives from the fact that the vehicle/vehicle combination must still comply with the traction requirements in the directive. Rear-mounted devices and equipment do not affect the turning capabilities of the vehicle/vehicle combination.

The proposal for implementing regulations concerning the use of rear-mounted aerodynamic devices from July 2015 suggested two separate sets of regulations: one for devices protruding up to 500 mm behind the vehicle and one for devices protruding more than 500 mm, but with no limitation on how far the devices may protrude. The Commission expected that the proposal would be adopted by the end of 2015, but due to a number of factors including concerns about the distinction between requirements for use and technical requirements, no new proposal was put forward by February 2017. The directive also states that devices adding more than 500 mm to the length of a vehicle must be type-approved, and tasks the Commission with amending Regulation (EU) No 1230/2012 to provide type-approval requirements.

It should also be noted that regardless of the new provisions in Directive 2015/719/EU, devices adding a length of up to 500 mm are already permitted as Regulation (EU) No 1230/2012 exempts devices and equipment, 'provided that they do not protrude at the back by more than 500 mm from the outermost length of the vehicle and they do not increase the length of the loading area.'

2.1.2 Increased weight of alternatively fuelled motor vehicles (and 2-axle coaches)

Sixteen out of 17 countries answered the questions about increased weight. In response to the question as to whether their bridges have sufficient bearing capacity for the proposed weight increase, ten countries answered 'yes' (AT, SI, EE, DE, SK, LU, IT, LT, SE, NO); four answered 'no' (IS, PL, BG, NL), one answered 'yes and no' (UK), and one answered 'studies on-going' (MT). One country, (UK) specified that while the proposed increase would not pose a problem for motorway and trunk road bridges, as they were designed for heavier lorries, it would pose a problem for local road bridges unless they were specially designed for heavier lorries. No other respondent made this distinction, but it is likely that the situation is the same in many countries. Some countries[7] have divided their road networks into several categories based on total weights and axle loads, which means that they have the option of only permitting the increased weights on roads that are designed for heavy vehicles or the heaviest vehicles and vehicle combinations. The increase may be more problematic in those cases where there is no or very little differentiation between permitted vehicle weights as the increase is more likely to be permitted on roads where the current weight is already pushing the limit.

In response to the question as to whether the proposed increase would affect the maintenance costs and life expectancy of their bridges, nine answered 'yes' (AT, SI, IS, EE, DE, SK, LU, PL, BG), five answered 'no' (IT, LT, NL, SE, NO), one answered 'yes and no' (UK), and one answered 'studies on-going' (MT).

The question—and therefore the answers—do not specify whether the increase in maintenance costs and/or reduced lifespan expectancy is 'significant' enough to be a real concern or if a negligible or minor increase and reduction is considered acceptable. Additionally, the question does not take into account whether the environmental benefits (climate effects as well as local effects such as air quality and noise) of increased weights will be reduced, offset, or even exceed the costs associated with maintenance and reduced lifespan expectancy. Also, it is not known how many vehicles the respondents had in mind when answering the question, i.e. what percentage of heavy vehicles will be allowed to increase their total weight and to what extent these vehicles will actually take advantage of this possibility. Furthermore, respondents may have been concerned that although this particular increase is only 1 tonne, increasing the permitted weight incrementally will eventually result in weights that do generate increased maintenance costs.

[7] See for example the Norwegian Regulations Concerning the Use of Vehicles Section 5-3 tables 3a and 3b, http://www.vegvesen.no/_attachment/780694/binary/1013098?fast_title=Regulations+Concerning+the+Use+of+Vehicles+Chapter+5+and+Sections+6-2+and+3-4.pdf,

The increases in permitted weights were adopted more or less as proposed. It should also be noted that the permitted total weight is not increased by a full tonne for all motor vehicles using alternative fuels, just the weight increase in comparison with the same vehicle with a traditional diesel engine. If the batteries, gas tanks, hybrid drivelines, etc. only add 500 kg, the permitted total weight of the vehicle is increased by 500 kg. The suggested weight increase only applies to motor vehicles. The directive does not require member states to increase the permitted weight for vehicle combinations, which means that rather than adding one tonne of weight to the combination, one tonne is **moved** from the trailer to the motor vehicle. However, if member states wish to increase the permitted total weight for vehicle combinations, they are allowed to do so as the directive does not specify upper limits to permitted weights in national transport.

One possible explanation for the directive not mentioning vehicle combinations is that today's alternative fuel technology is, for the most part, not suitable for (long haul) vehicle combinations, especially electricity-only variants. Today's LNG/CNG, electric, and hybrid technology is most relevant for buses/coaches and specialised vehicles such as garbage trucks operating within a fairly limited area as well as (smaller) lorries for the distribution of goods. However, it is not certain how long this will be the case.[8]

2.1.3 Other potential complications arising from the proposed amendments

The respondents were also asked to indicate whether they foresaw other complications relating to the proposed increase in permitted weights (other than maintenance costs) and dimensions (other than reduced accessibility for heavy vehicles).

Six (AT, IS, DE, SK, PL, MT) of the 14 countries that responded to this question replied that the proposed increases in length and total weight could potentially have other consequences. Suggested complications included additional construction costs, a negative impact on traffic flows (e.g. breakdowns, take-overs, acceleration lane, etc.), a negative impact on road safety, a negative impact on rail and combined transport (distortion of competition), a negative impact on the environment, increased maintenance costs for pavements with poor bearing capacity, an impact on existing road restraint systems, and an impact on road pavements in general.

2.2 Directive 96/53/EC and derogations in national legislation

Directive 96/53/EC sets out two derogations for increased length (beyond 18.75 m) in national transport. A section of the questionnaire was dedicated to determining the extent to which the respective member states have made use of these derogations.

Opposition to increases in permitted weights and dimensions are usually based on either infrastructure concerns, reluctance to increase the load capacity—and therefore the competitiveness of road transport—or a combination of the two. An enquiry about the extent to which the respondents have made use of the possibility to permit greater dimensions for certain types of transport might show that some countries are less opposed to greater weights and dimensions than is immediately apparent, which in turn might suggest that the gap between the position of certain countries is not as great as today's discourse indicates.

[8] See https://nikolamotor.com/

2.2.1 Derogations under article 4 (4) a)

Article 4 (4) of the directive allows member states to permit longer vehicles in 'Transport operations performed by specialized vehicles or specialized vehicle combinations in circumstances in which they are not normally carried out by vehicles from other member states, e.g. operations linked to logging and the forestry industry.' The derogation is not limited to forestry; other specialised local transport operations (such as the transport of cars, ore, asphalt, etc.) can also be permitted.

Ten of the 17 responding countries reported having some form of special regulations for either length, total weight, or both. The table below shows the various regulations reported by respondents. As is apparent from the footnotes, some of the regulations listed are not technically derogations from the directive, as the directive does not regulate permitted weights in national transport. However, the information is still of interest as it demonstrates the extent to which the respondents have taken advantage of the possibility to permit greater weights. Increased weights are also of interest because increased weight without increases in length results in a greater impact on road infrastructure and especially on bridges.

Table 1: Derogations under article 4 (4) a)

Country	Type of transport	Length	Width	Height	Tonnes
Austria	Timber	/	/	/	44
	Combined transport from/to the next technically suitable terminal/harbour. The rear axle of the trailer must have twin wheels or super single tyres, each vehicle more than 2 axles [1]	/	/	/	44
Estonia	Timber, 7 axles[2]	/	/	/	52
	Timber, 6 axles[2]	/	/	/	50
	Trucks, 6-axles, double tyres,[2] expected to start after 2 years	18.75	2.55	4.00	48
	Trucks, 7-axles, double tyres[2] expected to start after 2 years	18.75	2.55	4.00	52
	All road trains with 6 axles or more[2]	/	/	/	44
	Vehicles transport (loaded full trailer)	20.75 m	/	/	/
	Vehicles transport (loaded semitrailer)	18.50 m	/	/	/
Iceland	This is only allowed on selected routes and with special tyre and suspension conditions. [3]	25.25	2.60	4.20	44-49
Italy	Transport of vehicles, transport of straw/hay rolls, transport of ISO containers	+ 12%	2.55	4.30	44
	Excavation and mining materials[2]	18.75	2.55	4.00	56
Luxembourg	Timber	25	2.55	4.00	44
	Construction	individual	/	/	
Netherlands	All other transport operations[2]	/	/	/	50
Norway	Timber, road trains with 7 or more axles and 19.00 m or more from first to last axle	24.00	2.55	4.00 m (trailer)	60
	Transport of vehicles	20.00 (22.00)	2.55	/	/
Slovenia	Commercial vehicles modified for transportation cars (Revoz)	22.00	/	/	/
Sweden	Timber[4]	24.00	2.60	/	60
	All other transport operations[4]	24.00	2.60	/	60
UK	Articulated vehicles, where the semitrailer is a low loader	18	/	/	/
	Road trains may have a loading length exceeding 15.65 m provided both vehicles in the combination are car transporters.	> 15.65 m	/	/	/
	Semitrailers that are car transporters (4.19 m)	> 2.04 m from king-pin to front of semitrailer	/	/	/
	Rigid vehicles equipped with ‘crash cushion' devices with the device deployed.	> 12.00 m	/	/	/

1) Not technically a derogation as the directive requires member states to permit such transport (96/53/EC Annex I no. 2.2.2)
2) Not technically a derogation under art 4 (4) a) as this derogation does not concern permitted weights in national transport.
3) Depending on the types of vehicles used, possibly a form of EMS.

4) Not technically a derogation under art 4 (4) a), but under art 4 (4) **b)**, which permits member states to keep their nationally permitted dimensions after the directive's entry into force provided they also permit EMS.

Even though not all examples are of derogations given through art 4 (4) a), they indicate possibilities for willingness to allow (longer and) heavier transport operations if the right considerations apply.

The respondents were also asked to indicate if specific challenges in their countries/parts of their countries make it difficult to permit longer and/or heavier vehicles. The options were geographical conditions, topography, road curvature, climatic conditions, bearing capacity of bridges, bearing capacity of roads and other. Three countries indicated geographical conditions (AT, SI, NO), seven indicated road topography (AT, IS, DE, IT, BG, MT, NO), 14 indicated road curvature (AT, SI, IS, DE, SK, LU, PL, IT, BG, MT, LT, NL, UK, NO), six indicated climatic conditions (AT, IS, PL, BG, LT, NO), 12 indicated the bearing capacity of bridges (AT, SI, IS, EE, SK, LU, PL, IT, BG, MT, LT, NO), and nine indicated the bearing capacity of roads (IS, EE, SK, PL, IT, BG, MT, LT, NO). Two countries also indicated 'other'. Austria listed 'limitations of road infrastructure such as lay-bys, parking areas, safety recesses etc.' and the UK listed 'road issues relating to longer vehicles – overtaking by other vehicles, turning, braking distance, parking'.

2.2.2 Other projects

In addition to derogations to Article 4 (4) a), respondents were asked to list other current trials and research projects involving longer and/or heavier vehicle combinations.

Table 2: 18.75/40 < transport < 25.25/60 and transport > 25.25/60

Country	Type of transport	Length	Width	Height	Tonnes	Time frame
Germany	*Lang-Lkw* (longer truck combinations)	17.8	2.55	4.00	40/44	until 31.12.2016
	Lang-Lkw (longer truck combinations)	24.00	2.55	4.00	40/44	until 31.12.2016
	Lang-Lkw (longer truck combinations)[1]	25.25	2.55	4.00	40/44	until 31.12.2016
Sweden	Forestry/logging	30.00	/	/	90	
	Forestry/logging	24.00	/	/	70	
	Grouped goods	32.00	/	/	80	
UK	Longer Semitrailer trial, 14.6 m semitrailer	17.50	/	/	44	January 2012[2]
	Longer Semitrailer trial, 15.65 m semitrailer	18.55	/	/	44	January 2012[2]

1) Technically an EMS combination?
2) See https://www.gov.uk/government/collections/longer-semitrailer-trial

2.2.3 Derogations under Article 4 (4) b) – EMS

Article 4 (4) of the directive allows member states to permit longer vehicles and vehicle combinations 'if a Member State which permits transport operations to be carried out by vehicles or vehicle combinations with dimensions deviating from those laid down in Annex I, also permits motor vehicles, trailers and semitrailers which comply with the dimensions laid down in Annex I to be used in such combinations as to achieve at least the loading length authorized in that Member State, so that every operator may benefit from equal conditions of competition (modular concept) (EMS).' EMS is usually understood as 25.25 m in length with a total weight of 60 tonnes.

Respondents were asked if EMS combinations are permitted by national regulations on their roads, either in a trial or on a permanent basis. Finland, Sweden, the Netherlands, and Norway, which currently permit EMS either as a trial or on a permanent basis, responded to the questionnaire. Only two other countries (Denmark and Belgium-Flanders) permitted EMS at the time the survey was carried out.

Respondents were also asked to indicate if their use is permitted on a limited road network or on all roads. In Norway and the Netherlands (and in Denmark), the use of EMS is limited to a specified road network. In Sweden and Finland, they operate freely on the entire road network. However, these two countries are required to permit EMS on their entire road network in order to keep their national regulations on permitted vehicle length and width (which exceeded what was permitted by the EU when Sweden and Finland joined the EU).

2.2.4 Transport of 45-foot containers

Road transport of 45-foot containers on a semitrailer is not possible without exceeding the permitted distance from the king-pin to the rear of the semitrailer as stated in Directive 96/53/EC Annex I. From 2006, such transport has been deemed acceptable through a working document issued by the Commission, and the proposal for an amending directive gave provisions regulating such transport.

The amending Directive 2015/719/EU (new article 10c) states that when transporting a 45-foot container in an intermodal transport operation, the distance from the king-pin to the rear of the semitrailer and the total length of the vehicle combination may exceed what is given in Annex I by up to 15 cm. The directive gives no derogation for transport operations carried out with side loaders.

Respondents were asked to indicate whether the transport of 45-foot containers was/is permitted in their national regulations, and if so, what the permitted dimensions of such transport vehicles are. They were also asked if the transport could be carried out with semitrailers with side-loaders.

The responses showed that regulations varied from country to country. About half of the countries had some sort of special regulations. Three permitted the use of side loaders.

