Conférence Européenne
des Directeurs des Routes

Conference of European
Directors of Roads

Impact of freight on road infrastructure

A comparison between methodologies and techniques used by NRAs

to monitor road freight transport and determine the impact on infrastructure

CEDR Technical Report 2023-02

CEDR Working Group
Road Freight Transport

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CEDR Working Group Road Freight Transport

CEDR Technical Report 2023-02 is an output from CEDR's Working Group 3.11 Road Freight Transport. The Working Group's main task is to monitor developments and exchange of knowledge regarding heavy-duty vehicles in relation to constructional safety and the management of assets and traffic.

The Working Group consists of technical experts on road freight transport from Austria, Denmark, Estonia, Finland, Italy, Netherlands, Norway, Portugal, Spain, Sweden and UK.

The Working Group Chairs are: **Loes Aarts, Rijkswaterstaat, Netherlands** and **Thomas Asp, Trafikverket, Sweden**

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1. Executive summary

The infrastructure is largely built on the expected weight of freight transport by road. As decisions about infrastructure investments become more critical, it is important that decision makers have the right information to make the right choices. Despite the strong relationship between the use of the infrastructure by heavy duty vehicles and the wear and tear of the infrastructure, at the moment relatively little is known about the (real-time) use of the infrastructure by road freight transport. In addition, developments in road freight transport are not or only partially included in models and techniques used for asset management. Heavy duty vehicles are largely black boxes on wheels.

This study is therefore a comparison of the methods and techniques for impact assessment used by CEDR Members and not a comparison of research results. By not focusing on the results, we avoid more politically tinted discussions about the desirability of certain developments in road freight transport.

The general result of this study is that there is a large variety of practice in dealing with the impact of traffic loads on road infrastructure within CEDR member States. This has made it possible to highlight some good practice, and therefore some considerations whose objective is mainly to include developments in road freight transport in methods and techniques used in asset management in order to provide more accurate management information for policy makers.

2. Introduction

The decision-making process on infrastructural budgeting, for new construction as well as management and maintenance, depends strongly on political and social priorities at a given time, taking into account societal costs and benefits.

In the coming years many countries will face difficult choices on infrastructural investments, because of:

- Aging infrastructure that is reaching the end (or the second half) of their service lifetime,
- Higher demand in road freight traffic, with higher expectations on environmental issues,
- Change of heavy vehicle fleet composition and new vehicle concepts such as truck platooning and HCT,
- Budget constraints that require more careful investment considerations.

Infrastructural budget allocation needs therefore to be made to guaranty accessibility and safety to road users, while ensuring the economic development by giving good conditions to Road Freight Transport (RFT).

The usage of road networks by RFT has grown since the first generation of structures and is still growing, and regulations concerning weights and dimensions have widely evolved. For example, the transport sector has to reduce emissions to contribute to the reduction of global warming, which led in some countries to larger vehicles that carry more goods with relatively less fuel. In contribution to these climate goals, the European Commission considers adjusting the 96/53/EC regulations to allow higher maximum vehicle weights and ease border crossing for vehicles that are allowed in the same conditions by neighbouring countries. But other measures to reduce emissions and measures to meet the shortage of truck drivers can also lead to an average higher vehicle weight, such as powertrains for alternative fuels or better loading to reduce the number of journeys. These developments might accelerate the wear of infrastructure, therefore costs for infrastructure maintenance, repair and strengthening increases. For a National Road Authority (NRA) these effects are obvious, although not easily monetized. To be able to make effective policy, it is very important that the information about these effects is understandable for policymakers, contains the correct details and that the costs are transparent with a certain degree of reliability, see Figure 1.

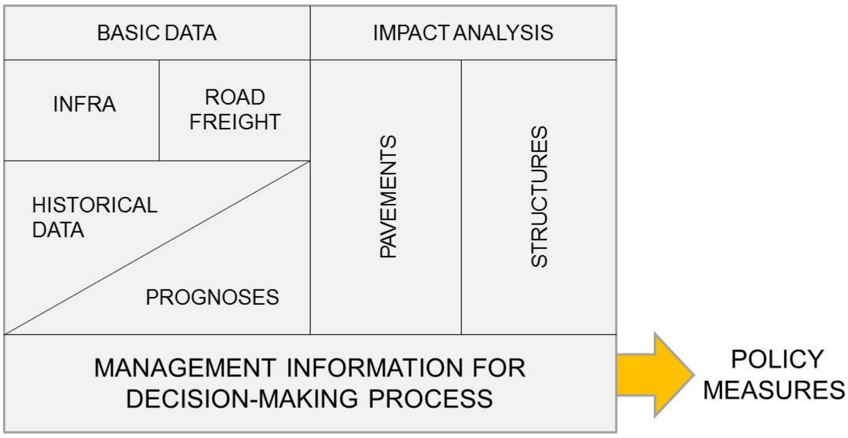


Figure 1: Positioning of this study.

Therefore, the CEDR Working Group on RFT has made an overview of how European countries include RFT in their infrastructure budget allocation decision-making process, examining what information about RFT is available from NRAs and how this information is processed. The type of management information (MI) may vary and may include country-specific information.

The goal of the report is to identify and present best practices on the way information of traffic and infrastructure is managed. For that, an overview of existing methodologies and data for traffic impact assessment is made, for several European countries. Observation and data are key to ensure good analysis of structures and pavement evolution linked to road freight traffic. A big issue is accurate and extensive data collection, from keeping track of current and past data about infrastructure stock and traffic loads to the successive and evolving impact assessment methodologies.

The ultimate goal is to improve the quality of management information on the impact on road assets by road freight transport for the decision-making process regarding road network planning.

This report has the following structure: Chapters 2 and 3 will provide an overview on existing impact analysis methodologies on respectively pavement and structures, i.e. how countries have introduced additional adjustments on the standards to cope with RFT developments. Chapter 4 will give information on how NRAs monitor the state of the road infrastructure and the use of the road network by RFT. Subsequently, chapter 5 describes best practices of ways in which countries try to better include developments in the RFT in road asset management and to improve the MI. The report ends in Chapter 7 with conclusions, discussion and considerations.

3. Impact assessment on pavements

3.1. Questionnaire on impact of freight trucks on road pavements

Increasing road freight traffic, both in volume and weights of vehicles, will have an impact on deterioration of pavements. It is important that the NRAs have the accurate data, tools and methods to evaluate and document the impact of increasing freight traffic on the road infrastructure.

