Study on Weights and Dimensions

Impacts of the Proposed Amendments to the Weights and Dimensions Directive on Combined Transport and Rail Freight Transport

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Contents

Acknowledgments

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Management Summary

The proposals presented by the European Commission as part of the Greening Freight Transport Package include the revision of the Directive on the Weights and Dimensions of commercial road vehicles. The declared objectives of the amendment include the promotion of zero-emission vehicles, facilitating the use of heavier and longer vehicles in cross-border transport, and supporting intermodal transport. However, upon closer examination, it appears that the measures may not necessarily be effective in achieving the latter goal of promoting Combined Transport.

For zero-emission vehicles, the proposal allows for additional 4 tonnes of gross weight, which will also be applicable to conventional combustion vehicles during a transitional period until 2035. Without the need for further agreements, the cross-border circulation of longer vehicles is intended to be allowed between countries where such vehicles are permitted in domestic operations. These measures result in interoperability risks between road and rail freight transport.

In order to facilitate capacity gains for intermodal transport, an extension of the weight allowance of 44 tonnes to non-containerised units, the possibility to further increase the weight allowance for Combined Transport, and an increase of height limits to facilitate the transport of high cube containers on the road legs are proposed.

However, the analysis shows that these measures are partially impractical and ineffective.

- None of the longer combinations according to the European Modular System can be handled in Combined Transport without increased complexity – in operations, transshipment, and terminal access.
- Most extended semi-trailers (> 13.6 m) are technically not compatible with Combined Transport assets and for those that are, only about half of the existing fleet of intermodal pocket wagons is compatible.
- A further increase in the gross weight allowance poses operational challenges for the access to terminals, the handling limits of equipment and the composition of trains.
- Opportunities for Combined Transport due to the allowance of additional weight and dimensions are outweighed by compatibility risks, an undermining of standards and greater complexity.

The measures for road transport are justified with their greenhouse gas emission reductions potential, which appears to be below 10 %. This is marginal compared to the potential of combined and rail transport that rises up to 90 %. Yet, the latter modes are threatened by the cost savings potential of 7 % to 25 % per tonne or m^3 for road, due to the utilisation of heavier or longer vehicles depending on the transport case.

The measures involve externalities, where the situation is multifaceted. More axles potentially reduce the stress on the road infrastructure, but also result in higher unladen weight and lower efficiency per tonne of freight. There is also a considerable risk that axle loads increase and cause disproportionate deterioration of infrastructure. 10 trucks with 44 tonnes gross weight are more damaging than 15 trucks of 40 tonnes.

The increase in the permissible gross weight and the authorisation of EMS would lead to a reverse modal shift of up to 21% on average for all rail segments and 16 % for Combined Transport. This results in up to 10.5 million additional truck journeys, 6.6 million tonnes of additional CO_2 emissions and a tripling of external costs.

Introduction

In order to address climate change and its consequences, the European Union has set itself the goal of becoming the first climate neutral continent by 2050 as part of the European Green Deal [1]. The transport sector, which is responsible for 26 % of the EU's total emissions [2], needs to reduce its greenhouse gas emissions by 90 % until 2050 compared to 1990.

Yet, the EU has observed that the sector is struggling to achieve the rapid emissions reductions necessary to meet its ambitious climate targets [3]. **While total EU-27 greenhouse gas emissions decreased by 29 % between 1990 and 2021, they increased by 28 % for road freight transport over the same period** [4].

The proposed revision of the Weights and Dimensions Directive (WDD, 96/53/EC, [3]) has several objectives. Firstly, it aims to **harmonise regulations for heavy-duty vehicles (HDVs) in cross-border traffic**. The proposal contains specifications for the maximum permissible length and weight of vehicles, while also giving Member States the option to authorise longer vehicles or vehicle combinations such as the European Modular System (EMS) including for cross-border traffic. In addition, the revision aims to enable the ramp-up of zero-emission vehicles (ZEV, [5]) by providing **special allowances for higher weights to accommodate emission-free powertrain technologies[1]**. However, the increase in weight to 44 tonnes is also intended to **apply to vehicles powered by conventional combustion engines during a transitional period** proposed to last until 2035.