Table 3: Permitted weights and dimensions for transport of 45' containers

	Total length (m)	Distance from king-pin to rear of semitrailer (m)	Height (m)	Total weight (t)	With side-loaders	Length with side-loaders
Austria	/	/	/	44	No	
Bulgaria	/	/	/	/	/	
Estonia	18	-	4.3	40	No	
Finland	18	/	4.4 / 4	48	Yes	18
Germany	16.50	12.00	4	40 (44)	/	
Iceland	18.75	(2.04 max+11.26) = 13.30	4.20	40	Yes	up to 13.3 m
Italy	18.75 m + 12%	12.00	4.30	44	No	
Lithuania	16.50	2.04 m (?)	4 m	44 t	No	
Luxembourg	/	/	/	/	/	
Malta	The max permitted is 40 ft so this is not applicable	/	/	/	/	
Netherlands	17.30	/	/	50	No	
Norway	17.5 m (same for all articulated vehicles)	> 12.00 m	No limit	No special regulations (max. 50 t)	No 1)	
Poland	No special regulations	/	/	/	No	
Slovakia	16.65	/	4.00 + 2%	44	No	
Slovenia	16.50	12.00	4.20	44	/	
Sweden	24	not regulated	not regulated	60	Yes	up to 24 m (not regulated)
United Kingdom	16.5	12	not specified	44	No	

1) As of autumn 2015 a general exemption for length up to 18.60 m with side loaders
Note: / indicates that no answer was provided.

2.2.5 Developments since 2014

Since the questionnaire was distributed/the survey was carried out in 2013/2014, there have been several developments in the field. While the subject of longer and/or heavier vehicles remains a sensitive issue, several countries now allow longer and in some cases heavier vehicle combinations.

Estonia

In 2015, the Ministry of Economic Affairs and Communications issued a special regulation that permits timber transport operations with a total weight of 52 tonnes. The vehicle must have at least 7 axles (for 48 t, 6 axles); double tyres and GPS[9].

The permit can be granted for up to one year and the fee must be paid in advance. The municipalities can authorise the road administration to give a permit for their roads and collect the fee (via the VELUB programme, see Figure 3). The driver enters loading information in ELVIS (the State Forest Management's electronic cargo information system) before starting the transport. If the e-cargo permit shows that the vehicle is loaded, the vehicle's GPS may be traced. The purpose of tracking the GPS is to make it easier for road owners and the police to monitor the vehicles. The system is still at the development stage.

[9] https://www.riigiteataja.ee/akt/109092015002

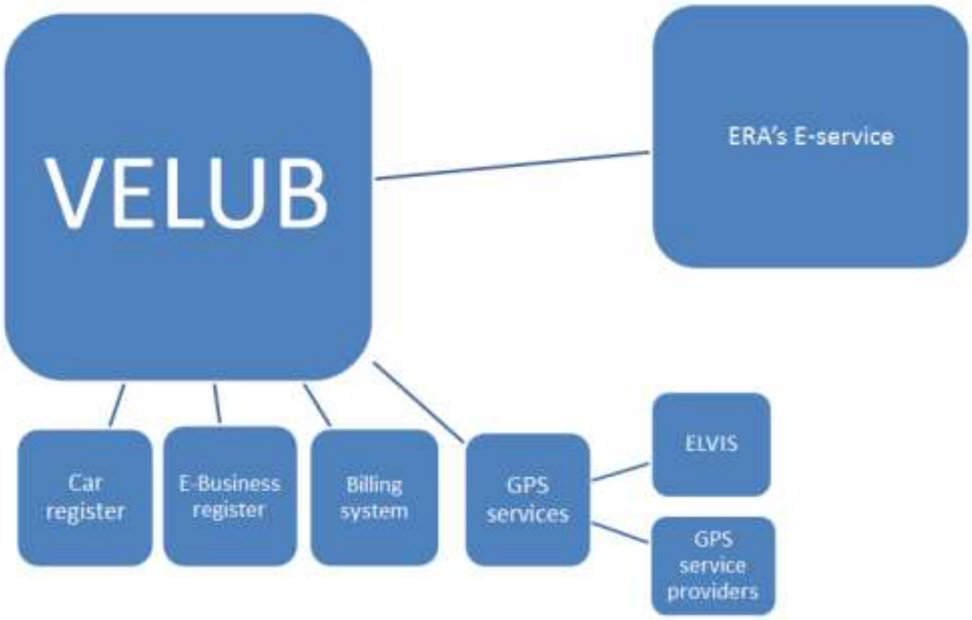

Figure 3: VELUB – The Estonian Road Administration's special permit application system; ELVIS – State Forest Management's electronic cargo list information system

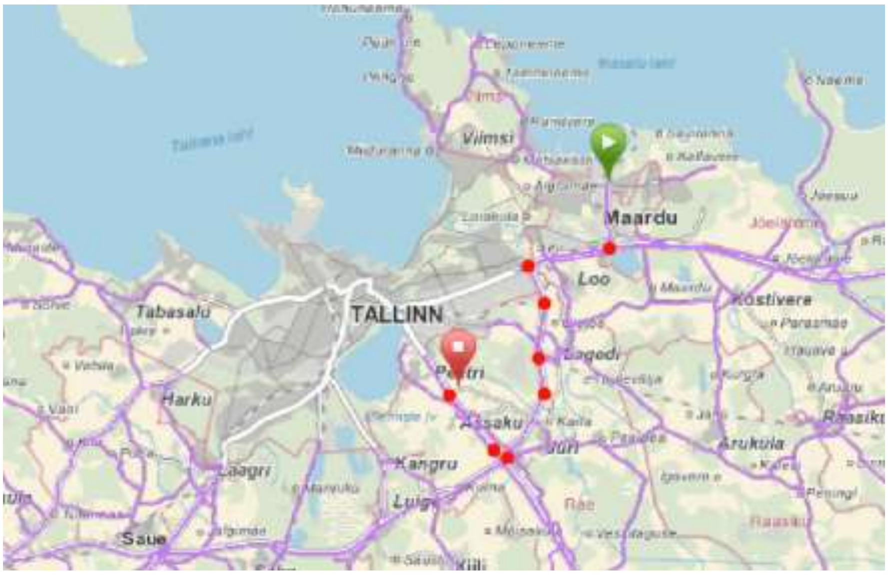

Figure 4: Sample of the 52 tonne driving route, starting at the green mark with the red dots marking the tracking route. Roads in purple are open to vehicles weighing up to 52 tonnes

Germany[10]

The original *Lang-Lkw* (longer truck combinations) trial ended on 31.12.2016. From 1.1.2017, two of the three types of *Lang-Lkw* (24 and 25.25 m combinations) are permanently permitted in Germany on a dedicated road network. For the third type (17.8 m articulated vehicle with a 14.9 m semitrailer), the trial has been extended for seven years on a dedicated road network.

[10] http://www.bast.de/DE/Verkehrstechnik/Fachthemen/v1-lang-lkw/v1-lang-lkw.html

Norway

The EMS trial finished in autumn 2014. The use of EMS is now permitted on a permanent basis. Their use is still restricted to a limited road network. The Directorate of Public Roads has issued criteria for approval of new EMS roads. The criteria cover the weight classification of the road, road width and curvature, vulnerable traffic users in intersections, inclines on hills and in tunnels and rail crossings. As an aid to assess the criteria for road width and curvature, a simulation programme has been developed.

Spain[11]

As of December 2015, Spain permits the use of vehicle combinations with a maximum total weight of 60 tonnes and a maximum length of 25.25 metres. Transport operators will need permission to use LHVs on specific routes, which has to be obtained from road maintenance officials and be approved by the traffic authority.

Sweden

The maximum total weight has been increased from 60 to 64 tonnes; 74 tonnes will soon be permitted on dedicated parts of the road network. The Swedish Transport Administration recommends an Intelligent Access Control (ITK, Intelligent Tillträdeskontroll) system that provides access to the road network and verifies that the road network is used in the right way.

A road network for road trains up to 74 tonnes gross weight would be identified and registered in the NVDB (Nordic Road Data Base). On-board units (OBU) in the vehicles would automatically and continuously capture and save the GNSS position every minute, the gross weight with a precision of +/- 3 tonnes when gross weight changes 3 tonnes or more, the VIN for all its vehicles, the ID of the responsible operator, and the ID of the responsible driver. The data in both the OBU and 'back office' is readable via the assigned interface on the site or can be sent in advance of checks and audits[12].

United Kingdom[13]

The Longer Semitrailer Trial has been extended by 5 years.

2.3 Other national legislation

This section of the questionnaire aimed to collect information on national rules relating to heavy vehicles that affect transport efficiency and that could form the basis for considering measures in a broader perspective.

2.3.1 Axle loads: single, super single, and twin tyres

According to the studies referred to in Appendix 3, the impact of single tyres on the elastic road pavement varies greatly. If the elastic pavement is thin, the greater the negative impact

[11] https://www.fedemac.eu/EU-Policy/News/Latest-News/ArtMID/594/ArticleID/61/Spain-allows-eco-combie-vehicles-longer-and-heavier, https://www.boe.es/diario_boe/txt.php?id=BOE-A-2015-14026
[12] http://www2.vinnova.se/PageFiles/751290063/Slutrapport%20ITK-projekt.pdf
[13] https://www.gov.uk/government/collections/longer-semitrailer-trial

of single tyres compared with twin tyres, especially in the case of the tridem axle configuration case (see Appendix 3).

Wider super-single tyres were developed to reduce the big difference between single and double tyres (these tyres do help as long as they are not over inflated).

Respondents were asked to provide the maximum permitted axle loads for single axles fitted with single tyres, super single tyres, and twin tyres in their respective countries. Fourteen countries (AT, SI, IS, EE, FI, DE, LU, IT, BG, MT, LT, UK, SE, NO) answered the questions about permitted single axle loads. None of the countries differentiate between single, super-single, and twin tyres on single axles. Two countries (LU, IT) permit 12 tonnes, IT with tyre pressure limitations of 12 tonnes and 8 kg/cm^2.

2.3.2 Spring thaw restrictions

Respondents were asked to indicate if special measures are taken during the spring thaw to prevent damage to the pavement and road structure. Eight (SI, IS, EE, FI, PL, LT, SE, NO) of the countries reported having some form of measures. Six countries (SI, IS, EE, FI, PL, NO) reduce permitted axle loads, five (IS, EE, FI, LT, SE) reduce permitted total weight, and one country (IS) lowers the speed limit. The size of the reduction varies. Not all answers specified if the reduction is limited to specific roads or areas. However, it is most likely that this is the case in all of the countries. Norway also added that on many roads, the permitted axle load is increased from 8 to 10 tonnes on frozen roads. The decision to introduce increased winter axle loads and to decrease them is made by the local Norwegian Public Road Administration office. Announcements are usually made in the local newspaper and also on the Norwegian Public Roads Administration website.

2.3.3 Traffic restrictions

Respondents were asked to indicate whether their road traffic legislation contains traffic restrictions. Nine countries (AT, SI, DE, SK, LU, PL, IT, BG, NL) responded that their national legislation contains some form of traffic restrictions for heavy vehicles[14], while eight (IS, EE, FI, MT, LT, UK, SE, NO) said that it does not. The most common restrictions were weekend (7), holiday (7), and tourist season (4) restrictions.

Five of these nine countries said that the restrictions noticeably affect the efficiency of the road transport. Austria, however, did not specify whether the effects are positive or negative.

It is not known to what extent the restrictions affect the efficiency of goods transport by road. For example, it could be argued that local restrictions on road freight transport reduce the efficiency of such transport because hauliers have to take a longer route or have to put extra vehicles into operation. While such restrictions may have a positive impact locally, they may also reduce the overall efficiency of road transport by forcing the vehicles to take a longer route, which prolongs the duration of the transport (and increases the costs). In addition, a longer route will result in a corresponding increase in emissions.

It would be worthwhile to conduct more research into the macro-level impact of local, regional, and national restrictions on heavy vehicle traffic. The purpose is not to remove these restrictions; the purpose should instead be to increase the awareness of the impact on a macro level and to look for solutions such as harmonisation or digitisation of the network.

[14] Websites such as www.trafficban.com provide updated information on temporary and regular traffic bans.

Digitisation of the road network could offer opportunities for the optimisation of route choice and/or times of delivery.

Table 4: Traffic restrictions

	Type of restrictions	Dates consistent with neighbouring countries	Restrictions applicable to parallel transit roads	Restrictions noticeably affect transport efficiency	Comments on transport efficiency
Austria	Weekends, holidays, other (night)	YES	YES	YES	Positive impacts especially on road safety, noise and traffic flow
Bulgaria	Weekends, holidays, tourist season, other (high temperatures)	YES	YES	NO	
Germany	Sundays, holidays, tourist season	NO	NO	No answer	
Italy	Weekends, holidays	NO	YES	YES	
Luxembourg	Weekends, holidays, other (transit)	YES	YES	YES	
Netherlands	No restrictions at national level	NO	NO	NO	
Poland	Weekends, holidays	NO	NO	YES	
Slovenia	Weekends, holidays, tourist season	YES	YES	YES	
Slovakia	Weekends, tourist season	YES	YES	NO	

Respondents were also asked to indicate the reasons for the introduction of the restrictions (e.g. road safety, noise, emissions, other reasons). Eight out of nine countries (AT, SI, DE, SK, LU, PL, IT, BG) gave traffic safety as the reason for the restrictions. Austria also listed noise and emissions. Other reasons were also mentioned: traffic flow, to reduce traffic jams during the holiday and tourist season, and infrastructure concerns.

2.4 Heavy vehicle inspections and weight checks

Overloaded vehicles damage pavements and reduce traffic safety. For longer span bridges, the total weight of the vehicle is the most important factor. For smaller spans (less than the length of the truck), the axle load becomes more critical.

For elastic pavements (widely used asphalt pavement), the axle load is the most critical factor, followed by the distance between the axles (in case of dual/bogie, tridem, etc.). The more space between the axles, the better for the pavement. This also applies to bridges.

If the axle load is exceeded, the impact on the pavement rises to the power of four[15]. Road owners' expenses in terms of road repair and maintenance are much greater than what hauliers gain from exceeding the permitted axle loads. Socio-economically, at state level, this is not a good solution and must be avoided by monitoring the loads on the network.

An important prerequisite for permitting higher weights is to have an efficient control regime to ensure that the limits set out in legislation etc. are not exceeded. The closer one gets to the maximum of what the infrastructure can tolerate, the more important it becomes to make sure that transport operations do not exceed what is permitted.

[15] (ie:10t standard/15t axle=1,5 to the power of 4 = (1,5*1,5*1,5*1,5*)= **5,1** times **(510%)** impact compared to 10t, but the axle weight is only increased by 150%)

Directive 2015/719/EC gives two reasons for adding new regulations on weight checks: 'Infringements in relation to overloaded vehicles need to be addressed adequately by Member States in order to avoid any distortions of competition and to ensure road safety' (preface point (12)). The effect on the road infrastructure is not mentioned in the directive itself.