A questionnaire was sent out to participating countries in 2021 to find out how the NRAs evaluate the impact of increasing road freight traffic on roads. The objectives of the questionnaire were to find out:

- Which method the NRAs use to design pavement structures and how they calculate traffic loading,

- Whether the NRAs consider the effect of tire configuration[1], tire pressure, suspension type, and pavement layer materials and thicknesses in the calculation of loading effect,
- Whether the NRAs use performance prediction models that enables them to evaluate the effect of changes in weights and dimensions of road freight trucks on the deterioration of pavements,
- How the NRAs evaluate the effect of increased gross weight of trucks and axle loads, and the effect of closely placed axles on the pavement structures,
- Whether the NRAs have data that shows correlation between increase in freight traffic volume and weights and deterioration of pavement structures,
- Whether there has been an accelerated pavement testing or field study in the participating countries with the purpose of evaluating the effect of changes in weights and dimensions of freight trucks on road pavements, and
- How the NRAs evaluate the effects of special transport (heavy machinery, customized trucks, etc).

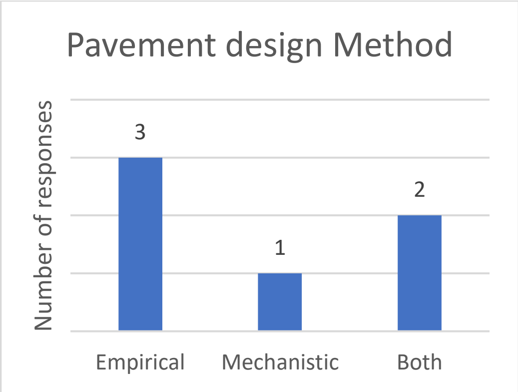
In short, the objective of the questionnaire was to gather information on existing data, tools, and methods that are used for assessment of impact of increasing weights and dimensions of freight trucks on road pavements, and to find out if there is an impact analysis approach that could be considered a best practice. To obtain this information simple, straight forward questions were prepared and distributed to the participating countries. Response was received from 7 countries, and not all of these countries answered all the questions. The countries that returned the questionnaire are: Austria, Denmark, Estonia, Finland, The Netherlands, Sweden and the United Kingdom. The results should therefore be regarded as indicative. Because the aim is to look for best practices, interesting data can still be extracted from the response and considerations can be made.

3.2. Findings

Concerning currently applied pavement design methods, three out of six respondents use empirical methods to design pavements, two use both empirical and mechanistic methods, and one uses only mechanistic methods (Figure 2). Regarding calculation of traffic loading in connection to design of pavements, two countries use the equivalent single axle load concept, which was developed in the 1960s in the USA, while two countries use the more rational traffic loading spectrum, which is based on measured traffic data from Weigh-In-Motion (WIM) or Bridge Weigh-In-Motion (BWIM).

Empirical methods are based on experience, and as such, have limited capacity (if any) to handle changes, such as modifications of freight traffic loading. The most widely used traffic calculation method, which is based on the concept of equivalent single axle load (ESAL) is based on the so-called fourth power rule (5th power in some countries). Such calculation method often ignores the effect of tire configuration, suspension type, and the conditions of the pavement structure, and might not provide a reliable basis for assessment of the impacts of changes in weights and dimensions.

[1] https://www.cedr.eu/download/Publications/2017/2017-05-Conditions-for-efficient-road-transport-Appendices.pdf (see Appendix 3)



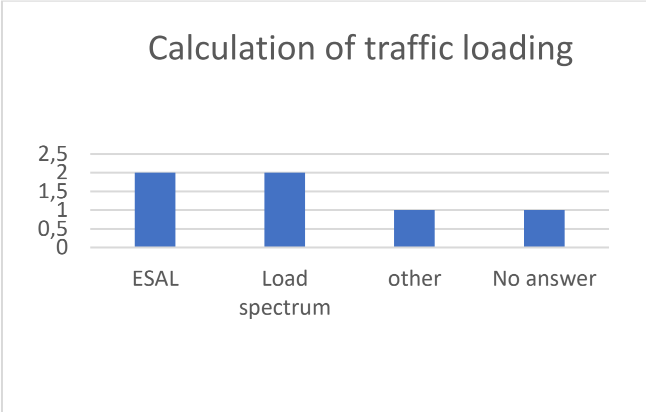
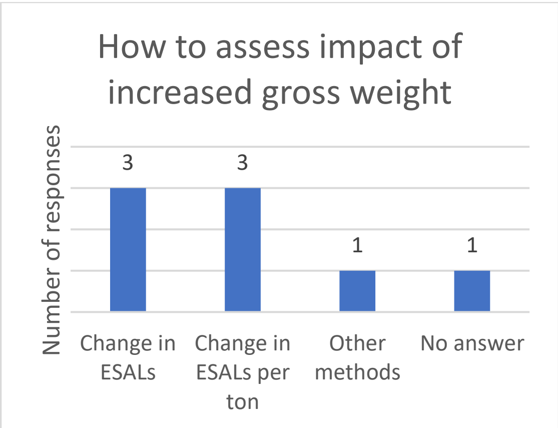


Figure 2: NRAs response to questions on pavement design methods and calculation of traffic loading.

Only one of the six respondents (England) uses a pavement deterioration model that might enable NRAs to assess the impact of changes in freight traffic (Figure 3). Most of the countries assess the effect of increased gross weight based on changes in ESALs, or ESALs per ton, transported. High-capacity vehicles (higher gross weights than normal) usually come with increased number of closely spaced axles. Field experiments conducted in Finland and Norway indicate that heavy trucks with an increased number of axles create pore pressure build up in the pavement structures, especially for roads with relatively thin pavements (which are usually low volume roads). It is also conceivable that vehicles with increased number of axles might lead to more permanent deformation in asphalt layers during the hot summer months.

In response to the question on whether the NRAs take into account the effect of closely spaced axles on pore pressure build up and possibly increased deformation, almost all respondents answered no. Similarly, none of the respondents consider the effect of increased horizontal forces at curves and intersections. Four of the respondents assess the impact of increased axle loads based only on changes in ESALs, one respondent uses both ESALs and ESALs/ton, and one respondent uses only ESALs/ton.



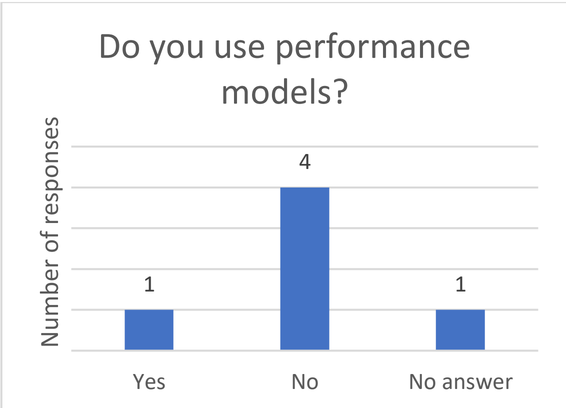
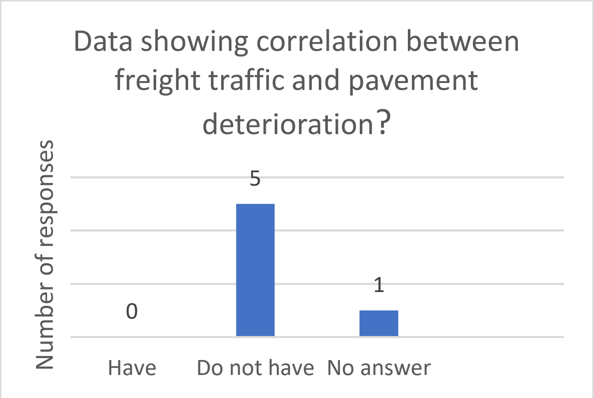


Figure 3:NRAs' response on how to assess the impact of increased weights.

