MOVING AWAY FROM BLACK BOXES ON WHEELS: THE PATH TO BETTER POLICY INFORMATION ON THE IMPACT OF FREIGHT TRANSPORT ON ROAD ASSETS

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Abstract
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 plea 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.

Keywords: Aging infrastructure, increasing traffic loads, assessment methodologies.

1. Introduction

Each National Road Authority (NRA) faces the challenge of reconciling the growth of road freight transport and the increase in the average weight of trucks (for example through an improved load factor due to sustainability measures or the introduction of High Capacity Vehicles), the issue of accelerated end-of-life of pavements and structures, and the objectives of tackling climate change.

In order to list, describe and compare the NRAs methodologies to deal with this issue, a Road Freight Transport (RFT) Working Group has been created within CEDR. CEDR is the organization of European National Road Administrations. The CEDR Working Group RFT gathers around ten CEDR Members dealing with and/or interested by this issue. The aim is not to promote one specific solution direction, but rather to exchange different visions with each other and to see where we can work together. Another goal is to identify best practices and maybe encourage uniformed (technical) approaches among CEDR Members.

The CEDR WG RFT consists of 3 task groups, namely: TG1 Impact of heavy duty vehicles on pavements and structures; TG2 Intelligent Access; and TG3 Lorry Parking Facilities. This paper covers the work of TG1. TG1 has made an overview of how (some) 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 output of this TG is a report, whose aim 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.

2. Problem statement and ultimate goals

In the coming years, many countries will face difficult choices on infrastructural investments, because of aging infrastructure, higher demand in road freight traffic, change of heavy vehicle fleet composition and new vehicle concepts such as truck platooning and high capacity transport, and/or budget constraints.

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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 plea 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.

The ultimate goals are:

- Improved Asset Management strategies:
    - Differentiating design requirements according to use;
    - Tailor-made solutions based on the actual load;
    - Delaying or accelerating replacement and renovation etc.
- Cost savings and fewer roadworks because of longer lifetime of the infrastructure;
- Contribution to preventing surprises due to bridge failures;
- Better policy advice on the impact of new vehicle concepts, because the data used as a basis is more reliable (truck platooning, High Capacity Vehicles, less empty running, increased average total weight because of the use of batteries etc.).

3. Research approach and results

A questionnaire was sent out to participating CEDR members in 2021 to find out how the NRAs evaluate the impact of increasing road freight traffic on roads: its objective 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.

The questions have been related to the existence, quality, recording and prediction of basic data (traffic data and data about the health state of road infrastructure (RI)), and the quantitative assessment of current and future traffic on RI, see Figure 1.

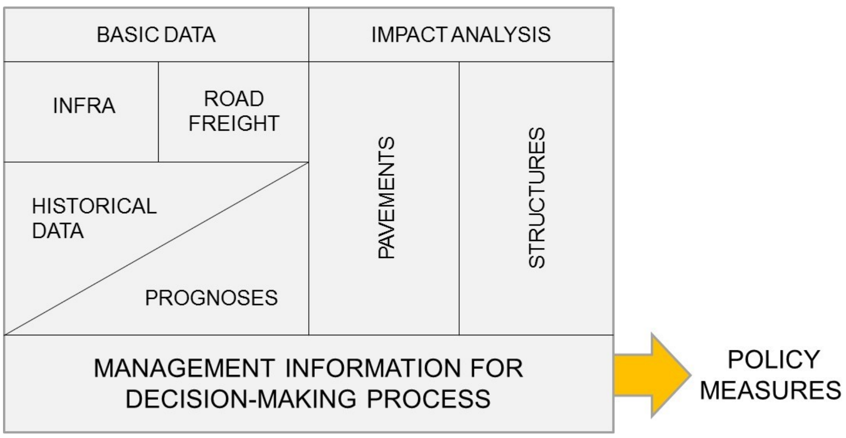
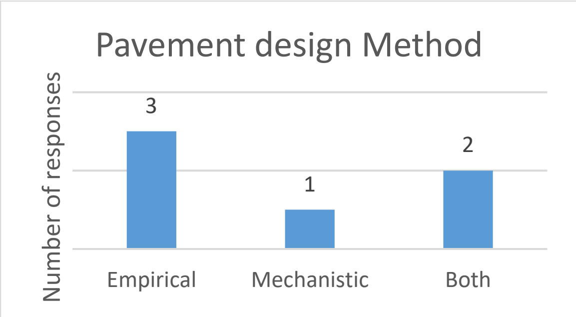