Overloaded vehicles contribute more to the deterioration of the infrastructure than vehicles operating within the permitted weight limits, thus generating greater maintenance costs. According to the Commission, as many as one in three heavy vehicles are overloaded[16]. Directive 2015/719/EU adds new provisions to Directive 96/53/EC to enable inspection authorities to better detect infringements. Member states must carry out a minimum number of vehicle checks, using either weighing systems built into the road or by means of on-board sensors in vehicles that communicate remotely with roadside inspectors. The new regulations must be implemented by May 2021.

2.4.1 Statistics, methods, control authority

Respondents were asked to indicate the percentage of overloaded vehicles, the methods of preselecting vehicles for weight checks, and control authorities for weight checks. All 17 countries answered the questions about overloading, although two countries did not provide statistics.

The percentage of overloaded vehicles varies from 2% to 18%, with some numbers higher due to targeted checks. The responses do not indicate whether the stated numbers apply to axle load infringements, total weight infringements, or a combination of the two. The UK figure cannot be taken into account as it uses a targeted approach to weighing. The figure from Malta also seems unnaturally high (due to targeted checks). Unless some of the countries that did not answer the questionnaire experience very high numbers of overloaded vehicles, the 30% estimate from the Commission appears to be incorrect. Another possible explanation is that the figures do not differentiate between axle load infringements and total weight infringements, as it is possible to exceed permitted axle loads while not exceeding the permitted total weight.

Only two countries reported having special programmes for reducing the number of overloaded vehicles, and only one (UK) provided any additional information. As one overloaded vehicle causes more road damage than vehicles operating within the permitted weight limits (4th power rule), reducing the number of overloaded vehicles will reduce the maintenance costs and extend the life span expectancy of the infrastructure.

All 17 responding countries answered the question about pre-selection.

[16] document accompanying proposal COM (2013)195, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0195&from=EN

Table 5: Weight checks

Country	Average	Basis for data	Control authority
Austria	/	Manual	Police
Bulgaria	6%	Manual	Police, Road Directorate
Estonia	10.8%	WIM, manual	Police
Finland	10%	WIM, manual	Police, Road Directorate
Germany	/	WIM, manual	Police, Road Directorate
Iceland	8%	Manual	Police, Road Directorate
Italy	5%	Manual	Police
Lithuania	25% (from WIM)	WIM, on-board weighing systems, manual	Road Directorate
Luxembourg	/	Manual	Police
Malta	48% (targeted approach)	Manual	Road Directorate
Netherlands	6,5% total weight, 19,7% axle loads*	WIM, manual	Police, Inspectorate
Norway	11%	Manual	Police, Road Directorate
Poland	8%	WIM	Other
Slovenia	10,8% motorways 18,2% state roads	WIM, manual	Police, private company
Slovakia	2% (motorways 2012), 2,5% (state roads 2012)	Manual	Police, Road Directorate
Sweden	17%	WIM	Police
United Kingdom	67% (this is the percentage of overloaded vehicle which we weighed as oppose to all vehicles on the road. We adopt a targeted approach to weighing)	WIM, manual	Police, Road Directorate

** number as of 2016*

2.4.2 Parties responsible for overloading

The party that is considered responsible for overloading varies from country to country. Respondents were asked to indicate if the responsible party according to their regulations is the driver, a legal person, the sole proprietor, or other. In all countries except Norway, the driver can be held responsible for overloading. Both a legal person and the sole proprietor can be held responsible in four countries, (SI, DE, SK, and LT in the case of a legal person; SI, DE, IT, and LT in the case of the sole proprietor). Other parties which can be held responsible are the loader (AT, SI, IT), the Tpt holder (LU), and the vehicle operator, which could be a limited company, a self-employed person, partner, etc. (UK), and the owner/lease holder (NO).

2.5 Accessibility for heavy vehicles in winter conditions

Accessibility for heavy vehicles in winter conditions has a major impact on traffic flow and, therefore, on transport efficiency. A section of the questionnaire examined the extent to which the responding countries allow and require the use of equipment that improves accessibility.

Respondents were asked to indicate if accessibility for heavy vehicles in winter conditions is considered a problem**.** Ten countries (IS, FI, DE, SK, IT, SE, LU, NO, PL, SI) answered 'yes', and five (AT, EE, LT, NL, UK) answered 'no'. Accessibility for heavy vehicles in winter is a prioritised issue in eight (IS, FI, DE, SK, IT, SE, LU, NO) of the ten countries that consider this to be a problem; seven (IS, FI, DE, SK, IT, SE, NO) are actively working to find solutions to these problems. However, answering 'no' to the question as to whether accessibility is a problem or not could be interpreted in two ways. Either the winter conditions are dealt with in such a way that accessibility does not become a problem, *or* snowfall and winter conditions are a rare occurrence.

2.5.1 Drive axle loads and steering axle loads

Directive 96/53/EC Annex I no. 4 requires that the weight borne by the driving axle or driving axles of a vehicle or vehicle combination must not be less than 25% of the total laden weight of the vehicle or vehicle combination when used in international traffic. The requirement ensures sufficient traction in difficult driving conditions.

Respondents were asked if their national regulations require the axle load of the driving axle(s) not to be less than a given percentage of the actual total weight of the vehicle/vehicle combination when the vehicle is used in *national transport* and if their national regulations require the axle load of the steering axle(s) not to be less than a given percentage of the actual total vehicle weight of the vehicle/vehicle combination when the vehicle is used in *national transport*.

Five (AT, SI, SK, BG, LT) of the 15 countries that responded indicated that they require the drive axle load to be at least 25% of the total weight of the vehicle/vehicle combination. Italy requires 20%, but with a haul ratio of 1.45. Finland requires 25%, but only 18% or 20% for the heaviest combinations. The remaining seven countries (LU, PL, EE, DE, UK, SE, NO), do not require a minimum drive axle load. Of those who have requirements, five countries (AT, IS, FI, SK, LT) enforce them in national transport and six (AT, SI, IS, FI, SK, LT) in international transport.

Respondents were also asked if they have the same type of requirement for steering axles. Four countries (FI, BG, SK, NO (20%)) of the 16 respondents indicated that they have such requirements, while the remaining 12 (AT, SI, IS, IT, LT, LU, PL, EE, DE, NL, UK, SE) do not.

2.5.2 Snow chains and studded tyres

Several types of equipment improve traction in winter conditions. However, such equipment sometimes also causes damage to the pavement.

Respondents were asked to indicate if they permit the use of snow chains and studded tyres.

Eleven (AT, SI, IS, FI, DE, SK, LU, PL, IT, SE, NO) of the 15 countries that responded permit the use of snow chains, and eight (AT, SI, FI, DE, SK, PL, IT, NO) require heavy vehicles to carry snow chains (with some variations as to which heavy vehicles). Six (IS, EE, FI, IT, SE, NO) of the 14 countries that responded permit the use of studded tyres during the winter season.

2.5.3 Lift axles

A lift axle or retractable axle is defined in Regulation (EU) No 1230/2012 Article 2 Point (35) as an 'axle which can be raised from its normal position and re-lowered by an axle-lift device'. Use of such axles is regulated in the Regulation's Annex IV, which requires such equipment to be fitted so that under normal driving conditions, the registration/in-service maximum permissible masses on solo axles or groups of axles are not exceeded, and that if said masses are exceeded, the lift axles are automatically lowered.

A derogation has been made from this main requirement which allows the axle lift device to actuate the lift- or loadable axle(s) of a motor vehicle or semitrailer to increase or decrease the mass on the driving axle of the motor vehicle in order to help motor vehicles or vehicle combinations move off on slippery ground and to increase the traction of the tyres on these surfaces as well to improve their manoeuvrability. In such cases, the maximum permitted axle load for a single axle may be exceeded by up to 30%, provided that it does not exceed the value stated by the manufacturer for this special purpose. This load may be exceeded in this way until the vehicle has moved off. Before its speed exceeds 30 km/h, the axle(s) shall automatically be lowered to the ground again or be reloaded.

However, in some countries, lift axles and loadable axles may be used in conjunction with axle loads greater than 11.5 tonnes + 30% and at speeds exceeding 30 km/h. The use of such equipment does provide better traction, but is detrimental to the integrity of the roads. It could be argued that the detrimental effects of such axles on the pavement and road structure is to a certain extent negated by the fact that the road is frozen and more resilient. On the other hand, as a result of current climatic conditions, roads are no longer frozen throughout the winter in many places, but fluctuate between freezing and thawing, making it less resilient (Statens vegvesen (2010) *Klimaets påvirkning på tilstandsutvikling for vegdekker - E136.* Rapport Teknologiavdelingen nr. 2599).

The respondents were asked to indicate if the use of lift axles exceeding permitted axle loads is accepted in their regulations, and if so, which axle loads are permitted.

At least one country, Norway, permits the use of lift axles to improve traction in difficult conditions, especially on slopes. Loadable and liftable axles can be individually approved for an axle load greater than the nationally permitted maximum axle load on a single driving axle plus 30%, that is, for axle loads greater than 14.9 tonnes (11.5 + 30% = 14.9 tonnes) and for maintaining this axle load at speeds exceeding 30 km/h. In order to gain approval, the manufacturer must guarantee that the driving axle is manufactured to tolerate such loads and speeds. If so, the entire load of the bogie axle may be transferred to the driving axle.

2.5.4 Winter tyres

Winter tyres, or special tyre requirements during the winter season, help ensure that vehicles have sufficient traction in difficult winter conditions. If such tyres are required and under what circumstances varies from country to country, as does what is considered a winter tyre.

Ten (AT, SI, IS, DE, SK, LU, PL, IT, SE, NO) of the 15 countries that responded require the use of winter tyres. The questionnaire did not specify which vehicles the requirement must apply to, so we do not to know to which categories of vehicles the requirement apply. They were also asked to indicate if the requirement is related to periods or dates, specific driving conditions, or specific roads or areas.

There is no common definition of what constitutes a 'winter tyre'. Directive 1992/23/EEC Annex II No. 2.2 defines a 'snow tyre' as 'a tyre the tread pattern and structure of which are primarily designed to ensure in mud and fresh or melting snow a performance better than that of a normal tyre. The tread pattern of a snow tyre generally consists of groove (rib) and/or solid-block elements more widely spaced than on a normal tyre'. 'Snow tyre' is also defined in Regulation 661/2009 Article 3 No. 11,' as 'a tyre whose tread pattern, tread compound or structure is primarily designed to achieve in snow conditions a performance better than that of a normal tyre with regard to its ability to initiate or maintain vehicle motion'.

Respondents were asked to indicate the requirements a tyre must fulfil in order to be considered a winter tyre in their national legislation (tread depth, tread pattern, shore value, and markings). Of the 11 [countries] that responded to the question, seven (AT, SI, IS, EE, DE, SE, NO) checked tread depth, one (IS) checked tread pattern, none checked shore values, and ten (AT, SI, EE, DE, SK, LU, PL, IT, SE, NO) checked markings (M+S etc). However, only a few provided additional information on their actual tread depth and marking requirements. On the basis of the information provided, it transpires that the definition varies from country to country. Iceland requires a tread depth of 3 mm, and the tread pattern to be a 'rough pattern'. Austria requires a tread depth of at least 4 mm and M+S markings. Sweden requires a tread depth of 5 mm, while Germany requires 1.6 mm. At the moment, Norway has the strictest requirements for winter tyres in Europe, namely that during the winter months, all heavy vehicles must have tyres with at least 5 mm tread depth and M+S or 3PMSF on all axles.

3 Conclusions

Based on the responses outlined in section 2, some conclusions and tentative recommendations can be made.

- The revision of Directive 96/53/EC regarding aerodynamic devices at the rear and the front are not specified exactly. Many CEDR members are concerned that the extra length will cause difficulties for road design and reduce traffic safety. It is therefore recommended that both CEDR and its individual NRAs participate closely to the further development of this open end of the Directive 2015/719/EC.
- The maximum weights of heavy vehicles appears to be a very sensitive issue, not only politically but also, as expected, technically. This is illustrated by questionnaire responses relating to the expected impact of 1 extra tonne that was proposed in the revision of Directive 96/53/EC for alternative fuelled motor vehicles. A country like Norway can handle this kind of change more effectively because it differentiates between different categories of road (in terms of vehicle combination length and axle load/total weight). This could be an option for other European countries.
- If countries are considering differentiating between different categories of roads in their networks (with clear, nationally defined criteria), the environmental benefits should be compared with the maintenance costs in a socio-economic analysis.
- The demand for extra weights and dimensions and the extent to which the possibility for increased maximum weights and dimensions has been taken advantage of, differs according to type of transport and region.
    - The possibility of allowing extra length (i.e. vehicles longer than those permitted in Directive 96/53/EC, amended by the Directive 2015/719) has been taken advantage of for two types of transport operations: the transport of vehicles and transport operations in the forest industry. Of all respondents, eight countries made special provisions for this within their national regulation.
    - The possibility of allowing extra weights (i.e. vehicles heavier than those permitted in Directive 96/53/EC, amended by Directive 2015/719) has been taken advantage of for transport operations relating to the forestry and mining industries. Three countries made provisions in their national regulation just for these types of transport.
    - In nine countries (Belgium Flanders, Denmark, Estonia, Finland, Iceland, the Netherlands, Norway, Sweden, and Spain), extra weights (i.e. vehicles heavier than those permitted in Directive 96/53/EC, amended by Directive 2015/719, over 50 t, including EMS) are permitted for all transport operations. In some of these countries, such weights are only permitted on a dedicated road network. With the exception of Spain, these countries are all located in the north of Europe.
    - Regarding the demand for extra weights, the Netherlands constitutes an exception because it imposes no restrictions on 50-tonne transport operations, other than the prescribed maximum axle loads, which do not deviate from EC regulations. Most other countries that permit total weights over 40 tonnes have some form of requirement relating to the distance from the rearmost axle on the motor vehicle to the front axle of the trailer/semitrailer, and in some cases also from the first to the last axle of the vehicle combination and axle configuration[17].
    - In Germany the concept of the *Lang-Lkw* (extra length, but no extra weight) shows that there is a demand for longer vehicles for all transport operations. This seems to be the case in several other countries as well[18].