In response to a question on whether the NRAs have data showing correlation between increases in freight volume and weights and pavement deterioration, all five NRAs that responded to this question answered they do not have any (Figure 4). This shows a serious lack of data on the impact of increased weights and dimensions on the pavement deterioration. Three countries (Finland, Sweden, and Norway) indicated that they have done some field studies to evaluate impact of increased weights. The data from such studies could be very useful for decision makers. Regarding special transports, 2 respondents (England and Sweden) said they do some assessment of the impact, while the other four said they do not have a special method/procedure to assess the impact of special transports. Denmark and Estonia[2] have investigated the effect of HCV vehicles (52t and 60t) on pavements. Some 60t studies are still ongoing in Estonia.



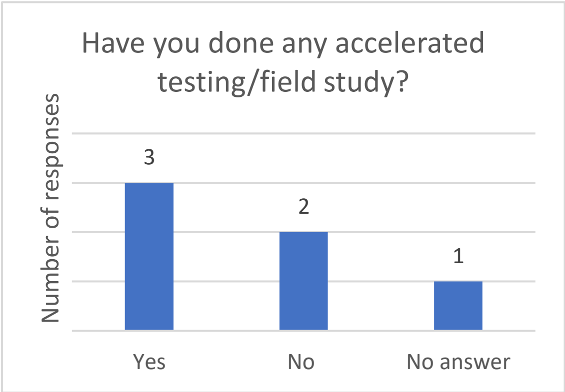


Figure 4: NRAs response to questions on availability of data and correlation between changes in freight traffic and pavement deterioration.

3.3. Conclusions

A questionnaire was sent out to gather information on existing data, tools and methods used to assess the impact of increased RFT volumes, weights and dimensions on pavements and to identify approaches that could be adopted as best practices. The main conclusions are that a difference in approach between countries in measuring the impact of the use of pavements by RFT is the standard and that none of the countries monitors developments in a structural manner.

Responses from seven NRAs indicate that NRAs mostly rely on empirical approaches to calculating traffic loads in pavement design and do not have rational analysis tools/models to assess the impact of changes in RFT traffic characteristics to evaluate the deterioration of pavements.

There is also a lack of data correlating changes in RFT with changes in pavement deterioration. Three countries have conducted or are conducting field tests that can provide useful information on the impact of high-capacity vehicles on pavements. It appears that the NRAs do not currently have sufficient data or information and analysis methods to support management decisions regarding possible effects of changes in RFT characteristics on pavements. As a result, it can be difficult to make an accurate estimate of the budget needed to maintain the road network. The risk of this is that surprises can arise with pavements that reach the end of their life earlier than previously calculated. On the other hand: safety margins may be too large to compensate for the uncertainties.

[2] https://transpordiamet.ee/media/3148/download : impact on pavements
https://transpordiamet.ee/media/3121/download : impact on bridges

4. Impact assessment on structures

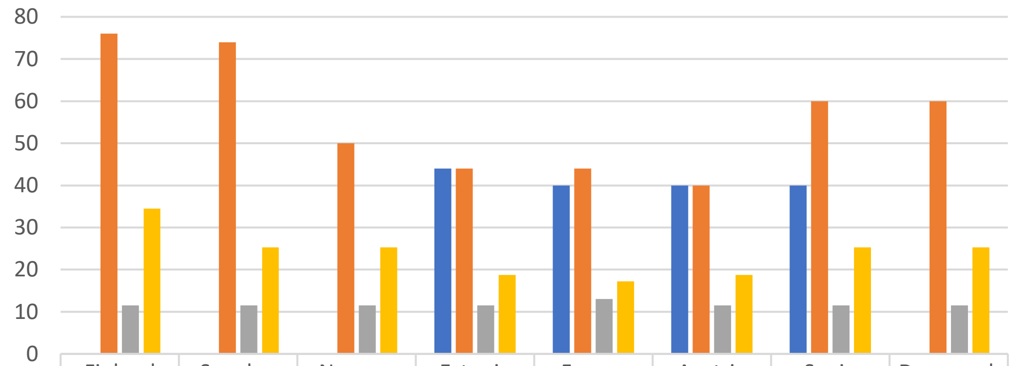
A questionnaire was sent to the participating countries to collect information about real traffic and to design numerous new structures. Eight countries responded to the questionnaire: Austria, Denmark, Estonia, Finland, France, Norway, Spain and Sweden.

Three groups of heavy-duty vehicles are elaborated below: regular road freight transport, Special Transport such as mobile cranes, and High Capacity Vehicles (HCVs). These three groups have been elaborated because with the impact of RFT on bridges, the total weight is especially important in the load on the structure. The impact differs depending on the type of construction (steel or concrete) and the span length of the bridge.

4.1. Variety in national legal frameworks for weights and dimensions

The legal frameworks for RFT vary widely in the different CEDR member countries. No major differences in legal axle loads emerged from the completed questionnaires, but the legal total weights of trucks and truck combinations varied greatly. Larger total weights automatically mean more axles. This means that when it comes to structures with shorter spans and secondary structures, there is only a small difference between countries. With spans over 10 m, the difference in bending moment and shear starts to increase.

An overview of the legal maximum axle loads, total mass and lengths for normal RFT and HCVs are shown in figure 5:



	Finland	Sweden	Norway	Estonia	France	Austria	Spain	Danemark
Normal				44	40	40	40	
Total mass (t)	76	74	50	44	44	40	60	60
Axle load (t)	11,5	11,5	11,5	11,5	13	11,5	11,5	11,5
Max Length (m)	34,5	25,25	25,25	18,75	17,25	18,75	25,25	25,25

Normal · Total mass (t) · Axle load (t) · Max Length (m)

Figure 5: Maximum total mass, axle load and length in 7 CEDR countries.

Moreover, it has also been obvious that the state of the national regulations at a given time might vary often and very fast, which highlights the fact that the time scale for the heavy traffic regulations is not the same as for infrastructure standards.

4.2. Special transports

According to the received answers, most countries have centralized permit groups that give permits for Special Transports. Some countries have developed their own digital systems for permitting Special Transports. Permit types varies from single permits to continuous permits. Also automated systems that compares the load effect to bearing capacity of bridges and road superstructure are used.