Figure 1: Elements contributing to a rational, traffic-linked infrastructure budget allocation decision-making process.

3.1 Impact on pavements

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.

Concerning currently applied pavement design methods, three out of six answers use empirical methods to design pavements, two use both empirical and mechanistic methods, and one uses only mechanistic methods. 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).



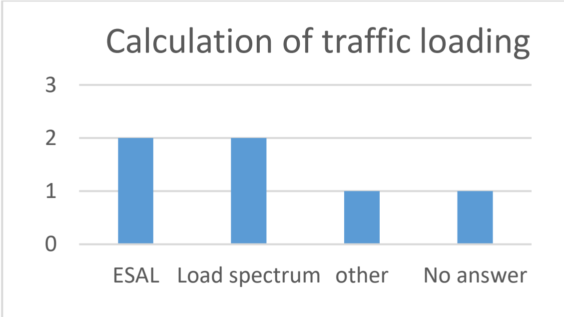


Figure 2: Current practice in RFT impact assessment on pavements.

Empirical methods are based on experience, and as such, have limited capacity (if any) to handle changes in RFT, such as modifications of freight traffic loading or truck shapes. The most widely used traffic calculation method, which is based on the concept of equivalent single axle load (ESAL) is based on the fourth power rule (which is a 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.

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.

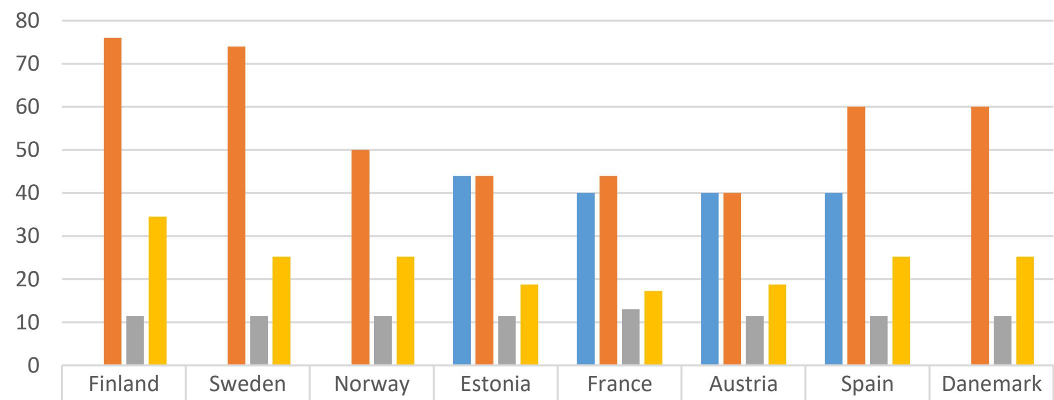
Responses from seven NRAs indicate that NRAs mostly rely on empirical approaches to calculating traffic loads in pavement design and do not have rational analysis tools/models to assess the impact of changes in RFT traffic characteristics to evaluate the deterioration of pavements.

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.

3.2 Impact 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.

Legal frameworks
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 (**Figure** 3).



	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 3: 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.

According to the received answers, most countries have centralized permit groups that give permits for Special Transports and some countries have developed their own digital systems for permitting them. 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).