[17] For the Nordic countries, see http://www.notisum.se/pub/Doc.aspx?url=/rnp/sls/lag/19981276.htm Annex 1 - 3 (Sweden), https://lovdata.no/forskrift/1990-01-25-92/§5-4 (Norway) http://www.finlex.fi/sv/laki/ajantasa/1992/19921257#L4P23 (Finland), https://www.retsinformation.dk/Forms/R0710.aspx?id=185300#idf959da1c-5bcb-4120-9a35-0560c473f91c chapter 6 (Denmark)
[18] http://portal.research.lu.se/portal/files/16727368/Systemanalys_HCT_Slutversion_okt2016.pdf, https://www.toi.no/getfile.php?mmfileid=36910

- From this overview, consideration should be given to focusing on the implementation of the *Lang-Lkw* concept rather than on EMS in continental Europe. If, as predicted, most of the growth in freight transport by 2030 will take place on the roads, it might be beneficial to focus on longer vehicle combinations such as *Lang-Lkw* rather than EMS, as the *Lang-Lkw* trial, the Norwegian EMS trial, the UK's Longer Semitrailer trial and to some extent the Swedish High-Capacity Transport (HCT) study shows that there is a greater demand for increased volume than for increased weight. This would allow increased efficiency without raising concerns about the impact on road infrastructure, especially on bridges.
- There is an enormous societal need for the restriction of free circulation of heavy vehicles 24/7, all year round. This results in a patchwork of local, regional, and national driving bans. These restrictions have been imposed on heavy vehicles for very good reasons. At macro-level, however, they can lead to inefficient road freight transport (extra kilometres and/or extra vehicles in operation). More research is needed in order to get a better understanding of the impact on efficiency and the possible measures that can be taken to mitigate the impact (harmonisation and route choice/times of delivery optimisation by digitisation of the road network).
- Next to the type of tyres (single or super single), tyre pressure is decisive when it comes to road surface damage. CEDR members could consider conducting research into optimum tyre pressure and enter into discussions with tyre producers and hauliers how to meet this optimum pressure level and to devise efficient means of checking tyre pressures.

Part 2 The regulatory basis for performance-based standards for heavy vehicles and infrastructure

Summary

Performance-based standards for vehicle combinations with weight and/or dimensions that exceed the limits specified in the Directive 96/53/EC

The predominant worldwide regulatory principle used for regulation of heavy vehicles is prescriptive regulations with explicitly defined and quantified mandates. The common approach is to set limits on vehicle weight and length to ensure safety and to protect the infrastructure. Other approaches are, however, also in use. In Australia, Canada, and New Zealand, for instance, performance-based standards (PBS) are implemented. Under a PBS approach, standards specify the performance required of a vehicle, rather than specifying how this level of performance should be achieved by limiting vehicle length or weight.

Many of the organisations within the Conference of European Directors of Roads (CEDR) are interested in developing a harmonised PBS for infrastructure, which could be used to objectively assess the suitability of the road infrastructure for vehicle combinations with weights and/or dimensions that exceed the limits specified in Directive 96/53/EC. This section is the outcome of a study that reviews existing legislation that imposes limits on the weights and dimensions of heavy vehicles in Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden. Furthermore, it discusses performance measures for safety and the manoeuvrability of longer and/or heavier vehicles (LHVs) as well as relevant infrastructure and environmental aspects.

When investigating the performance of heavy vehicles with respect to safety and manoeuvrability measures, both vehicle design and infrastructure design should be considered since they are closely related. If a heavy vehicle is to be permitted on a certain road network, features of the roads play an important role in determining the required level of performance from the vehicle. This is why the list of relevant performance measures in this report also contains the corresponding influential infrastructure features. Similarly, the dynamics and design of the vehicles that will use a road should be considered when constructing the road. One approach to this is to use reference vehicles for road design, an approach that is adopted in both Sweden and Norway.

The main infrastructure design features that should be considered with respect to LHVs are: grade, lane width, curvature, roundabout and intersection dimensions, and crossfall. Other important infrastructure aspects include the availability of parking and rest areas, tunnel safety, safety barriers, turn lane length, distance between a railroad crossing and intersection, sight distance at an intersection, and the regulation of traffic signals.

Heavier LHV loads can be compensated for by axle and tyre configurations that reduce the loads on the pavement. Nevertheless, it is important to note that there are load history-dependent deterioration mechanisms in the pavement structure. There are gaps in the knowledge of these effects, and further investigation is required. Another important issue with regard to the bearing capacity of a pavement is its variance during a year. Thus, axle load limits can be adjusted with regard to seasonal changes, an approach which is implemented in Estonia, Norway, and Canada.

Bridges are the primary factor in deciding on permitted axle loads and gross vehicle weights. To avoid excessive loading of bridges, permitted axle loads and gross weights are restricted/limited. In Sweden, the bearing capacity of a bridge is determined by calculating the load effects and resulting stresses using reference vehicles. One possible approach to accounting for the effects of LHVs on bridges is to consider more reference vehicles. This approach has been investigated by the Swedish Transport Administration for vehicles with a gross weight of up to 74 tonnes. Another common approach, which is used in Australia and the United States, is to use a bridge formula to calculate the effects of the vehicle loading on the bridge.

1 Introduction and definition of the issue

This section brings together information gathered by the members of TG N4 (Heavy Vehicles) with the objective of listing relevant safety-, manoeuvrability-, infrastructure-, and environment-related criteria for longer and/or heavier vehicles. It also identifies research areas that need to be further investigated in order to develop harmonised performance-based standards for assessing longer and/or heavier vehicles' access to a road network. Their emphasis is not on determining whether longer and/or heavier vehicles should be allowed on a given road network or not, but on developing a harmonised framework for the objective evaluation of the suitability of the infrastructure for such vehicles. In this context, the Swedish Transport Administration and Norwegian Public Road Administration commissioned the Swedish National Road and Transport Research Institute, VTI, to conduct a study and literature review on this topic. The objective of the study was to list the relevant safety-, infrastructure-, and environment-related criteria for longer and/or heavier vehicles and to identify research areas that needs to be further investigated.

There is a wide spectrum of regulatory principles that differ significantly in terms of how specific and well quantified they are, from 'principle-based regulations' at one end to prescriptive regulations at the other. Principle-based regulations do not include quantified limits and are specified very broadly in terms of objectives (OECD 2005). An example of a principle-based regulation for heavy vehicles is that the vehicle operators have to minimise the risk of the involvement of their vehicles in accidents, without specifying any policies for achieving such an objective.

On the other hand, prescriptive regulations outline in detail how an objective should be achieved and include explicitly defined and quantified mandates. Prescriptive regulations are currently the predominant regulatory principle used for the regulation of heavy vehicles, worldwide. The common approach is to set limits on the vehicle weight and length to ensure safety and to protect infrastructure.

The performance-based standard (PBS) is a regulatory principle that falls between the two above-mentioned approaches and includes specific performance criteria/measures with a quantified required level of performance. It is more precise than the principle-based regulation, but provides more flexibility than the prescriptive regulation, which encourages innovative novel products. PBS has been implemented in Australia, Canada, and New Zealand to regulate the access of heavy vehicles to the road network. The country that has made the most progress in PBS is Australia. The Australian PBS scheme is divided into two parts: four infrastructure standards and 16 safety standards. For each standard, four performance levels are defined, each corresponding to a different access level to the road network (NTC 2008).

This part of the report is structured as follows: first, existing legislation that imposes limits on the weight and dimensions of heavy vehicles in Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden is reviewed and compared. Other relevant pieces of legislation relating to safety and the environmental impact of heavy vehicles are also presented. Performance measures for safety and manoeuvrability of longer and/or heavier vehicles (LHV) are then discussed. This is followed by sections on relevant infrastructure and environmental aspects.

The following definitions, which are taken from Directive 96/53/EC, are used in this part of the report:

Motor vehicle: any power-driven vehicle which travels on the road by its own means.

Semitrailer: any vehicle intended to be coupled to a motor vehicle in such a way that part of it rests on the motor vehicle with a substantial part of its weight and of the weight of its load being borne by the motor vehicle, and constructed and equipped for the carriage of goods.

Trailer: any vehicle intended to be coupled to a motor vehicle excluding semitrailers, and constructed and equipped for the carriage of goods.

Articulated vehicle: a vehicle combination consisting of a motor vehicle coupled to a semitrailer.

Road train: a vehicle combination consisting of a motor vehicle coupled to a trailer.

2 Legislation

In this chapter, relevant European legislation and corresponding regulations implemented in a number of European countries (Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden) are compared and reviewed. It should be noted that two types of European legislation are cited in this review: regulations and directives. The difference is that a regulation has general application and is applicable in all member states, while directives set out general rules to be transferred into national law by each country as they deem appropriate (EC 2015).

2.1 Weight limits

The weight limit for international traffic in the EU, as stated in the Directive 96/53/EC, depends on the number of axles of the vehicle/vehicle combination (EC 1996). These limits are also implemented in three of the countries studied: Austria, Estonia, and Slovenia (see Table 7). In Sweden, the weight limit depends on the axle distance between the foremost and rearmost axles in the vehicle/vehicle combination; there are additional limits for motor vehicles based on the number of axles (Sweden 1998). Norway has a more detailed approach; there are weight limits for a vehicle based on the vehicle type and number of axles. Furthermore, there are weight limits for the vehicle combination, based on the combination type and axle configuration (Norway 2013). In the Netherlands, there are limits for the total weight of the vehicle combination, and the axle load limits determine the weight limits on the constituent units.

Table 6: Vehicle weight limits (tonnes) in the European countries studied

	Austria, Estonia, Slovenia (EU, Dir 96/53/EC)	The Netherlands	Norway	Sweden
Motor vehicle	**18/25(26)*/32** for 2/3/4 axles	**21.5/29(31.5)** for 2/3/4 axles, based on number of drive axles	**19/26/26-32*** for 2/3/4 axles, based on wheelbase	**18/25(26)*/31(32)*** for 2/3/4 axles
Semitrailer/trailer	**18/24** for 2/3 axles	Depends on the axle distance and number of axles, see Table 7	**10/18,20/24,27** centre-axle trailer & semitrailer with 1/2/3 axles 20/28/30 drawbar trailer/dolly-semitrailer with 2/3/4 axles	**GVW/GCW table** based on axle distance for all vehicles/vehicle combinations; some specific values for drawbar trailers (33–36), also based on axle distance
Vehicle combination	**36/40** road trains with 4/5 axles **36(38)[1]/40(44)[2]** articulated vehicles with 4/5 axles [1] If the semitrailer axle distance is bigger than 1.8 m and the driving axle is fitted with twin tyres and air suspension [2] If carrying a 40-foot ISO container as a combined transport operation	**Max 50** **Max 60** modular vehicles	**Max 50, GCW table** based on combination type, number of axles and distance between motor vehicle rearmost axle and trailer foremost axle **Max 60** timber transport & modular vehicles	**Max 60, GVW/GCW table** based on axle distance

* If the driving axle is fitted with twin tyres and a) air suspension (or equivalent) or b) drive axle load does not exceed 9.5 t

2.2 Axle load limits

The approach towards axle load limits is very similar in the countries studied. Moreover, the actual axle load limits are comparable with the EU limits for international traffic in Directive 96/53/EC. However, the reference axle distance which is the basis for the load limits, is slightly different in Norway and the Netherlands (see Table 8). It should also be noted that in Sweden and Norway, axle load limits depend on the road bearing capacity; Sweden has three categories of bearing capacity and Norway has four (Sweden 1998, Norway 2013). The values provided in Table are for the roads with highest bearing capacity in the two countries.

Table 7: Axle load limits (tonnes) in the European countries studied

	Austria/ Estonia/ Slovenia (EU, Dir 96/53/EC)	**The Netherlands**	**Norway (BK10)**	**Sweden (BK1)**
Single Axle Load				
Axle that is not a driving axle	10	10	10	10
Driving axle	11.5	11.5	11.5	11.5
Bogie Load				
d < 1 m (Norway: d < 0.8 m)	11 (11.5)*	11.5 (14?)**	10	11.5
1 <= d < 1.3 m (Norway: between 0.8-1.19 & 1.2-1.29 m)	16	16	15 & 16	16
1.3 <= d < 1.8 m	18(19)***	18 (19)***	18 (19)***	18 (19)***
d >= 1.8 m	20	20/21.5/23****	20	20
Triple Axle Load				
d < 1.3 m (Norway: less than 1 m & between 1.00-1.29 m)	21	21	16 & 22	21
d >= 1.3 m	24	27	24	24
d >= 1.8 m	-	30	-	-

* For the driving axle

** For trailer axles

*** For motor vehicles, if driving axle is fitted with twin tyres and a) air suspension (or equivalent) or b) drive axle load does not exceed 9.5 tonnes

**** Treated as single axles, thus based on number of driving axles, it can be either 20, 21.5 or 23.

2.3 Length limits

The length of single vehicles in the EU is regulated in Regulation (EU) No 1230/2012, which is also applied in the countries studied (EC 2012). In Norway, however, it is not applied to timber transport, and in Sweden, it is only applicable to modular vehicles (see Table 8). The length of vehicle combinations in Europe is regulated in the Directive 96/53/EC. However, Article 4 of the directive gives each member country the possibility to use longer vehicle combinations in its territory as long as they are based on the modular system (EC 1996); a modular combination is a vehicle combination that consists of vehicle units defined in Annex I of the directive.

Table 8: Vehicle dimension limits (m) in the European countries studied

	Austria, Estonia Regulation (EU) No 1230/2012 & Dir 96/53/EC	**Sweden**	**Norway**	**Netherlands**	**Slovenia**
Motor vehicle	**12**	**12** (only modular)	**12**	**12**	**12**
Semitrailer	**12** kingpin to rear	**12** kingpin to rear (only modular)	**12** kingpin to rear	**12** kingpin to rear	**12** kingpin to rear
	2.04 kingpin to front corner	**2.04** kingpin to front corner (only modular)	**2.04** kingpin to front corner	**2.04** kingpin to front corner	**2.04** kingpin to front corner
Trailer	**12**	**12** (only modular)	**12** (not timber transport)	**12**	**12**
Vehicle combination	**16.5** (articulated vehicle)	**24**	**17.5** (articulated vehicle)	**16.5** (articulated vehicle)	**22**
	18.75 (road train)	**25.25** (modular)	**19.5** (road train)	**18.75** (road train)	
			24 (timber transport)	**25.25** (modular vehicle)	
			25.25 (modular)		
Width	**<= 2.55 (2.6)***	**<= 2.55 (2.6)***	**<= 2.55 (2.6)***	**<= 2.55 (2.6)***	**<= 2.55 (2.6)***
Height	**<= 4.0**	Not regulated	Not regulated	**<= 4.0**	**<=4.2**

* For conditioned vehicles (vehicles fitted with a bodywork with insulated walls of at least 45 mm thickness)

In Sweden, the overall length limit is 25.25 m for a modular vehicle combination and 24 m for other combinations (Sweden 1998). The length limit for a vehicle combination in Norway depends on the road category; the largest value is 19.5 m with exceptions of 24 m for the transport of timber and 25.25 m for modular vehicles, which are allowed on parts of the road network (Norway 2013). Similarly, in the Netherlands, 25.25-m modular vehicles are allowed on parts of the road network. The vehicle length limits in the countries studied are summarised and compared in Table 8. Additional constraints on the loading length and axle distance of road trains are listed in Table 9.