Typical masses for special transports are difficult to simplify. Some countries do not get exact information about the number of driven special transports because one permit may contain several transports. However, it seems that the majority of special transports weigh less than 100t. These transports generally are composed of a higher number of axles (up to 50 axles).

4.3. High Capacity Vehicles

Generally, HCVs is composed by European Modular System modules (EMS), connected to each other. EMS1 is a maximum of 25.25m-long, and EMS2 a maximum of 34.5m-long.

Five Countries out of eight told in questionnaires that they have ongoing trials with HCVs. Allowed masses for HCVs in trials vary from 60t to 104t. There has been interest in HCVs also in countries that have not started official trials. Savings in costs and CO2-emissions make HCVs-trials beneficial for transport business and local industry[3], and interesting for governments in the light of the ambition of the European Commission to be Fit for 55.

Determining the impact of HCVs on structures is a difficult exercise. A number of countries have carried out field tests. but because so many variables can come into play, outcomes differ. Besides that, it is not about the effect of 1 HCV on structures, but about the cumulative effect of HCVs in combination with the use of structures by other RFT vehicles at the same time. To determine the impact for the longer term, it is also important to take the developments in the RFT fleet into account in its entirety.

In addition to a study into the impact on structures, a number of countries have also carried out a cost-benefit study to weigh up the benefits against the costs. The methodology of cost-benefit analyses could be developed and applied at larger geographical scales.

4.4. Design loads for new bridges

New bridges are designed with Eurocodes, a set of standards for structural design, which are developed under the guidance and co-ordination of CEN Technical Committee 250 (CEN/TC250) "Structural Eurocodes". CEN is a technical organization composed of the National Standardization Bodies of 34 European countries.

Traffic loads are defined in EN 1991-2 (Traffic Loads on bridges). For road bridges, there are four different load models (LM1 to LM4) for static design and five load models (FLM1 to FLM5) for fatigue design.

LM1 consists of concentrated tandem loads and uniformly distributed loads for each lane on the bridge deck, in which the so-called α-values are stated nationally to quantify the variations from a uniform European load model. LM2 consists only in one axle, and it is meant for the local design of the bridge (e.g. punching of the deck slab). LM3 takes into account special transportations, and it increases the capacity especially on the intermediate support of the bridge deck. LM4 is additional verification for crowd loading (not always needed).

Table 1, Table 2and Figure 6 give an overview of the selections within some European countries for Load Model LM1 (each country has to present the alpha-values in the National Annex for EN1991-2).

[3] https://www.itf-oecd.org/high-capacity-transport-0

	Recommended values[1)]	LM1 - α-values by country									
		Finland	Sweden	Norway	Estonia	Austria	Netherlands	France	UK[(2]	Czech[(2]	Germany[(2]
α_{Qi}	1,00	1,00	0,90	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
α_{Q2}	1,00	1,50	0,90	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
α_{Q3}	1,00	0,00	0,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
α_{qi}	1,00	1,00	0,80	0,60	1,00	1,00	1,15	1,00	0,61	1,00	1,33
α_{q2}	1,00	2,40	1,00	1,00	1,00	1,00	1,00	1,00	2,20	2,40	2,40
α_{q3}	1,00	1,20	1,00	1,00	1,00	1,00	1,00	1,00	2,20	1,20	1,20
α_{qr}	1,00	1,20	1,00	1,00	1,00	1,00	1,00	1,00	2,20	1,20	1,20

Table 1: Alpha-values in selected countries.

	Recommended values[1)]	LM1 - Characteristic values by country									
		Finland	Sweden	Norway	Estonia	Austria	Netherlands	France	UK[(2]	Czech[(2]	Germany[(2]
Q_1 [kN]	600	600	540	600	600	600	600	600	600	600	600
Q2 [kN]	400	600	360	400	400	400	400	400	400	400	400
Q3 [kN]	200	0	0	200	200	200	200	200	200	200	200
q_1 [kPa]	9	9	7,2	5,4	9	9	10,35	9	5,5	9	12
q_2 [kPa]	2,5	6	2,5	2,5	2,5	2,5	2,5	2,5	5,5	6	6
q_3 [kPa]	2,5	3	2,5	2,5	2,5	2,5	2,5	2,5	5,5	3	3
q_r [kPa]	2,5	3	2,5	2,5	2,5	2,5	2,5	2,5	5,5	3	3

Red = Higher than recommended
Black = Recommended
Blue = Lower than recommended

[1)] Corresponds to traffic for which a heavy industrial international traffic is expected, representing a large part of the totatl traffic of heavy vehicles. [EN1991-2 4.3.2 (3) Note 2] part of the totatl traffic of heavy vehicles. [EN1991-2 4.3.2 (3) Note 2]
[2)]Extracted from NA (not from questionnaire)

Table 2: Characteristic values for tandem loads (Qi) and uniformly distributed loads (qi) for selected countries.

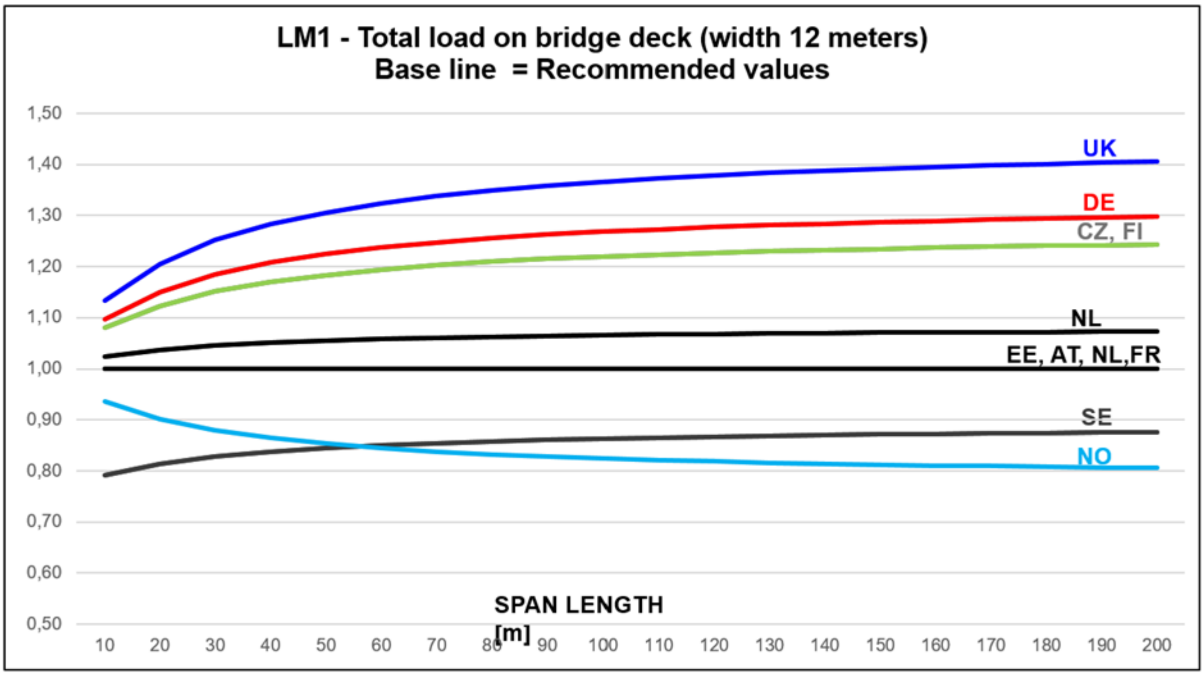


Figure 6: Total load on bridge deck (calculated with characteristic loads from Table 2) for selected countries.