Road-Rail Combined Transport is a system of freight forwarding which is based on efficiently and economically inserting electric rail into long-distance (road) transport chains through the use of intermodal loading units (ILUs).

The proposal also contains initiatives intended to promote Combined Transport (CT), e.g., by **allowing an extra height of 30 cm** for vehicles carrying high-cube containers on intermodal road legs. By broadening the definition of intermodal transport to include non-containerised options, **semi-trailers and trucks carried in intermodal transport operations would benefit from CT incentives**. Member States are offered the decision to increase the permissible weight of vehicles in intermodal operations beyond the standard limits for conventional and ZEVs.

Allowing higher weights and longer vehicle combinations in long-distance road transport can potentially support road transport while limiting the attractiveness of CT for certain types of goods. **The extent to which measures for CT are beneficial and profitable remains questionable.** This study aims to investigate the compatibility of measures with CT and to evaluate the potential for a reverse modal shift for CT, but also for other types of rail segments.

The first chapter of this study examines the impacts of the proposed measures on CT, such as the compatibility of EMS with CT. The second chapter focusses on the impacts on rail freight transport, followed by a third chapter on road transport, including the effects on energy efficiency and infrastructure. The fourth chapter examines the potential for reverse modal shift from rail and CT to road and its consequences. Recommendations for measures under the Weights and Dimensions Directive, focusing on the effects for CT and rail transport, are provided in a final chapter.

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[1] Zero-emission denotes that no combustion engine is installed or that it emits max. 1 g CO_2/kWh. Emissions can still occur during energy generation and supply.

1. Impact of measures on Combined Transport

The amendment to the WDD includes measures intended to support CT. **While these measures are aimed at increasing the attractiveness of CT, their applicability and effect are often limited by operational and technical incompatibilities.** The increase in the permissible gross weight and dimensions of trucks, which affects semi-trailers in particular, leads to an undermining of standards for these loading units. Together with the possibility of using longer vehicle combinations in international transport in accordance with the EMS, these **measures lead at least to greater complexity for the operation of road-rail CT as well as to incompatibilities with standard pocket wagons and terminal infrastructures**.

Key findings	
Key findings	▪ Possible opportunities for CT due to increased weight and dimensions are outweighed by compatibility risks, undermining of standards and greater complexity. ▪ None of the EMS combinations can be handled in CT without increased complexity. ▪ The majority of extended-length semi-trailers for high-volume transport are technically incompatible with CT assets and for those that are, only about half of the existing fleet of pocket wagons is suited. ▪ A further increase in the gross weight allowance poses operational challenges.

1.1 Compatibility assessment of EMS with Combined Transport

Regarding CT and EMS, several aspects are relevant for assessing compatibility. EMS combinations consist of modules – vehicles, (semi-)trailers and equipment – some of which are standard, but some may also have a non-standard configuration. The EMS includes module combinations extending up to 25.25 m or even 32 m in length.

Consequently, both the individual modules and the long vehicle combinations as a whole, can be challenging for CT. Terminals may encounter difficulties in handling EMS combinations if they lack the required manoeuvrability. These aspects are examined below.

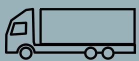
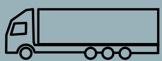
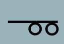
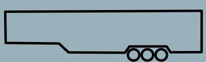
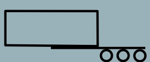
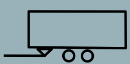
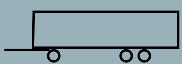
1.1.1 Overview of EMS and loading units

EMS is a road transport configuration in Europe that may be authorised for temporary trials in the Member States under the existing Directive on Weights and Dimensions (96/53/EC, [6]), and has been field-tested in various countries for several years [7, 8, 9]. EMS configurations consist of modular units that can be combined to form longer (and heavier) vehicle combinations. **The trials include variations in length ranging up to 25.25 m or even 32 m.** Some countries that allow higher gross vehicle weights for EMS are also evaluating their operational handling as well as their impacts on road safety and logistical effectiveness. The modules of EMS and the possible combinations are illustrated in Table 1 and Table 3, respectively.