Table 9: Additional constraints on the loading length and axle distance of road trains

	Austria, Estonia, Slovenia (EU)	Sweden	Norway	Netherlands
Loading length behind the cabin	**15.65**	**21.86** (modular)	**15.65**	**15.65** **21.82** (modular)
From foremost point of the loading area to the rear end of the vehicle	**16.4**	**22.9** (modular)	**17.15**	**16.4**
From rear axle of the motor vehicle to the front axle of the trailer	**>= 3**	**>= 3, 4, 5** (based on axle configuration)	**>= 3**	**>= 3**

2.4 Manoeuvrability and traction

In Regulation (EU) No 1230/2012, there are extra criteria that indirectly impose restrictions on the dimensions and load distribution of the vehicle to ensure manoeuvrability and traction (EC 2012). Examples of this are the swept area in a roundabout, the ratio of the load on steer or drive axles, and engine power based on the vehicle weight. These regulations and their counterparts in the countries studied are listed in Table 10.

Table 10: Restrictions imposed by manoeuvrability and traction criteria

	Austria, Estonia, Slovenia (EU)	Sweden	Norway	The Netherlands
Outer & inner circle radius of the swept area in a 360° turn	**12.5 & 5.3** semitrailer is deemed to comply if wb <= [(12.5-2.04)2 – (5.3 + w)2]0.5	**12.5 & 5.3** (motor vehicle) **12.5 & 2** (modular vehicle) deemed to comply if axle distance <= 22.5m & trailer wb <= 8.15m	**12.5 & 5.3** **12.5 & 2** (timber transport) **13 & 2 in a 180° turn** (modular vehicle)	**12.5 & 5.3** (motor vehicle) **14.5 & 6.5** (modular vehicle)
Rear swing-out in a turn with radius of 12.5 m	**<= 0.8 (1.0) m** (motor vehicle) based on rearmost axle type **<= 1.2 m** (articulated vehicle) Stated in Dir 97/27/EC	**Not regulated**	**<= 0.8 (1.0) m** (motor vehicle) based on rearmost axle type **Not regulated** (vehicle combination)	**Not regulated**
Steering axles load	**>= 20% of GVW**	**>= 20% of GVW**	**>= 20% of GVW**	**>= 20% of GVW**
Driving axles load	**>= 25% of GCW** Stated in Dir 96/53/EC, for international traffic	**Not regulated**	**Not regulated**	**>= 20% of GVW**
Engine power	**>= 5 kW/t of GCW**	**>= 5kW/t of GCW** (GCW <= 44 t) **>= 220+2(GCW-44) kW** (GCW > 44 t)	**>= 5.15 kW/t of GCW** (GCW <= 40 t) **>= 206 kW** (GCW > 40 t)	**>= 3.68 kW/t of GCW**
Gradeability	**>= 12%** starting five times within five minutes at a grade (with maximum load)	**>= 12%** starting five times within five minutes at a grade (with maximum load, up to 44 tonnes)	**>= 12%** starting five times within five minutes at a grade (with maximum load)	**Not regulated**

2.5 Brakes

The braking performance of heavy vehicles is another relevant issue that is extensively addressed in the existing regulations in Europe and is also applied in the countries studied. In Regulation (EC) No 661/2009, which addresses the type approval of vehicles and their components, UNECE regulation No. 13 is listed as the regulation that should be followed for brakes (EC 2009b). ECE R13 includes criteria on deceleration, braking efficiency, parking ability on a grade, and braking stability on a straight path and on a split friction surface, which are summarised in Table 11 (UNECE 2008).

Furthermore, in Regulation (EC) No. 661/2009, the mandatory fitment of a number of active safety systems, including electronic stability control systems (ESC), advanced emergency braking systems (AEBS), and lane departure warning systems (LDWS) for heavy vehicles are included. In addition to being fitted to the motor vehicles, the ESC system should also be fitted to trailers and semitrailers with air suspension and with less than four axles (EC 2009b). The detailed technical requirements for AEBS and LDWS are given in Regulation (EU) No. 347/2012 and Regulation (EU) No. 351/2012, respectively.

Table 11: Heavy vehicles brake regulation in Europe

Criteria	**Required level of performance**
Braking deceleration	**5 m/s^2** (from 60 km/h with engaged engine) **4 m/s^2** (from 90 (80) km/h* with disengaged engine) **4 m/s^2** (from 60 km/h, after 20 repeated braking from 60 to 30 km/h) **3.3 m/s^2** (from 60 km/h, after 6 km continuous braking)
Braking efficiency, ratio of achievable deceleration to the ideally supported deceleration by the tyre/pavement friction	**>=75%** (on roads with friction coefficient of 0.8 & 0.3 with an initial speed of 50 km/h)
Braking stability on a straight path	**Judged Subjectively** (in a 4 m/s^2 deceleration from 90 (80) km/h*)
Braking stability on a split friction surface, measured by required steering correction	**< 240° (120°)**** (from 50 km/h on a surface with kH>0.5, kH/kL>2)
Parking ability on a grade	**>=18%** (single vehicle loaded up to GVW) **>=12%** (vehicle combination loaded up to GCW, with unbraked trailer)

* Value in parenthesis is for tractors
** Value in parenthesis is for the first 2 seconds

2.6 Exhaust emissions

The exhaust emission regulation for heavy vehicles in Europe is included in Regulation (EC) No 595/2009, which is normally called Euro VI. The main regulation is complemented by Commission regulations Regulation (EU) No 582/2011 and Regulation (EU) No 133/2014, which stipulate all technical details regarding test procedures, measurement instruments, and administrative procedures. Euro VI has been applied in all the countries studied.

The emission limits in Euro VI, which are listed in Table 12, have been in effect for all new engines since 31 December 2013. The exhaust emissions are measured with respect to two driving cycles: the World Harmonized Steady State Cycle and the World Harmonized Transient Cycle, which have been created to cover typical driving conditions in Europe, USA, Japan, and Australia (EC 2009a, EC 2011, EC 2014a).

Table 12: Euro VI emission limits

	CO (mg/kWh)	THC (mg/kWh)	NMHC (mg/kWh)	CH4 (mg/kWh)	NOX (mg/kWh)	NH3 (ppm)	PM mass (mg/kWh)	PM number (#/kWh)
Compression Ignition (WHSC)	1500	130			400	10	10	8.0×10^{11}
Compression Ignition (WHTC)	4000	160			460	10	10	6.0×10^{11}
Positive Ignition (WHTC)	4000		160	500	460	10	10	6.0×10^{11}

CO: carbon monoxide, THC: total hydrocarbon, NMHC: non-methane hydrocarbons, CH_4: methane, NO_X: nitrogen oxides, NH_3: ammonia, PM: particulate matter, ppm: parts per million

2.7 Vehicle and tyre noise

The vehicle noise regulations in Europe are stated in Regulation (EU) No 540/2014, which replaced Directive 70/157/EEC in April 2014 and is similar to the UNECE Regulation No. 51, rev 3. The procedure for measuring vehicle noise is based on the ISO 362:2007 pass-by-noise standard, where the noise of heavy vehicles is measured while the vehicles accelerate with wide open throttle (WOT) on various gear settings past two microphones (one on either side), with an approach speed of 50 km/h, or 3/4 of the rated engine speed, whichever is the lower. The new regulation for vehicle noise adopts ISO 362:2007 as the testing procedure and proposes new noise limits to be implemented in three phases. The new limits for heavy vehicles with engine power greater than 250 kW are 82, 81, and 79 dB for the three phases, in effect in year 2016, 2020(2022), and 2024(2026), respectively. There are two different dates because new vehicle types and first registration are not treated equally (EC 2014b).

Tyre noise level limits are set out in European Regulation (EC) No. 661/2009, which has been in effect for the so-called replacement tyres (tyres sold as replacement to the original-equipment tyres on new vehicles) since November 2012; the implementation deadline for original-equipment tyres is 2016 (EC 2009b). Tyre noise emissions should be measured in a coast-by-noise test, where the vehicle is travelling at high speed on a specified road surface (ISO 10844). When reaching the recording section, the vehicle should be in neutral gear with the engine switched off. The vehicle and tyre noise limits in the studied countries, are same as the ones laid down in the European regulations (see Table 13).

Table 13: Heavy vehicle and tyre noise limits in Europe

	Heavy vehicle	Normal tyre	Traction tyre
Noise limit [db]	82, 81, 79*	73**	75**

*Limits for the three phases **Plus 1db for winter tyres

3 Safety and manoeuvrability of LHVs

In the previous chapter, existing regulations on heavy vehicles in a number of European countries were reviewed. These regulations apply to conventional heavy vehicles with a limited length and weight (18.75m/44t in the EU and 25.25m/60t in Sweden, Norway, and the Netherlands). This means that in order to ensure the safety and manoeuvrability of LHVs (if they are allowed on the road), extra requirements are needed. One possible approach is to use performance-based standards (PBS), which have been implemented in Australia, Canada, and New Zealand. Under a PBS approach to regulation, standards would specify the performance required from the vehicle rather than mandating how this level of performance should be achieved by putting limits on the vehicle's length or weight.

This section reviews the relevant performance measures relating to the safety and manoeuvrability of heavy vehicles found in literature, current regulations, and existing PBS approaches. These measures can be divided into four groups based on the practical goals they address: traction, tracking, stability, and braking. This categorisation is adapted from the goals used by Fancher, et al 1989. Each of these categories is reviewed in a separate section below.

When investigating the performance of heavy vehicles with respect to safety and manoeuvrability measures, both vehicle design and infrastructure design should be considered since they are closely linked. If a heavy vehicle is to be permitted on a certain road network, the features of the road have an important impact on the required level of performance from the vehicle. Likewise, when building a new road, the characteristics of the heavy vehicles that will drive on it make demands on the road's design. For this reason, the influential infrastructure features for each measure (if relevant) are listed in the lists of performance measures in the upcoming sections. Some examples of the nominal values of these infrastructure features in the studied countries are provided in Table 14 (Trafikverket 2012a, Trafikverket 2012b, Statens vegvesen 2013).

Table 14: Nominal values of the relevant infrastructure features in the studied countries

Infrastructure feature	Nominal values
Road grade	**Sweden:** 6-8% main roads, 10% minor roads **Norway:** 6% **Austria:** 4% highways, 6–8% main roads, 10% minor roads **Estonia:** 5–6.5% main roads, 6–7% minor roads, 10% minor roads (≤40km/h)
Friction (winter maintenance)	**Sweden:** 0.35 main roads, 0.25 minor roads **Norway:** 0.25 main roads, 0.20 minor roads **Estonia:** 0.3 class III-IV, 0.25 class II, 0.2-0.25 class I
Lane width*	**Sweden:** 3.5–3.75 m highway, 3.0–3.75 m main roads, 2.75–3.25 m minor roads **Norway:** 3.25–3.5 m, depending on speed limit **Austria:** 3.0–3.75 m highway/main roads, 2.75–3.0 m minor roads **Estonia:** 3.75 m (120km/h), 3.5 m (100km/h), 3 m (≤80km/h)
Crossfall	**Sweden:** 2.5–5.5% **Norway:** Min 2% **Austria:** 2.5% **Estonia:** 2.5% normal, (1.5–3.5%)
Road curvature	**Sweden:** Minimum 100–1200 m depending on speed limit **Norway:** Minimum 125–800 m depending on speed limit **Estonia:** Minimum 60–900 m depending on speed limit
Reference roundabout dimensions (outer and inner circles)	**Sweden:** 12.5 m–2.5 m **Norway:** 12.5 m–2.5 m **Austria:** EU 12.5 m–5.3 m, Standard outer circle radius: 17.5–20m **Estonia:** EU 12.5 m–5.3 m
Reference intersection dimensions (available width in a 90° turn)	**Sweden:** 8.5 m

3.1 Traction

Heavy vehicles should be able to start motion, maintain motion, and attain a desirable level of acceleration. Measures that can be used to assess the vehicle's performance with respect to these goals are listed in the traction group of performance measures. The existing European regulation on engine power, driving axle loads, and gradeability belongs to this category. Table 15 lists the relevant performance measures relating to traction and the corresponding influential infrastructure features.

Table 15: Performance measures that address the traction of heavy vehicles

Performance measures that address traction	Influential infrastructure feature
Startability Measure of vehicle ability to commence from rest on an upgrade road	Road grade Friction (winter maintenance)
Gradeability Measure of vehicle ability to maintain acceptable speed on an upgrade road	Friction (winter maintenance)
Acceleration capability Measure of vehicle ability to accelerate from rest with an acceptable level of acceleration	Friction (winter maintenance)

3.2 Tracking

The rear of the vehicle and all the units within the vehicle combination should follow the path of the front end of the vehicle with adequate fidelity. Measures that can be used to assess the vehicle performance with respect to this goal are listed in the tracking group of performance measures. The existing European regulation on swept area and rear swing-out belongs to this category.

Table 16 lists the relevant performance measures relating to tracking and the corresponding influential infrastructure features. Road surface friction is also important for these measures, but it is not repeated in the table.

Table 16: Performance measures that address the tracking of heavy vehicles

Performance measures that address tracking	Influential infrastructure feature
Tracking ability on a straight path Measure of deviation of the towed units from the prescribed path on an uneven straight road with a crossfall	Lane width Crossfall
Frontal swing Measure of deviation of front outer corner of the vehicle from the prescribed path in a tight turn at low speeds	Reference roundabout dimensions Reference intersection dimensions
Tail swing Measure of deviation of rear outer corner of the vehicle units from the prescribed path in a tight turn at low speeds	Reference roundabout dimensions Reference intersection dimensions
Low-speed offtracking/swept path Measure of deviation of the towed units from the prescribed path in a tight turn at low speeds	Reference roundabout dimensions Reference intersection dimensions
High-speed steady-state offtracking Measure of deviation of the towed units from the prescribed path in a turn at high speeds	Road curvature Lane width
High-speed transient offtracking Measure of deviation of the towed units from the prescribed path in a sudden manoeuvre at high speeds	Lane width

3.3 Stability

The vehicle should be stable, attain directional control, and remain upright during manoeuvring. Measures that can be used to assess the vehicle performance with respect to these goals are listed in the stability group of performance measures. The requirement on the steady-state rollover threshold of tank vehicles in Europe, according to the UNECE regulation no 111, and ESC fitment belongs to this category.