It is obvious that there are substantial differences in the used load models between European countries.

However, at least following aspects should be taken into account when comparing the curves to each other of Figure 6:

- The used partial safety factors may differ between countries (also on the permanent load side),
- The curves show the highest load level (heavy industrial international traffic), depending on the country, whereas not all bridges are necessarily designed to highest level,
- The maximum allowed weights of vehicles (see Figure 5) differ considerably between countries.

When fatigue limit state is the governing limit state, the effect of load level to the structure is not linear (the effect depends on the slope of SN-curve of the fatigue detail, being often to the power of 3-6 for typical service load levels). This may affect the design service life considerably if fatigue load models are not correctly applied.

The load model LM2 (for local design) is mostly used with recommended values.

Some countries are using nationally defined load model for special vehicles (LM3) instead of the load models in EN1991-2 Annex A. It can be demonstrated that if special vehicle load model LM3 is not used at all for design, this may create some bottlenecks for special transportations especially for continuous bridges (negative moment area at support).

Overall, there are not enough data linking the actual load level and used load models in a country to give any conclusions about the differences between reliability levels of new bridges in member countries. The future research should focus on the continuous measurement of traffic (e.g. Bridge Weigh-in-Motion) together with continuous health monitoring of bridges. This is much more important for existing bridges, as new bridges often have even some excess capacity for future increase of traffic density and weight.

4.5. Design loads for strengthening

Strengthening design of existing bridges is a very touchy issue. It is often not possible to reach the same load capacity as for new bridges, and some cost-benefit analysis is usually needed.

Many European countries have nationally defined load models for strengthening, but some countries are using the same load models as for new bridges with reduced values.

4.6. Load capacity checking

Separate load models are often used for bearing capacity calculations. This is natural, since the load model should represent the local traffic composition very closely. Some countries also use Eurocode load models or previous design standards for calculations. Load factors for Eurocodes are often reduced compared to new bridges. Real traffic data has been used in assessments only in individual bridge cases.

4.7. Conclusion

There are hardly any differences between countries with regard to the legally permitted axle loads; however, there are considerable differences between the legally permitted total weights. However, larger total loads also mean more axles. This means that when it comes to impact on structures with shorter spans and secondary structures, there is only a small difference between countries. At spans of more than 10 m, the difference in bending moment and shear begins to grow.

The insight into the use of the road infrastructure by **special forms of road transport** in the heavy segment (abnormal loads, High-Capacity Vehicles) is very limited. That although special forms of transport could be considerably damaging the road assets more than regular heavy-duty vehicles.

Each country applies its own mix of models based on international and/or national standards in the application of load models for calculating the required load-bearing capacity for new bridges, for strengthening the load-bearing capacity of existing bridges and for load-bearing capacity measurements. In general, there is insufficient data linking the actual coupling load level and load models used in a country to draw conclusions about the differences between confidence levels of new bridges in CEDR Members.

5. General information on infrastructure and RFT fleet development

In the previous sections, the impact analysis was described for pavements and structures. However, there is more data available than static information on structures and pavements.

The disclaimer mentioned in the beginning of the report holds for this chapter. Questionnaires are filled in to the best knowledge of the member of the working group. Some information could not always be gathered which does not mean that it is not present at the NRAs.

5.1. Rating of infrastructural assets for NRAs

In the questionnaire NRAs were asked if there was a rating system used to prioritize or to indicate urgency in infrastructure repairs or renovation. In Figure 7, the availability of a rating system for structures and pavements for the countries is stated. It is clear to see that a rating system is already in use in most countries.

Thresholds for the ratings was the next question in the questionnaire. For pavements it can be said that the same aspects are generally used:

- Fatigue,
- Roughness,
- Cracks,
- Rutting.

The actual rating and thresholds were not given. For structures a lot of countries have rating based on visual inspection, or ratings that differ between different types of structures. Therefore, the comparison between this rating aspect is not further researched. However, it can be said that monitoring the state of the infrastructure is a well-known issue by the NRAs, who try to bring solutions for it.

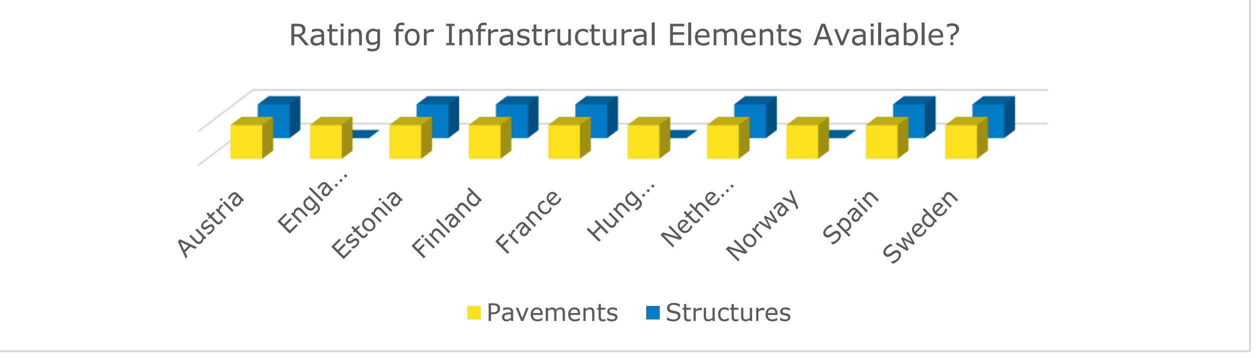


Figure 7: Availability of rating systems in the various countries.

5.2. Data storage and accessibility

The countries were asked if they had a database for national data storage, and if it was available for third parties (such as researchers, construction companies, etc.): Most countries have a detailed data base on the state of the infrastructure, but the data availability for third parties differs.

On the one hand, sharing this data let researchers develop and test innovations or developments in data analysis. On the other hand, it might be harmful for NRAs in terms of political incidents (terrorism, spying) or liability. What if an accident happens due to poor infrastructural quality while the NRA was (according to the database) aware of the infrastructural condition? Since the amount of repair and renovation projects will rise in the coming years this is something to keep in mind.

Is there a data collection available on the state of the infrastructure?