High Capacity Vehicles are also a hot topic, when dealing with new types of traffic loads and adequation with existing road infrastructures in the CEDR countries: there are several 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.

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).

	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.

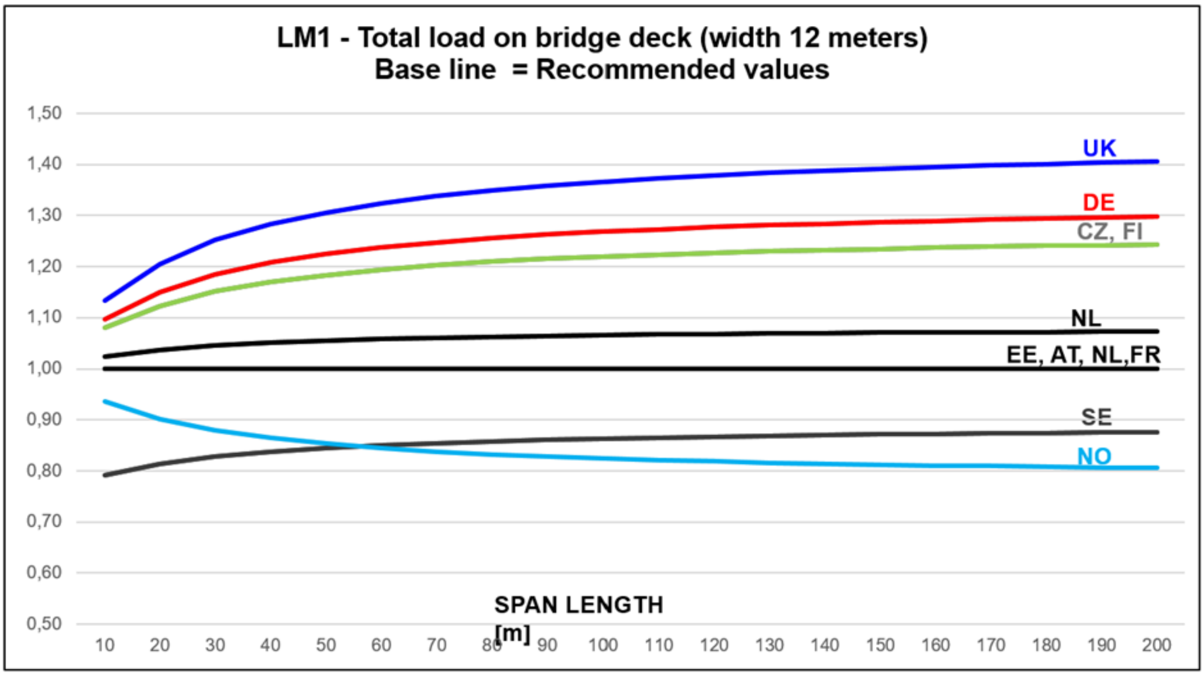


Figure 4: Total load on bridge deck (calculated with characteristic loads from Table 2) for selected countries.

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).

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. The future research should focus on the continuous measurement of traffic (e.g. Bridge Weigh-in-Motion) together with continuous health monitoring of bridges.

3.3 Use of the road infrastructure by heavy duty vehicles

Most countries have a detailed database 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.

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 mainly obtained from 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, where counting loops are much more used. So 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. In particular, 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 installed or used everywhere and/or permanently.

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.

4. Conclusions and recommendations

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. 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.

5. 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 specified 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, 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;
    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 technology (6);
    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. References

1. CEDR (June 2023) 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.
2. CEDR (July 2017) Conditions for Efficient Road Transport in Europe
3. OECD International Transport Forum (2019) High Capacity Transport - Towards Efficient, Safe and Sustainable Road Freight
4. https://transpordiamet.ee/media/3112/download (Summary in English)
5. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015L0719&from=LV (Directive 719/215)
6. CEDR (June 2022) Intelligent Access (IA): current NRA practices