Table 17 lists the relevant performance measures relating to stability. They are not as closely related to the infrastructure features as the previous categories, thus only the description of the measure is provided in the table. However, road surface friction also plays an important role for the stability-related measures.

Table 17: Performance measures that address the stability of heavy vehicles

Performance measure that address stability
Steady-state rollover threshold Measure of maximum severity of the steady turn, i.e. lateral acceleration, which the vehicle can sustain without rolling over
Load transfer ratio Measure of the proximity of a wheel lift-off in a sudden manoeuvre
Rearward amplification Measure of the amplification of motions (e.g. yaw rate or lateral acceleration) in the rearmost unit in a sudden manoeuvre
Yaw damping coefficient Measure of quickness of decay of towed units oscillations after a sudden manoeuvre
Friction demand of steer tyres Measure of excessive understeering risk, i.e. demanded friction at steer tyres, to overcome the resistance of other axles, in a tight turn at low speeds
Friction demand of drive tyres Measure of jackknife risk, i.e. demanded friction at drive tyres, to overcome the resistance of trailer axles, in a tight turn at low speeds

3.4 Braking

The vehicle should safely attain a desirable level of deceleration during braking. Measures that can be used to assess the vehicle performance with respect to this goal are listed in the braking group of performance measures. As mentioned earlier, this category is addressed within the European regulations rather comprehensively. Table 18 lists the relevant performance measures with respect to braking and the corresponding influential infrastructure features.

Table 18: Performance measures that address the braking performance of heavy vehicles

Performance measures that address braking	Influential infrastructure feature
Braking deceleration Measure of stopping distance	Friction
Braking efficiency Ratio of achievable deceleration to the ideally supported deceleration by the tyre/pavement friction	Friction
Braking stability on a straight path Measure of required space during a heavy brake	Lane width Friction
Braking stability in a turn Measure of required space during a heavy brake in a turn	Road curvature Lane width Friction
Braking stability on a split friction surface Measure of vehicle controllability by the driver when it is braked on a road with split friction	Friction
Parking ability on a grade Measure of vehicle ability to stay still on a graded road	Road grade Friction

3.5 Extra safety features

In addition to the listed performance measures, the applicability and effectiveness of demanding extra safety features on LHV vehicles for ensuring safe performance should be explored. Examples of such safety features include full EBS functionally on all units for faster braking response and splash guards for decreasing the risks associated with overtaking.

4 LHV impact on Infrastructure

In this chapter, the effects of heavy vehicles on the infrastructure are discussed. Important aspects to consider include road design (geometry and position of roadway elements), pavement design, bridge design, tunnel design, and road services.

4.1 Road design

Road design requirements can be found in regulatory documents. They ensure function on the basis of typical traffic situations, several reference vehicles, design speed, physics (dynamics, friction), aesthetics, reliability, safety, costs, and driver behaviour and needs. These functional needs are stated in the documents as performance-based or geometrical constraints. Examples of geometrical constraints include road width, free height, and available area at intersections.

The previous section listed the infrastructure features that should be considered when studying the safety and manoeuvrability of heavy vehicles. Similarly, the dynamics and design of vehicles that will travel on a road should be considered when constructing that road. In practice, several reference vehicles are used for road design. Figure 5 shows the reference vehicles used in Norway and the reference heavy vehicles used in Sweden. The two reference heavy vehicles used for road design in Sweden are a tractor-semitrailer and a truck-dolly-semitrailer. The tractor-semitrailer is used in the design of intersections and the swept area needed in curves, while the latter is used to determine the required space for turn lanes and parking lots (Trafikverket 2012b). If LHVs are to be allowed on a road network, the reference heavy vehicles for the road design should be updated accordingly. For instance, the minimum length of left-turn lanes at intersections in Sweden is currently 30 m, which can accommodate a truck-dolly-semitrailer and a passenger car; this minimum length should be increased if LHVs are to be allowed on a road network. Another example is the distance between a railroad crossing and intersection, which also has a minimum length of 30 m in current road design guidelines.

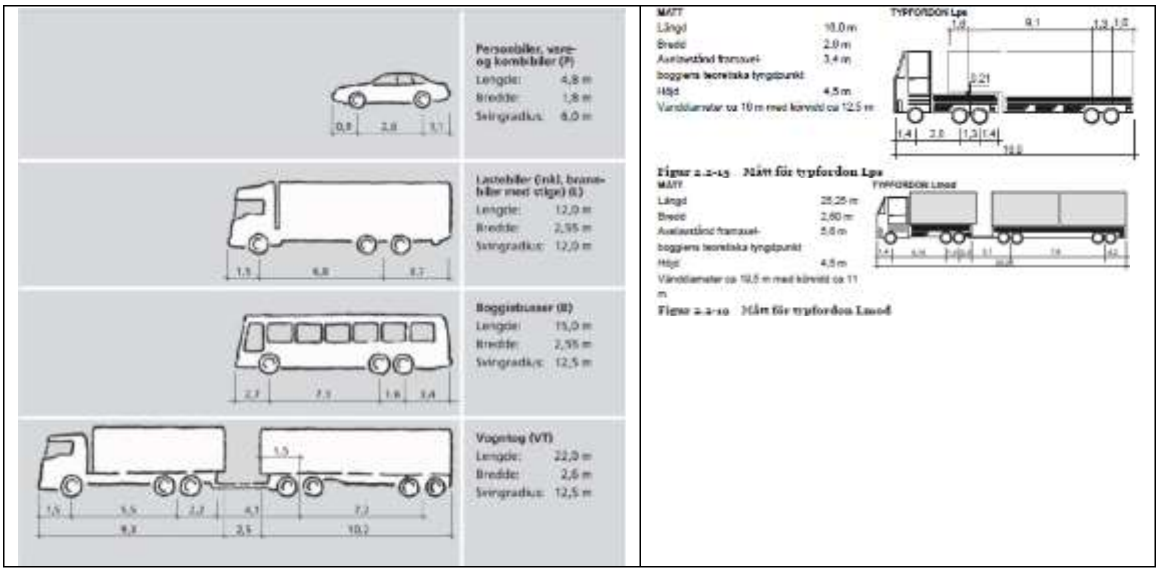

Figure 5: Left: reference vehicles for the Norwegian road network (Statens vegvesen 2013). Right: reference heavy vehicles for the Swedish road network (Trafikverket 2012b)

The main infrastructure design features, which were discussed in the previous section are: grade, lane width, curvature, roundabout and intersection dimensions, crossfall, and friction. Turn lane length and distance between a railroad crossing and intersection have been also mentioned. Other important infrastructure features that should be mentioned are sight distance and signalised intersections. Longer vehicles might require more time to pass an intersection. This means that the available sight distance at an intersection should be sufficient for an LHV. In the case of a signalised intersection, the calculation of the required time for departing the intersection, which is used to regulate the traffic signals, should be updated to accommodate longer vehicles.

4.2 Pavement design

Limiting the axle loads is a widely used approach to controlling the effect of heavy vehicles on pavements. In addition to axle load limits, the Australian PBS includes maximum limits on the gross mass of the vehicle and the tyre inflation pressure in order to control the pavement horizontal loading and pressure distribution.

Heavier LHV loads can be compensated for by axle and tyre configurations that reduce the loads on the pavement. Nevertheless, it is important to note that there are load history-dependent deterioration mechanisms in the pavement structure. Examples include:

- the viscous rheological behaviour of bitumen bound materials means that asphalt concrete subject to multiple loads at short intervals will not be able to regain shape between loads.
- soil sensitivity to repeated loading which leads to reduced resistance to permanent deformation.

There are gaps in the knowledge of these effects.

It should be noted that the bearing capacity of roads differs very much throughout the year, depending on precipitation, temperature, drainage conditions, etc. A frozen pavement and a pavement during the thawing period represent two extreme bearing capacity situations. Consequently, there are periods when load restrictions can be eased and periods when traffic loads can be very detrimental to a pavement's condition. This has been reflected in vehicle weight or axle restrictions in some countries. For instance in Estonia and Norway some axle load restrictions are lifted during the frozen winter period. In some provinces in Canada, additional weight is allowed to be carried during a defined period of freeze-up in winter; some provinces allow winter weights for all vehicles, while others allow them only for a specific commodity, such as timber. Furthermore, all provinces in Canada impose spring weight restrictions during the thaw period; however, the onset and duration varies widely (NCHRP 2010). In Sweden, special regulations apply if the vehicle uses systems such as CTI (Central Tyre Inflation) that reduces air pressure in tyres, allowing the vehicle to maintain the ordinary weight all year around.

Another issue is vehicle vibration and its possible effects on residential areas along the road. Vibrations from heavy vehicles influencing residential areas are mainly related to the number of axles, axle loads, suspension, vehicle speed, and road surface evenness (Hunaidi, 2000). A potential problem might be very heavy vehicles travelling at high speed on soft soil (clay) and weak pavements. Loads from several axles may impact on the residential areas along the road and cause greater vibrations than would be expected on the basis of the individual axle loads.

4.3 Bridge design

Bridges are the primary factor in deciding on permitted axle loads and gross vehicle weights. To avoid excessive loading of bridges, permitted axle loads and gross weights are restricted/limited. A number of different bridge types exist such as slab, slab frame, girder, box girder, arch, truss, cable stayed, suspension, and composite bridges. Structural strength is achieved by components consisting of concrete, reinforced concrete, steel structures, and steel cables, which are joined together by components. The difference in static function and material types mean that bridge sensitivity to LHVs varies from one design to another. This is why the permissible traffic load is calculated for each individual vehicle and bridge when dispensations are issued in Sweden.

In Sweden, the bearing capacity of a bridge is determined by calculating the load effects and resulting stresses using reference vehicles, taking into account the bridge condition and its weight and other loads. The nine original reference vehicles (named 'a' to 'i') that are used when calculating the bearing capacity of bridges were selected in 1980s. The reference vehicle list was later expanded in two stages with three (j, k and l) and two additional vehicles (m and n) being added in each stage. The bridge bearing capacity calculation is currently based on all 14 reference vehicles ('a' to 'n') described in the regulation TDOK 2013:267, version 1.0 (Trafikverket 2013). The reference vehicle 'a' is used to determine the value of the permissible single axle load, while reference vehicles 'b' to 'n' are used to determine the permissible bogie axle load and the gross weight. The permissible gross weight versus axle distance is calculated by considering every axle distance in the reference vehicles and the corresponding sum of its axle weight, see Figure 6. It should be noted that in a new regulation, which came into effect in June 2015, the maximum gross weight on BK1 roads has been increased to 64 tonnes for heavy vehicles with an axle distance of 20.2 m or higher.

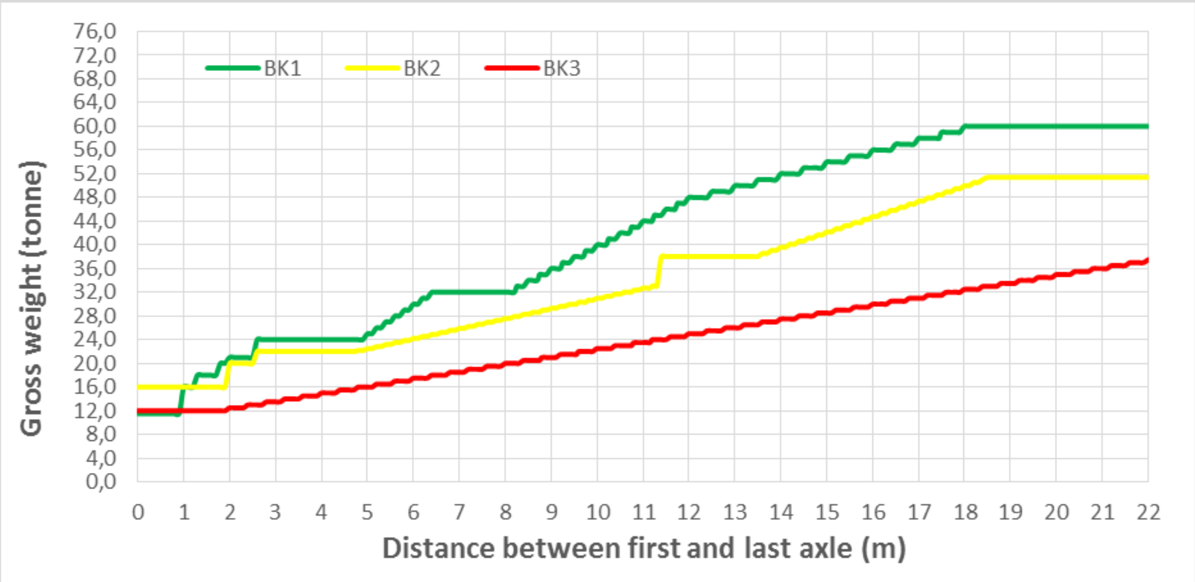

Figure 6: Permissible gross weight vs. distance between first and last axle of the vehicle, for the three bearing capacities (Trafikverket 2014)

One possible approach to accounting for the effects of LHVs on bridges is to consider more reference vehicles and to update the gross weight curve accordingly. This approach has been investigated by the Swedish Transport Administration for vehicles with a gross weight of up to 74 tonnes and is presented in Trafikverket 2014. Another common approach, which is used in Australia and the United States, is to use bridge formulae to calculate the effects of the vehicle loading. This approach recommends imposing limits on the total mass based on the axle configuration of the vehicle, namely axle spacing, and in some cases, the number of axles.

4.4 Tunnel design

Space in tunnels is certainly very expensive, and safety is a major concern. There are a range of issues and scenarios involving LHVs—either direct or indirect—that should be investigated. A scenario that directly involves LHVs would be one where the vehicle malfunctions; a scenario that indirectly involves LHVs would be one where other problems occur and the vehicle needs to adapt to the situation, for example by turning or reversing. The following aspects need to be further investigated when regulating LHVs:

- emergency parking space requirements
- turning possibilities inside long tunnels and the ability to reverse in case of emergency
- the overtaking of heavy vehicles in tunnels, sway and tunnel space
- the risk of fire, discussed in OECD 2011
- potentially dangerous situations involving the transport of dangerous substances

4.5 Vehicle restraint systems

Another relevant issue for heavier vehicles is the suitability of vehicle restraint systems, which can be divided into safety barriers, terminals/transitions, and crash cushions. Safety barriers are guardrails that are designed to prevent vehicles from leaving the road. These should comply with the EN 1317-5 standard, which includes product requirements. EN 1317-2 states the different performance classes, of which H1–H4 are the most demanding. A H1-level vehicle restrain system is required to contain a rigid truck weighing 10 tonnes colliding at an incident angle of 15 degrees at 70 km/h, while a H4-level vehicle restraint system is required to contain a 30-tonne rigid truck or a 38-tonne articulated vehicle, both colliding at an incident angle of 20 degrees and at 65 km/h. The EN 1317 standard also include safety zone requirements, which may also be affected by heavier vehicle allowances. One can conclude that the weight of vehicles used in the Nordic countries today exceed the limits set in the EN 1317 (Statens vegvesen 2014).