	Pavements	***Structures***	***Availability***
Austria			***No***
England			***Yes***
Estonia			***Yes***
Finland			***No***
France			***Yes***
Hungary			
Netherlands			***No***
Norway			***Partly***
Spain			***No***
Sweden			***Partly***

It should be noted that fleet development is hardly known: there exist forecasts and studies that give some information on the development of fleets. Nevertheless, there are a lot of uncertainties around this point, because parameters (economic development, political decisions, …) are numerous and their impact is uncertain. Here again, more comprehensive studies, linking socio-economical decisions and fleet development would be needed.

5.3. Data on heavy goods vehicle traffic

Traffic monitoring is undertaken in many CEDR member countries, but the extend to which it is done and the quality of the retrieved data vary between countries, and also along time. Traffic counts are quite common, but to assess correctly the impact of traffic on pavements and/or bridges more detailed data is needed, as the loading and the dimensions of the trucks. For that, Weigh-In-Motion (or Bridge Weigh-In-Motion) is needed, whose installation, maintenance and data retrieval might be costly. Therefore WIM/BWIM stations are not used everywhere and continuously in CEDR member countries.

Regulation compliance or enforcement statistics exist in several countries: from example, in Sweden 50% of trucks have been measured as overweighted, whereas this number decreases to 10% in Western European countries. But the data from which these statistics are drawn is not uniformly acquired and registered, and the statistics themselves are not assessed with the same rules, as e.g. the threshold above which a truck is considered overweighted, the minimal amount of data, the intrinsic quality of the data.

Tolling can both give some information on traffic data and be adapted on the vehicular loads and shapes. Some countries are considering implementing Intelligent Access Programs.

5.4. Conclusion

There is a serious lack of data on the impact of increased weights and dimensions on road assets deterioration. The knowledge that exists about this has been obtained from **one-off field tests**. The impact of developments in the truck fleet can therefore not be adequately estimated.

There are two main ways of collecting data about the use of road assets by heavy duty vehicles: counting loops and WIM. Traffic monitoring is carried out in many CEDR member countries, but the extent to which this is done and the quality of the data collected varies between countries and also over time. **Traffic counts** are quite common, but to correctly assess the impact of heavy duty vehicle traffic on pavements and/or structures, more detailed data is needed, such as on the load and dimensions of the trucks. **Weigh-In-Motion** (or Bridge Weigh-In-Motion) can be used for this, but because these monitoring systems are expensive, they are not everywhere.

The percentage of **overloading** varies from less than 10% to 50% between CEDR member countries. The data from which these statistics are drawn is not obtained and recorded uniformly, and the statistics themselves are not judged by the same rules. In fact, it can be concluded that insight into compliance with laws and regulations with regard to vehicle weights is strongly insufficient.

6. Best Practices in participating countries

From the questionnaires that have been filled out, several (best) practice actions have been identified, around the traffic-infrastructure ecosystem: some of them are focused only on the traffic or the infrastructure side, while others deal with the interaction or collaboration between both sides.

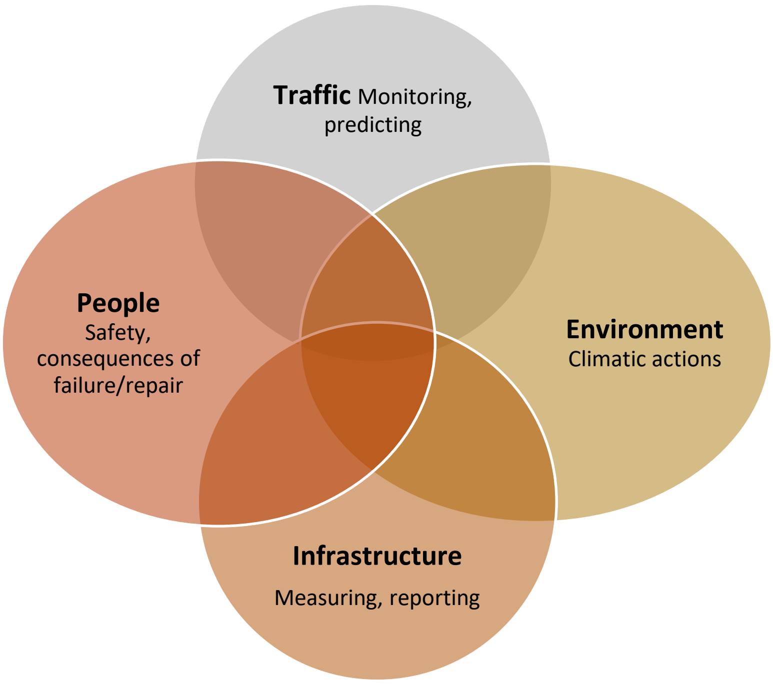


Figure 8: The traffic-infrastructure ecosystem.

- **High performance, quantitative surveys for infrastructure**
  - Denmark makes regularly extensive pavement assessment campaigns, using high performance tools: for example, the crack detection vehicle (ARAN) is used each year, while the bearing capacity is measured with TSD with a periodicity between

3 and 6 years. In England, similar vehicles (TRACS and SCRIM) carry out the surveys annually.

- The measured characteristics are different from one country to another, nevertheless it is possible to separate them in functional and structural indicators.
- In England, the KPI for pavement is linked to the percentage of the network that needs no further investigation for possible maintenance (and it must be superior to 95%).
- The parameters involved in this English KPI are numerous, and in particular it takes into account noise.
- In Finland, the frequency of measurements depends on the maintenance class and the traffic: each 1-2 years for main roads, and 3-4 years for secondary roads. This shows the concept of main corridors.

- **Quantitative thresholds for infrastructure condition assessment**
    - Denmark uses quantitative, fixed thresholds for the assessment of the infrastructure condition KPIs.
    - In Austria, these KPIs exist for both pavements and bridges: these thresholds depend on the area of the decks of the bridges (the number of bridges with a rate below 4 or 5, must be below 10% in square meters) and the length of the roads (the length of roads with a rating below 5 must be below 10%).
    - In Finland there are 3 maintenance classes, depending on the traffic and the regional influence of the road.
    - In Norway, the condition of bridges is described with 4 levels, while the consequences are detailed through 4 main functions: 1/ carrying capacity, 2/ safety, 3/ economic consequences of the condition, 4/ the bridge's effect on the environment or the surrounding. This gives a 4x4 matrix by combining condition rating and consequence rating, where thresholds are being fixed.
    - In Norway, the bridge condition rating also entails erosion and the correct functioning of the water management system, which are important in the climate change context.
    - In France, the methodology for road rating takes into account the cost of repairs, and this methodology is being used for national roads and concessions. Minimal required performance levels are being given for concessions, which is not the case for national roads where budget is an issue.
- **General infrastructure database**
    - A common national and (some) municipality-owned infrastructure exist in Denmark. This is also the case for Hungary. In this case, the municipalities that participate have to pay a fee.
    - In Austria, the whole national pavement stock is being shown in such a database, which makes it easy to determine the percentage of levels of health conditions (very good/good/…) all over Austria. On the contrary, there exist also a database for all assets of Asfinag.
    - Other countries do have a national PMS (England).
    - Bridge Management System exist in several countries: for example, in Estonia, this BMS shows a Condition Index and the design load.