The national trials demonstrated that EMS combinations are predominantly used for shuttles or main legs between production sites and warehouses. The conclusions from the trials that **EMS combinations tend to be filled by volume rather than weight and are predominantly loaded with palletised goods** can be explained by the fact that their advantages are best utilised when transporting high-volume goods [7, 19].

According to the proposed revision of the WDD, **EMS combinations can be authorised by Member States for national transport or operated in cross-border traffic** under specific conditions. Thus, they can potentially become a competitor to CT and rail on longer distances for both national and cross-border traffic.

Table 1: Overview of different vehicle units that can form longer EMS combinations. A compatibility assessment regarding their suitability for being transhipped or carrying a loading unit suitable for CT is given in the last column. Information on length and tare weight taken from [10, 11, 12, 13, 14, 15, 16, 17]. Registration statistics taken from [18].

		Module	Length	Tare weight	Registered vehicles[2]	Compatibility with CT
	**A**	3-axle truck	8.5 - 10.2 m	7.1 t	29.6 Mio	Rigid trucks only suited for RoLa
	**B**	4-axle truck	9.5 m	9.0 t		Rigid trucks only suited for RoLa
	**C**	Tractor	5.9 m	7.6 t	1.8 Mio	-
	**D**	Dolly	5.1 m	2.5 t		-
	**E1**	Semi-trailer	13.6 m	6.5 - 7.6 t	2.4 Mio	approx. 50% suitable for CT [3]
	**E2**	Container chassis	13.6 m	6.5 – 7.6 t		Loading units compatible[4]
	**F**	Extended semi-trailer	> 14.9 m	6.2 - 6.6 t[5]		predominantly not compatible (s. 1.1.2)
	**G**	Link semi-trailer[6]	10.0 - 13.0 m	5.0 - 9.2 t		ILU: yes[7] semi-trailer: s. above
	**H**	Two-axle trailer	7.8 m	5.8 t	1.4 Mio[8]	Rigid trailer with draw-bar not compatible, approx. 15 - 20 % container chassis[9]
	**I**	Three-axle trailer	9.9 - 10.1 m	5.4 t		

[2] 2021, EU27; missing countries for semi-trailers: (IE, GR, HU, IE, MT); missing countries for trailers: (GR, IE)
[3] Approx. 50% of the semi-trailers produced in Europe meet the requirements for transport in CT: suitability for standard transhipment techniques (incl. horizontal transhipment), compatibility with the envelope profile of standard pocket wagons and compliance with the P400 profile. Approx. 6% of semi-trailers are craneable [28].
[4] The share of container chassis is 9.5% among semi-trailers. The ILUs transported by them are compatible [29].
[5] Tare weights for different types of "X-tra Long" trailers from Fliegl (SDS 390 Gardine X-tra Long, SDS 390 MegaRunner X-TRA Long) [23]
[6] Curb weight and length for template interlink trailers (1-axle, 2-axle, 3-axle, 4-axle) and standard swap body superstructures taken from https://truckscience.com
[7] ILU corresponds to a swap body c-class with 7.82 m max. length.
[8] Only trailers with a load capacity over 10 t were considered.
[9] ILUs transported on chassis trailers are considered compatible. However, the unladen trailer is also required to be transportable out of the terminal. This may require tractors to pick up a semi-trailer unit to allow coupling of the trailer.

1.1.2 Compatibility of semi-trailers and loading units for CT

When analysing the compatibility of the EMS modules and their combinations, it is relevant to consider whether a specific module is in itself compatible with CT or whether the module is used to transport standardised loading units that are suitable for CT.