4.6 Road service

The availability of road services, such as parking and rest areas, is very important for longer vehicles. As stated in Hjort & Sandin 2012, driver fatigue is the cause of a considerable number of single vehicle accidents involving heavy vehicles. This illustrates the importance of access to sufficient rest areas. Service areas and places where drivers can apply snow chains are other examples of facilities that require space to accommodate vehicles.

4.7 Ferry traffic

Due to the geography of the country, ferries are essential for some transport links in Norway and cannot be neglected. Nevertheless, this topic was not included in the scope of this pre-study.

5 Environmental aspects of LHVs

The existing European environmental regulations, namely those on exhaust and noise emissions described above, are already performance based. These regulations are also in effect in all countries described in this part of the report. Consequently, the main issue with respect to LHVs is whether the existing regulations are suitable for them as well or not. Some of the main issues to be investigated are:

- Is it enough to impose an exhaust emission limit in accordance to Euro VI for LHVs?
- The vehicle noise is verified for the powered unit (truck/trailer), not the whole vehicle combination. In reality, however, the noise level of a truck/trailer hauling just one trailer or multiple trailers is not the same due to the differences in the engine load, number of axles, and aerodynamics.
- Should tyre noise limits be different for LHVs due to the fact that a long heavy vehicle combination is equipped with more tyres?

5.1 Fuel consumption

As of yet, there is no fuel consumption/CO_2 regulation for heavy vehicles in Europe. However, the Commission has recently set out a strategy to curb CO_2 emissions from heavy vehicles and has developed a test procedure to measure their fuel consumption and CO_2 emissions. The test procedure is based on tests of the individual components of the vehicle and simulations of the fuel consumption and CO_2 emissions of the entire vehicle (UniGraz 2012). In order to better reflect real world conditions, the procedure will include a number of different mission profiles that are typical of different categories of heavy vehicles. The CO_2 limits and the most suitable metric unit have yet to be decided. However, the likely metrics for the procedure are per tonne-km and per m^3-km, to reflect the fuel consumption or CO_2 emissions per transported amount of goods.

One possible approach to addressing LHV fuel consumption, is to consider them in the prospective regulations, e.g. in determining the typical mission profiles and the fuel consumption limits. Another issue that should not be neglected is alternative powertrains and fuels.

6 Conclusions

This section of the report reviews and compares existing legislation in Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden that imposes weight and dimension limits on heavy vehicles. Additionally, performance measures relating to the safety and manoeuvrability of LHVs, relevant infrastructure, and environmental aspects are discussed.

When investigating the performance of heavy vehicles with respect to safety and manoeuvrability measures, both vehicle design and infrastructure design should be considered since they are closely linked. If a heavy vehicle is to be permitted on a certain road network, the features of the roads impact on the required level of performance from the vehicle. This is why the list of relevant performance measures in this report contains the corresponding influential infrastructure features and their nominal values by way of example. Similarly, dynamics and the design of vehicles that will travel a road should be considered when constructing a road. One approach is to utilise reference vehicles for road design, as is done in both Sweden and Norway.

The main infrastructure design features that should be considered with respect to LHVs are: grade, lane width, curvature, roundabout and intersection dimensions, and crossfall. Other important infrastructure aspects are the availability of parking and rest areas, tunnel safety, safety barriers, turn lane length, distance between a railroad crossing and intersection, sight distance at an intersection, and the regulation of traffic signals.

The heavier loads carried by LHVs can be compensated for by axle and tyre configurations that reduce the loads on the pavement. Nevertheless, it is important to note that there are load history dependent deterioration mechanisms in the pavement structure. There are gaps in the knowledge of these effects, and further investigations are required. Another important issue with regard to the bearing capacity of a pavement is its variance throughout the year. For this reason, axle load limits can be adjusted with regard to seasonal changes, an approach that is implemented in Estonia, Norway, and Canada.

Bridges are the primary factor in deciding on permitted axle loads and gross vehicle weights. To avoid excessive loading of bridges, permitted axle loads and gross weights are restricted/limited. In Sweden, the bearing capacity of a bridge is determined by calculating the load effects and resulting stresses using reference vehicles. One possible approach to accounting for the effects of LHVs on bridges is to consider more reference vehicles. This approach has been investigated by the Swedish Transport Administration for vehicles with a gross weight of up to 74 tonne. Another common approach, which is used in Australia and the United States, is to calculate the effects of the vehicle loading on the bridges using a bridge formula.

Existing European environmental regulations, which are also in effect in Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden, are already performance based. Thus, many of these regulations can be applied to LHVs as well. In some cases, some adaptations might be required; for instance in the case of the prospective European regulation on fuel consumption, LHVs should be considered when determining typical mission profiles and fuel consumption limits.

Part 3 Introduction to Freight and Logistics in a Multimodal Context Part C: Fit for purpose road vehicles to influence modal choice

1 Background

Directive 96/53/EC, amended by Directive 2015/719/EC, limits the maximum dimensions member states are permitted to authorise in national transport on their respective territories. Article 4 prohibits member states from authorising vehicles and vehicle combinations in normal circulation within their territories that exceed maximum length, maximum width, turning circle requirements, maximum length of semitrailers and maximum length of the loading area of lorries with trailers as stated in Annex I of the directive. The directive does not impose restrictions on the maximum permitted height, vehicle and vehicle combination weight and axle loads.

In addition, Article 4(4) provides a derogation for certain types of vehicles and vehicle combinations in national transport. The derogation is limited to transport operations that are considered not to have a significant impact on international competition, specifically transport operations carried out by specialised vehicles/vehicle combinations that are not normally carried out by vehicles from other member states, e.g. operations linked to logging and the forestry industry (a), and European Modular System combinations (b).

The wording of the directive limits this derogation to traffic within the member states' territories. However, a few neighbouring countries also permit (or do not prohibit) border-crossing transport operations involving longer and/or heavier vehicles, particularly with EMS combinations. This sparked a discussion on whether the directive allows for such transport operations to be accepted between member states that have both made use of the derogation to permit specific types of transport. In an attempt to clarify the Commission's stance on the subject, Vice-President Kallas, the EU Commissioner responsible for Transport[19], issued a letter in June 2012 stating that provided certain conditions were met, permitting cross-border transport operations should not be considered a violation of the directive. The accompanying press release also signalled that the topic would be addressed in the upcoming revision of the directive.

Accordingly, in the original proposal from 2013, the Commission proposed to extend the derogation in Article 4(4) to allow border-crossing transport operations between neighbouring member states that have both adopted measures taken in application of the derogation. The EP on the other hand, not only proposed to remove this amendment, but proposed to replace it with a passage making it clear that such cross-border transport operations would *not* be allowed.

At this point, CEDR contacted the Heavy Vehicles group, pointing out that the basis of the reluctance to accept border-crossing transport operations involving longer and/or heavier vehicles was at least in part that such an arrangement would create a distortion of the internal market to have an agreement between two countries and not with other neighbours, which in turn could increase pressure on neighbours of countries using longer, heavier vehicles to accept them. In view of this fact, a number of road directors indicated that they would like to see a specification produced for the standards of infrastructure required before

[19] http://europa.eu/rapid/press-release_IP-12-611_en.htm

longer, heavier vehicles are allowed, which could be used to prevent or allow vehicles on an objective basis.

To formulate these standards, the group decided to submit a DoRN for a call for tender under the CEDR Transnational Road Research Programme Multimodality.

The initial idea was that such a specification would need to take into account the total weight of the vehicles (and vehicle combinations), the axle loads, the total length of the combinations, their turning capabilities, and other road safety factors. It soon became clear, however, that rather than looking at specific weights and dimensions, such as the typical EMS combination of 25.25 m and 60 tonnes, the subject should be approached from the point of the infrastructure. Furthermore, as the infrastructure only makes up part of the picture, it would also be beneficial to look into other factors contributing to the accessibility of heavy vehicles, such as their tracking, traction, and stability.

As the Swedish Transport Administration has already used the performance-based standards (PBS) approach in a national project relating to longer and/or heavier vehicles, the group decided to use this approach to formulate the CEDR standards. The performance-based standard is a regulatory principle between 'principle-based regulations' at one end to prescriptive regulations at the other, which includes specific performance criteria/measures with quantified required level of performance. It is more precise than principle-based regulation, but provides more flexibility than prescriptive regulations. A harmonised PBS framework would outline how the objective could be achieved while maintaining the flexibility to take into account specific national challenges such as topography, climate, and current standard of the road infrastructure, as well as not restricting the framework to set weights and dimensions.

The aim of these standards is not to determine if longer and/or heavier vehicles should be allowed on a given road or road network. They are intended to be a tool for objectively deciding whether the road infrastructure in itself is suitable for vehicles exceeding the weights and dimensions laid down in Directive 96/53/EC. Firstly, the application of the objective standards to a given road may well indicate that this road is *not* suitable for longer and/or heavier vehicles without minor or major investments and upgrades. Secondly, even if the standards are met, whether this road *should* be opened for longer and/or heavier vehicles is a political decision that may include other elements.

The standards will not just be relevant for EMS (25.25 metres/60 tonnes), but could be used to assess whether any increase in the currently permitted weights and dimensions is possible without upgrading existing infrastructure. While EMS has been the main focus, the system could be used for all types of (heavy) vehicles, from 3.5 to 100 tonnes and even beyond, as well as taking into account that it is not always the heaviest trucks that cause the most impact on the road infrastructure, for example, a short 4-axle 40 t truck can sometimes be worse than a 60 t 7-axle combination[20].

To this end, the task group commissioned a pre-study to help define which topics should be investigated further in the main study. The aim of the pre-study was to review the existing knowledge of the regulation of heavy vehicles using performance-based standards (PBS), to list relevant safety, infrastructure and environment related criteria, and to identify areas for further investigation. An extended version of the pre-study is described in part 2 of this report.

[20] 4th power calculation of how many the number ESAL (eqvivalent standard axles)

Based on the pre-study, the group formulated a DoRN (Description of Research Needs) for the sub-topic 'The right heavy vehicle combinations for the right road (Performance-based standards for infrastructure)' in the 2015 CEDR Transnational Road Research Programme Call 2015 Freight and Logistics in a Multimodal Context. The group selected the sub-topics Bridge design, Road design (including both road design and pavement design), and Tunnel design for further studies. The decision was based in part on the fact that vehicle-related topics are thoroughly regulated through EU legislation and are therefore very difficult to alter, as well as already being well described in existing literature. The road infrastructure factors, on the other hand, are to a much greater degree subject to national variations. In addition, CEDR's focus is primarily on road and road infrastructure, making these topics the most relevant to CEDR.

Description of Research Needs (DoRN) for topic C: Fit for purpose road vehicles to influence modal choice[21]

The right heavy vehicle combinations for the right road (Performance-based standards for infrastructure)

NRAs have difficulties maintaining the quality of their roads due to ageing infrastructure and limited funds. In addition to this many roads, especially close to urban areas, suffer from congestion. Therefore, a more rational utilisation of the existing infrastructure is needed. In this call we will explore if access policy in the form of performance-based standards (PBS) for road infrastructure works as a potential solution, and how this approach will affect multimodality.

The common approach is setting limits on the vehicle weight and length to ensure safety and to protect the infrastructure. Performance-based standards is a regulatory principle which includes specific performance criteria/measures with quantified required levels of performance. It is more precise than principle-based regulation, but provides more flexibility than prescriptive regulations, which encourages innovative novel products and logistic concepts.

Many of the member organisations within CEDR are interested in the development of standards that can be used to assess if a vehicle combination with weight and/or dimensions exceeding the actual specified limits should be allowed to circulate on a specific/selected part of the road network or not. A harmonised PBS framework would outline how this objective could be achieved while maintaining the flexibility to take into account specific national challenges such as topography, climate and current standard of the road infrastructure, as well as not restricting the framework to set weights and dimensions. The aim of this call is to specify objective and simplified performance-based standards for infrastructure and both the vehicle combinations that comply with the permissible weights and dimensions given in Directive 96/53/EC and those that do not.

These standards will be established on the basis of international regulations/standards/ guidelines and literature, and they will be designed to take into account road safety, accessibility and manoeuvrability, infrastructure and environmental factors. They must also ensure equal competition and predictability for the industry and road transport sector. The topics that will form the basis for the standards are given in Figure 7.

[21] DoRN in full as well as all documents related to the 2015 call available at https://irl.eu-supply.com/app/rfq/publicpurchase_frameset.asp?PID=94983&B=&PS=1&PP=ctm/Supplier/PublicTenders

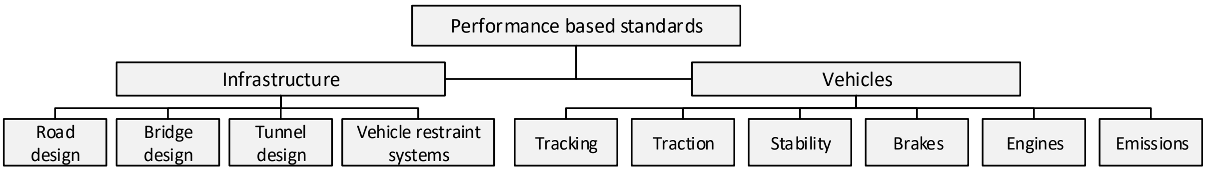

Figure 7: Topics forming basis for standards.

A pre-study and literature review on this topic has been conducted, and research areas that need further investigation are road design (pavement and road design), bridge design and tunnel design. Performance indicators must be defined for the infrastructure criteria, which will in turn form the base for road, bridge, and tunnel design.

We need to investigate if this will make the transport system more effective as a whole and if PBS can be a tool for access policy from the perspective of traffic management. It is also interesting to better understand if PBS might stimulate multimodal transport solutions and result in more efficient logistics. Increased authorised weights and dimensions for vehicle combinations might improve the competitiveness of the multimodal transport chain under certain conditions.