- In Norway, PMS and BMS exist, and parts of them are publicly available. They are also being used for forecasts.
- In Italy, the PMS which is in progress distinguish functional and structural performance, and thresholds are given for both.
- In Italy, the raw data for the infrastructure surveys is being stored in a big data database. This is then processed with various procedures to obtain the decision-making parameters for the road authorities.

- **Sharing policy of the infrastructure database**
  - In Denmark, the infrastructure database is available, but not the pavement database. In Spain, this data is completely private.
  - In France, the infrastructure information is publicly available, for national roads and bridges. The aggregated traffic data is also publicly available.
  - In Sweden, information is given about where the maintenance standard will not be fulfilled in the coming year.
  - In Sweden again, all measured data are available in a web-based system. Two versions exist, one for internal use, and one for external use to which contractors, consultants and researchers have access.
- **Rational impact assessment of changes in regulations or growth of RFT**
  - The impact of other types of traffic on pavement has been assessed through increase of the number of ESALs in Denmark and in England. This is being updated regularly.
  - Moreover, a change in maximum allowed GVWs has been enforced 15 years ago, in Denmark, based on an impact assessment study.
  - In Austria, different α-values and LM3 values, are being used for design and assessment. In the Netherlands, small reduction factors for reference period and trend factor are possible within load models for assessment or strengthening, but this is not often used.
  - In Austria and Estonia, for pavement, a 2%-growth rate per year is being assumed.
  - In France, the link between increased traffic and impact on pavement has been made, this is not the case for bridges.
- **Prediction of future traffic**
  - In Austria, this prediction is done collaboratively between the Ministry, the Highway operators and the rail operator.
  - In France, there is detailed, national traffic model: an annual growth of road traffic of 2.1% is being assumed, which amounts to 442 billion km.tons in 2030.
  - In Spain, each year, a questionnaire is sent to a sample of road carriers. Forecast based on traffic counts is being made all 10 years.
  - Similarly, in Norway, a selection of road freight companies must report their trips, for statistical purposes: 41% of transport work (tons.km) is being done by vehicles heavier than 50 tons, while 64% of transport work is being carried out by vehicles younger than 5 years. Multimodal forecast is being performed, yearly, for a large variety of vehicles and different types of products.
  - It should be noted here that a multimodal modelling tool, TransTools, is available at the European level.

- **Information on regular traffic**
  - It should first be noted that the definition of “truck” is not the same all over the CEDR countries.
  - Several countries use WIM stations: Austria has 10 WIM stations in use, the Netherlands have 18 WIM stations which are being used for non-site-specific assessment. Estonia has 2 WIM stations, which are being used all 10 years by universities to determine a “new” heavy vehicle reduction coefficient. Finland intends to install WIM stations, currently only counting loops are being used.
  - Traffic counting loops are being widely used: for example, in Spain, 700 stations are in use.
  - In the Netherlands, the function of road sections for logistics is determined by looking at the absolute number of trucks that use a connection where the main road network is connected to the secondary road network via entry and exit ramps. In addition, the volumes of the RFT on the road sections themselves are examined. Based on this data, it becomes clear whether routes are mainly important for local/regional or for regional/national freight transport. Investment decisions can be based on this.
  - In Spain, the number of static scales is not well known as transport enforcement and inspection have been partially transferred to regional governments.
- **Information on abnormal loads**
  - Several countries (like Denmark and the Netherlands) have installed a centralized platform to ask for abnormal loads permits. Transport operators can use a viewer to see which route is possible for their abnormal loads transport.
  - A distinction is made between incidental and long-term exemptions. In the first case, a transport must be announced prior to the trip and a certain control is possible. In the second case, it is unknown when and how often an exemption is used.
  - In Italy, the process of pre-announcing a trip with an incidental permit has been automated. As a result, truck drivers have to install an app to register a trip. The trip can then be tracked real-time via GPS. This makes it possible to check whether a transporter does not deviate from the mandatory route.
- **High-capacity vehicles**
  - The country should be checked for suitability for HCVs, and if not this type of transport should not be allowed: for example, in Austria, if the maximum GVW is increased to 60t, massive investments would be needed.
  - In Estonia, 52-ton, 18.75m-long trucks with a minimum of 7 axles and with double tires are allowed to drive in the strong corridor (marked digitally on the Tark Tee map) with the 1-year special permit (in VELUB system). 60-ton, 25.25m-long HCT is under analyses and testing since 2020.
  - In Sweden, the government proposed allowing longer vehicles (34.5 m) from fall 2023, to cater for 44ft-containers instead of 40ft-containers. It will, at least in the first step, only concern the main road network (highways).
  - In Denmark, in Project EMS2 (32m to 34.5m), these types of vehicles will be allowed on one highway segment. A trial is decided, and will probably start in the beginning of 2024.

- **Driving conditions**
  - Double tires have been made mandatory in several countries, especially in link with the authorization with HCT (for example, the 52t trucks in Estonia). Tire configurations are being studied in Sweden, to minimize the impact on pavements.
  - In Sweden, the main speed will be lowered to 80 km/h.
  - The need to restrict overloaded traffic is being highlighted: for example, in Sweden, Intelligent Access is proposed to limit overloading.
  - In Finland, GPS has been tested by the heaviest abnormal vehicles with digital options. This should be seen in link also with intelligent Access.
  - In the Netherlands, parts of the network where the larger volumes of freight traffic and/or the heavier freight vehicles can be handled have been identified. This means that not everything is facilitated everywhere, and that a distinction can be made between the requirements for constructive safety per road section, based on the load that the section has to process.
  - Studded tires are being used by cars in Estonia, and they are responsible for most of the rutting. Moreover, most of the damage happens in springtime when there is moisture in the pavement because of thawing. These specific damage conditions lead to specific regulations on driving conditions.
- **Link between infrastructure wear/damage and RFT**
  - Highway operators have access to infrastructure data, but no data on the RFT fleet. Therefore, even large renovation programs are been undertaken without link with RFT.
  - Site-specific assessment has been made for some bridges in the Netherlands, Finland, Sweden (for fatigue, and by using updated material parameters).
  - In Spain, the site-specific assessment is made with the weight limits of Directive 91/60, except for vehicles older than 1995.
  - In Finland, strengthening is designed according to cost-benefit analysis, with 4 load levels: the highest load level corresponds to a check according to the Eurocodes, and the lowest is according to the current Finish regulation.
  - It has been mentioned that this link is difficult to be made in some countries, as transport enforcement and inspection are not performed by the same entities.
- **Financing**
  - In Austria, the income is financed by the tolls.
  - In Spain, there is currently no tax system, but it is foreseen for 2024.
  - In England, a Programme Investment Tool allows to predict future needs for maintenance and plan capital expenditure, based on the national PMS: this is done based on data analysis on the condition assessment marks, and their deterioration rates.
  - In Estonia, the road tax is about 20.1 mln/€.
  - In Norway, a study has linked the type of vehicles and the damage of trucks heavier than 50 tons: the damage cost is about 0.23 NOK/km (which corresponds to 0.023€/km). Therefore, RFT pay road user tax, CO2 tax and road toll. For long haul, the user payment is supposed to be higher than the damage cost by accidents, emissions, noise, road damage, operations, …

- Sweden has shown that overloaded vehicles have a cost of 50 million euros per year.