EMS modules can be used to transport (standardised) loading units:

- Semi-trailers: standard length (13.6 m)/ extended length (14.9 m or longer [17, 22, 23])
- Swap bodies: class A (12.2 – 13.6 m), class B (30 ft, 9.13 m), class C (7.15 – 7.82 m)
- ISO containers: 20 ft, 30 ft, 40 ft, 45 ft (also high cube and pallet-wide dimensions)

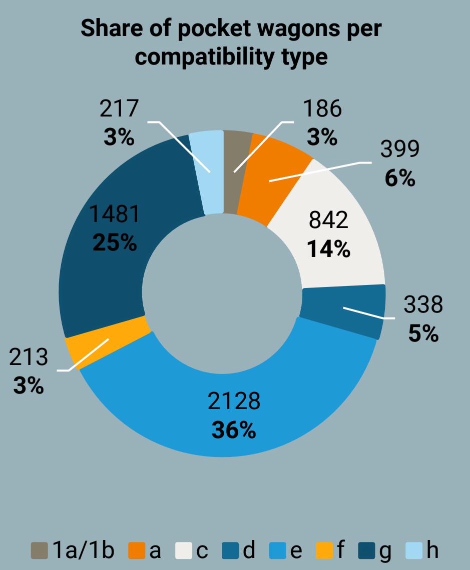
The dimensions of ISO containers and swap bodies are subject to international and European standards [24, 25]. This standardisation ensures their compatibility with intermodal transport requirements defined for example by the dimensions of standard container wagons used in rail transport.

The situation is more complex for semi-trailers. Even those with a standard length of 13.6 m must meet certain operational and technical requirements to be allowed for use in CT [26].

The construction and outer shell (e.g., the tarpaulin) must be designed for transport in both directions at 120 km/h and to withstand various acceleration forces, e.g., in the case of encounters in tunnels. Unlike transport on asphalt, transport by rail involves short, hard shocks at level crossings and points, for which the trailer construction needs to be designed. In addition, compliance with the P400 profile in combination with standard pocket wagons or wagons used by alternative horizontal techniques, and compatibility with terminal equipment are all

Table 2: Overview over the fleet of pocket wagon of UIRR members and further wagon keepers in Europe and illustration of the share according to their compatibility type. Shares were calculated from the absolute numbers taken from [20] *plus fleet of further wagon keepers. Loading length taken from* [21].

Pocket wagon type	Compatibility type	Loading length
1a / 1b	1a/1b	14.6 m / 15.2 m
T4	a	18.5 m
739 / 744	b	twice 16.1 m
T2000	c	twice 15.4 m
Mega II	d	16.5 m and 16.9 m
T5	e	18.6 m
T3000e	e	twice 16.18 m
T3000	f	twice 16.18 m
Twin, Twinb II	g	twice 15.7 m
T4.2	h	18.4 m
Multi pocket wagon	i	17.2 m and 17.7 m



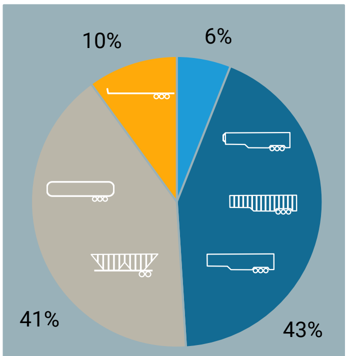


Figure 1: Share of semi-trailer types according to production numbers of European manufacturers [28].

necessary. Semi-trailers do not necessarily have to be craneable to be considered CT-compatible with standard techniques. The technical requirements for craneability (e.g., grapple zones) and lifting tests are essential for codification, i.e. compliance with IRS 50596-6 [27] and a codification plate for handling procedures in accordance with IRS 50596-5 [28]. **Approximately half of all semi-trailers produced meet the requirements for CT compatibility, with one in ten of the compatible ones being craneable** (see Figure 1) [26]. However, the other half includes about 10 % of container chassis [29] which would never be used as an intermodal loading unit but for the transport of compatible units such as ISO containers, as well as several other specialised trailers (e.g. concrete mixers, open tops for bulk goods, low belly movers or specialised small wheeled heavy equipment carriers).