The **outcome** of the research could consist of:

1. An inventory of infrastructure criteria in use in the various countries (calculations, criteria and models, regulations where relevant) for tunnels, bridges, pavement and road design
2. Based on the infrastructure criteria listed in the inventory, development of PBS criteria using knowledge from existing systems around the world for example from Australia, South Africa, and Canada
3. Application of these PBS infrastructure criteria in case studies for cross border traffic in three to five relevant European regions
4. The effects on congestion, safety and multimodality if PBS is used in a region must also be described.
5. Evaluation of whether PBS is a desirable alternative to the criteria in use.

The results will be utilised in CEDR guidelines for assessing infrastructure, based on the results of the case studies. PBS could also be used as an infrastructure management system to optimise cost/benefit, by providing a better overview of which roads are used by heavy vehicles and better possibilities of directing heavy transport into suitable transport corridors. Furthermore, PBS might be used as a tool for NRAs to influence modal choice and make logistics more efficient.

Relevant preconditions for this research include:

- solutions will be provided to ensure that the right vehicles are used on the right roads, and to control and enforce the vehicle criteria (requirements). The possibility of a trade of information from fleet management systems in return for more goods should also be taken into consideration.
- Expected developments in relevant automotive industry, including OEMs, should also be taken into account.

2 2015 Call Freight and Logistics in a Multimodal Context and FALCON Project

The CEDR Transnational Road Research Programme 2015 Call Freight and Logistics in a Multimodal Context focuses on the parameters that influence modal choice in freight transport, with the aim of providing NRAs with insight into the possibilities for optimising multi-modality and the impact that these might have on road infrastructure. The research is expected to produce specific tools to enable NRAs to influence these choices[22]. The programme consists of three parts:

A. Understanding what influences modal choice (including behaviour)
B. How can infrastructure and infrastructure services affect modal choice?
C. Fit for purpose road vehicles to influence modal choice (performance-based standards)

Part C Fit for purpose road vehicles to influence modal choice is the implementation of the DoRN written described in point 1.

The total budget for the Call is about €720,000, of which Part C accounts for about half. The participating CEDR members are Norway, Sweden, the Netherlands, and Germany. MAN Truck and Bus AG are also contributing directly €50,000 to the project as they wish to 'support this consortium to ensure a successful project … We see the highly strategic relevance of using the output of this project for future vehicle projects.' [23]

The call was launched in December 2015 and closed in March 2016. The FALCON group (Freight And Logistics in a Multimodal Context), a consortium consisting of VTI (Sweden), DLR (Germany), TNO (The Netherlands), IFSTTAR (France), BRRC (Belgium), CUTS (UK), PANTEIA (The Netherlands), MAN (Germany), and Michelin (France), coordinated by HAN University of Applied Sciences (The Netherlands) was selected for parts A and C as well as the final dissemination[24].The start-up meeting with the selected consultants was held in September 2016.

As stated in the FALCON tender, Work Package 3, which will cover topic C **Fit for purpose road vehicles to influence modal choice (performance-based standards),** '*Focuses on compiling Smart Infrastructure Access Policy (SIAP) to selected segments of the infrastructure network, for current and future commercial vehicles that have multimodal use potential. Proposed policy will be performance based, and will reflect on capabilities and design criteria of current infrastructure network including roads, bridges and tunnels. Loading conditions and behaviour of the commercial vehicles (including expected short term developments defined by OEM's) will be considered as decisive input for policy outline, as well as national topology, and climatic conditions.*

WP3 will deliver a smart infrastructure access policy (SIAP) for current, but also future road freight vehicles ensuring proper fit between the vehicle and the infrastructure network. (page xx)

The deliverables are as follows:

[22] As described on the CEDR Call 2015 website http://www.cedr.fr/home/index.php?id=313
[23] FALCON Template for submission Appendix C page C.16
[24] Topic B is a separate project FLUXNET (Freight and Logistics Using eXtended Network Empowerment Tools), see http://www.cedr.eu/download/other_public_files/research_programme/call_2015/freight_and_logistics_in_a_multimodal_context/CEDR_Call_2015_Summaries_-FLUXNET.pdf

No.	**Milestones and/or deliverables**: brief description of output of WP	Delivery date
D3.1	*Definition of Representative Fleet (HAN)* Library of representative Heavy Goods Vehicle (HGV) combinations including, vehicle configuration, parameters, capacity and loading conditions.	11/2016
D3.2	*Definition of Representative road Network (IFSTTAR)* Catalogue of representative infrastructure components including roads, bridges and tunnels (input to D 3.4, 3.5 and 3.6)	2/2017
D3.3	*Extensive Vehicle Policy Review (VTI)* Document summarizing vehicle performance criteria already used in different countries and mirrored against the European conditions	4/2017
D3.4	*Extensive Infrastructure Design Criteria Review (IFSTTAR)* Document summarizing overview: of infrastructure design criteria an legislation with the emphasis on roads, bridges and tunnels	4/2017
D3.5	*Definition of Smart Infrastructure Access Policy (UCAM)* Definition of the SIAP performance criteria as a function of road access class	11/2017
D3.6	*SIAP Validation (HAN)* Methodology and family of models that can quantify vehicle-infrastructure interaction and vehicle safety.	11/2017
D3.7	*Application of SIAP to Case Studies (VTI)* Compiled report of case studies documenting the impact of SIAP on infrastructure, congestion, and multimodality.	04/2018
	Smart Infrastructure Access Policy is ready (D3.7)	04/2018

The project will finish in the spring of 2018 with the final dissemination. FALCON will finalise its work in August 2018 and the dissemination of the results of the Call will take place in September 2018.

3 Possible next steps

The expected output of part C of the call is as follows:

The results will be utilised in CEDR guidelines for assessing infrastructure, based on the results of the case studies. PBS could also be used as an infrastructure management system to optimise cost/benefit, by providing a better overview of which roads are used by heavy vehicles and better possibilities of directing the heavy transport into suitable transport corridors. Furthermore, PBS might be used as a tool for NRAs to influence modal choice and make logistics more efficient.

TG N4 believes that a working group, preferably organised by CEDR, should continue the work on these criteria to ensure that the results of the project are implemented using PBS criteria and to facilitate the use of these criteria in CEDR countries.

The results of the project will be presented at a 'dissemination workshop' in the autumn of 2018. It would be beneficial if as many NRAs as possible attend the workshop, both those who represent countries that are generally positive towards longer and/or heavier vehicles, and those who take a more negative view.

A working group to continue the work on the criteria could be put together after the workshop. It would be particularly valuable if those who contributed to the DoRN were to join this working group.

Overall conclusions and recommendations

1 The demand for extra weights and dimensions and the extent to which countries have made use of the possibility to deviate from EU standards (Directive 96/53/EC, amended by Directive 2015/719), differs according to the type of transport and the region.

a) The possibility of using longer vehicles has been taken advantage of for two types of transport operations: the transport of vehicles and transport operations in the forest industry. Of all the countries that responded, eight have made special provisions for this within their national regulations. These countries are spread all over Europe.

b) The possibility of using heavier vehicles has been taken advantage of for transport operations relating to the forestry and mining industries. Three countries have made provisions in their national regulations exclusively for these types of transport.

c) In nine countries (Belgium, Denmark, Estonia, Finland, Iceland, the Netherlands, Norway, Sweden, and Spain) extra weights (over 50 tonnes, including the EMS) are permitted for all transport operations. In some of these countries, such weights are only permitted on a dedicated road network and in Belgium only on trial or with a special permit. With the exception of Spain, these countries are all located in the north of Europe.

d) In Germany, the concept of the *Lang-Lkw* shows that there is a demand for all transport operations for vehicles that are longer but not necessarily heavier on a dedicated network. This seems to be the case in several other countries as well.

2 If the growth in freight transport towards 2030 has to be absorbed mainly by the road network, it could be beneficial to focus on longer vehicle combinations such as the *Lang-Lkw* rather than on EMS. The German *Lang-Lkw* trial, the Norwegian EMS trial, the UK's Longer Semitrailer trial, and to some extent the Swedish HCT and Dutch EMS studies show that there is a greater demand for increased volume than for increased weight. This could result in an increase in road freight transport efficiency without raising concerns about reverse modal shift or the impact on road infrastructure, especially on bridges.

3 The revision of Directive 96/53/EC regarding aerodynamic devices at the front and the rear are not specified exactly. Many CEDR members are concerned that the extra length will cause difficulties for road design and reduce traffic safety. It is therefore recommended that both CEDR and its individual NRAs participate closely in the further development of this open end of Directive 2015/719/EC.

4 The maximum weights of heavy vehicles appears to be a very sensitive issue, not only politically but also, as expected, technically. This is illustrated by questionnaire responses relating to the expected impact of one extra tonne that was proposed in the revision of Directive 96/53/EC for alternative fuelled motor vehicles. A country like Norway can handle this kind of change more effectively because it differentiates between different categories of road (in terms of vehicle combination length and axle load/total weight). This could be an option for other European countries. A network of dedicated roads for heavy duty vehicles could be more easily combined to form a pan-European network (overlapping and in addition to the TEN-T network). If countries are considering differentiating between different categories of roads in their networks (with clear, nationally defined criteria), the environmental benefits should be compared to the maintenance costs in a socio-economic analysis. Moreover, the different preconditions in different countries,

such as being a transit country or if a large percentage of the network consists of expensive structures like tunnels and bridges, should be taken into account.

5 There is an enormous societal need to restrict the free circulation of heavy duty vehicles 24/7, all year round. This results in a patchwork of local, regional, and national driving bans. These restrictions have been imposed on heavy duty vehicles for very good reasons. At macro-level, however, they can lead to inefficient road freight transport (extra kilometres and/or extra vehicles in operation). More research is needed in order to get a better understanding of the impact on efficiency and the possible measures that can be taken to mitigate the impact (harmonisation and route choice/times of delivery optimisation by digitisation of the road network).

6 Estonia is developing an automatic monitoring system for abnormal transport. The system is used to collect the permit fee and to control, via GPS, compliance with weight regulations and route restrictions. The policy department at the Ministry of Infrastructure and Environment of the Netherlands is considering a similar test for the same type of transport operations. They see it as a building block on the road to digitising the road network and as a tool for making road freight transport more efficient and, at the same time, more compliant. Sweden is also developing a system that collects GPS and weight data, in order to protect roads and bridges from degradation. This system also works as a driver support system by sending data to the driver.

7 In addition to the type of tyres used (single or super single), tyre pressure is decisive when it comes to road surface damage. CEDR members could consider conducting research into optimum tyre pressure and enter into discussions with tyre producers and hauliers about how to observe this optimum pressure level and to devise efficient means of checking tyre pressures.

8 Overloaded vehicles contribute more to the deterioration of infrastructure and therefore generate higher maintenance costs than vehicles loaded in accordance with regulations. EU statistics indicate that the proportion of overloaded vehicles is as high as 30%. CEDR countries report varying proportions of overloaded vehicles, ranging from 2% to 18%, with higher numbers where targeted checks are used. Effective regimes for weight checks are therefore an important factor in preventing damage to the road infrastructure. On-board systems could provide an advantage to road-owners as they inform the driver of the vehicle's weight and indicate whether it is overloaded.

9 Climatic conditions vary greatly between CEDR countries. In the northern and the mountainous parts of Europe, winter conditions are an additional impediment to the efficiency of road transport. Some CEDR countries have strict requirements for tyres and snow chains and permit the use of equipment that increases traction in difficult conditions but are detrimental to the pavement, such as snow chains, studded tyres, and retractable axles. Permitting, or setting stricter requirements for winter equipment such as winter tyres and snow chains, as well as permitting studded tyres and taking a pragmatic approach to the use of retractable axles reduces the number of vehicles getting stuck in difficult conditions, could increase the efficiency of road transport, and is good from a socio-economic perspective.

10 Performance-based standards could also be seen as a starting point for differentiation and digitisation of the pan-European road network, in order to make road freight transport more efficient. Conclusions and recommendations regarding the operationalisation of PBS for longer and heavier vehicles are:

a) When investigating the performance of heavy duty vehicles with respect to safety and manoeuvrability measures, both vehicle design and infrastructure design should be considered since they are closely linked. If a heavy duty vehicle is to be permitted on a certain road network, the features of the roads play an important role in the required level of performance from the vehicle. This is why the list of relevant performance measures in this report also contains the corresponding influential infrastructure features along with their nominal values as examples. Similarly, the dynamics and design of the vehicles that will use a road should be considered when constructing the road. One approach to this is to use reference vehicles for road design, an approach that is adopted in both Sweden and Norway.

b) The main infrastructure design features that should be considered with respect to longer and heavier vehicles are: grade, lane width, curvature, roundabout and intersection dimensions, and cross-fall. Other important infrastructure aspects are the availability of parking and rest areas, tunnel safety, safety barriers, turn lane length, distance between a railroad crossing and intersection, sight distance at an intersection, and regulation of traffic signals.

c) Heavier LHV loads can be compensated for by axle and tyre configurations that reduce the loads on the pavement. Nevertheless, it is important to note that there are load history-dependent deterioration mechanisms in the pavement structure. There are gaps in the knowledge of these effects, and further investigation is required. Another important issue with regard to the bearing capacity of a pavement is its variance during a year. Thus, axle load limits can be adjusted with regard to seasonal changes, an approach which is implemented in Estonia, Norway, and Canada.

d) Bridges are the primary factor in deciding on permitted axle loads and gross vehicle weights. To avoid excessive loading of bridges, permitted axle loads and gross weights are restricted/limited. In Sweden, the bearing capacity of a bridge is determined by calculating the load effects and resulting stresses using reference vehicles. One possible approach to accounting for the effects of LHVs on bridges is to consider more reference vehicles. This approach has been investigated by the Swedish Transport Administration for vehicles with a gross weight of up to 74 tonnes. Another common approach, which is used in Australia and the United States, is to use a bridge formula to calculate the effects of the vehicle loading on the bridge.

e) Existing European environmental regulations, which are also in effect in Austria, Estonia, the Netherlands, Norway, Slovenia, and Sweden, are already performance based. Thus, many of these regulations can be applied to LHVs as well. In some cases, some adaptations might be required; for instance in the case of the prospective European regulation on fuel consumption, LHVs should be considered when determining typical mission profiles and fuel consumption limits.

11 In order to be able to implement these recommendations and the results of the FALCON project, a working group should continue to work on these criteria to ensure that the results of the project are implemented using PBS criteria and to facilitate the use of these criteria in CEDR countries. Such a group should preferably be organised by CEDR. The members of TG N4, who already have a good understanding of the issues through their work on this report, would provide a valuable contribution to this working group.

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