7. Conclusions

This report has described the current practice of NRAs concerning the knowledge of road freight traffic loads and regulations, the infrastructure health, and the impact of the first ones on the latter. Best practices have been identified in chapter 6, and future considerations are given below.

The conclusions are:

1. A difference in approach of measuring the impact of the use of infrastructure by RFT between CEDR Member countries is the standard. This is very clearly visible in the determination of the percentage of overload in the RFT: the percentage of overloading varies between CEDR member countries from less than 10% to 50%.
2. None of the CEDR Members monitors developments in the RFT fleet in a structural manner. Little is known about the current use of the infrastructure by freight transport, there is hardly any monitoring of future developments in the RFT with consequences for the load on the road infrastructure and if there is, the cumulative effects of the developments in the truck fleet as a whole are not taken into account.
3. As a result, it can be difficult to make an accurate estimate of the budget needed for road network investments. There is a high risk of underestimating or overestimating (because of keeping large safety margins) the required budget.
4. In the coming years many countries will face difficult choices on infrastructural investments, because of: aging infrastructure; growing demand in road freight traffic, with higher expectations on environmental issues and increasing automation; change of heavy vehicle fleet composition and new vehicle concepts, mainly under the influence of the energy transition; and budget constraints that require more careful investment considerations.
5. Many variables play a role in the wear and tear of the road infrastructure. This makes it difficult to indicate the precise correlation between RFT and wear. It is generally accepted that one third of the wear and tear on the road infrastructure is due to its use by RFT. Because the share of RFT in the wear and tear of the road infrastructure plays a significant role and NRAs have to do more with less budget, it is important to gain a better insight into the use of the road by the RFT.
6. This also applies in particular to special road transport such as abnormal load transport and High Capacity Vehicles, because these often remain outside the scope of the measuring and weighing instruments.
7. There are two main ways of collecting data on road usage by trucks, namely detection loop counting and WIM. However, due to a rough distinction in vehicle categories, counting loops provide insufficient information and there are too few WIM stations that are not always well maintained. Therefore, the current situation, both in terms of data availability and quality, is inadequate.
8. Improving the monitoring tools and methods and models for impact analysis is not only a matter of investing money, but also (and perhaps mainly) of reflecting its importance in the attention within the NRA organization. The report has produced a large number of (not always expensive) best practices on how improvements can be achieve

8. Discussion and future considerations

Among topics that are not fully settled yet and require attention, **High Capacity Transport** stands apart. Structures – mainly short to medium span bridges (15-40m) appear to be the most sensitive road item to assess cost and feasibility of developing HCT. HCT development is therefore tight with network definition (ensuring the right truck is on the right infrastructure, which could be helped by Intelligent Access Programs). Further research and studies and better knowledge of truck silhouettes and loads seems necessary in the short term.

Monitoring traffic data (from basic counts to more specific WIM or OBW data[4]) appears strategic, though not so well considered by some NRA. It is needed for budget allocation as for new transport development. A pilot test with 5 trucks with OBW have been made in Estonia, where good results were achieved[5] (Total mass error ca 1%). Wider study in CEDR may be considered, especially as changes in traffic regulations happen often and fast.

The EU 719/2015 Directive imposes to the countries to measure traffic data. It obligates trucks to have **On-Board Weighing** which means that trucks are aware of their weights and dimensions (among other parameters which could be of interest to road operators). This could be made accessible to the NRAs, road operators and managers. This is already a possibility in some countries, as France.

Currently, **a revision of building codes (EC1)** is underway, the traffic loads need to be specificized precisely. Considering the growing range of road freight transport in Europe, leading trucks to drive in many different countries, the NRAs should work more closely together to set the new frame of Eurocodes. The coming revision (2027/2028) appears as a good opportunity.

Improving the **state of knowledge about the actual axle loads** and total loads of the trucks would be a great added value for the infrastructure operators. This should be mandatory before any discussion around the increase of loads or dimensions.

It is considered to study **how the introduction of new loads/truck types affects** the whole traffic, i.e., how the axle load distribution changes and how this change affects the condition of the infrastructure

Tires, and in particular the **width of tires**, make it possible to decrease the impact of traffic loads on some types of pavements and/or structures. This should be investigated on a European level, and regulated.

In general, when considering the traffic – infrastructure ecosystem (Figure 8), four families of issues can be given:

1. **Definition of the state-of-the-art/knowledge:**
    a. Current traffic regulations, description of current traffic through measured traffic data (WIM stations, count loops), and the associated characteristics (for example, the percentage of overloaded vehicles),
    b. Current infrastructure design and assessment models,
    c. Procedures for site-specific infrastructure assessment.
2. **Leveraging the data:**
    a. Database for all types of infrastructure elements, condition rating, all types of road authority,
    b. Database of traffic data, across country, combining WIM data, counts and surveys,
    c. High-performance infrastructure surveys tools,

[4] Directive 719/2015: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L0719&from=LV

[5] https://transpordiamet.ee/media/3112/download (Summary in English)

d. Raw data to be shared for performance improvement and research,
e. Communication towards the large audience/public: how budget (and therefore tolls) is needed.

3. **Working and thinking out of the box:**
   a. Global treatment for all types of infrastructure, with harmonization of format around CEDR members,
   b. Global optimization of the ecosystem, taking into account externalities (noise, emissions, ...), and using the existing data,
   c. Collaboration between countries: data, formats, methodologies, tools, ...
4. **Creating win-win situations:**
   a. HCT (heavier or bigger loads) vs wide tires, slower speed or GPS signal to use IA[6] technology.
   b. Abnormal loads vs GPS signal, for number of trips monitoring,
   c. Higher loads or lengths with OBW and other signals sharing (younger trucks).

[6] https://www.cedr.eu/docs/view/62a343fc227be-en

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Conference of European Directors of Roads (CEDR)
Ave d'Auderghem 22-28
1040 Brussels, Belgium

Tel: **+32 2771 2478**
Email: **information@cedr.eu**
Website: **http://www.cedr.eu**