Longer semi-trailers up to 15,00 m could also in theory be transported by CT, however, **for standardised transport and for efficient transshipment operations, sector representatives recommend a standard length of 13.6 m** [26]. A consultation with wagon keepers has made it clear that, for extended semi-trailers, the rear underrun protection devices must be foldable to be operable in CT operations. But even folded, the height and shape of the underrun protection of the semi-trailers represent a challenge in fitting into the envelope of pocket wagons [30]. When loaded onto the different pocket wagons, the extended semi-trailers are required to maintain the targeted P400 profile. In this regard, not only the total loading length of the wagon is decisive, but also the geometry of the pocket wagon's envelope and the available saddle heights. According to a manufacturer's test, extended semi-trailers of less than 15 m with an internal height of max. 2.76 m fulfil this requirement when loaded onto a pocket wagon with a saddle height of 980 mm. Thus**, extended semi-trailers of less than 15 m could be transhipped on pocket wagons of compatibility types c, e, f, h, i** (see Table 2), although the transshipment is considered difficult due to small room for manoeuvring [21].

Partial compatibility can also be noted regarding the common horizontal techniques[10]. While a maximum length of 13.7 m is specified for Modalohr, Cargobeamer can accommodate extended semi-trailers of less than 15 m [31, 32]. Nevertheless, both share the same restrictions as regards extended height (max. 2.7 m) and foldable underrun protection. It should be noted that the benefits of extended semi-trailers for road transport arise from their efficiency potential for high-volume freight [33]. For this reason, these trucks are often built with increased interior heights and in a lightweight configuration, which means that CT-relevant reinforcement of the construction and lifting devices are omitted, making them incompatible with CT [34, 33]. **This means that extended semi-trailers optimised for high-volume transport, are basically not suitable for CT.**

Rigid trucks (modules A and B) are generally considered to be only compatible with rolling motorway (RoLa) if they comply with a maximum length of 18.7 m and maximum height of 4 m [35, 36]. However, accompanied CT has a relatively small market share of 6 % in terms of transport volumes compared to the total CT market [20]. Due to its lower efficiency[11], this product is particularly suitable for carriage over special geographic obstacles such as Alpine crossings.

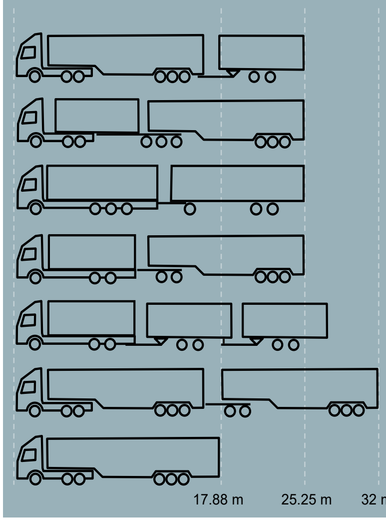
[10] Another technique, the Helrom Mega-Swing, can only be used on the relation Düsseldorf - Vienna and allows semi-trailers up to 14.7 metres in length and 48.5 t in weight [33, 21].
[11] Lower efficiency compared to unaccompanied CT as a result of the high vehicle weight compared to the payload.

Rigid trailers (modules H and I) are generally not compatible with CT as they do not fit in the profile of standard pocket wagons. Only 15-20 % of container chassis trailers can be considered compatible [29], given that the loading units they can transport align with compatibility requirements. However, one operational problem that may arise is the need to transport an empty chassis out of the terminal after unloading. The same applies to empty dollies of other EMS combinations. Advanced transport management may be required to ensure the pick-up of a unit at the terminal so that the empty trailer can be coupled. In addition, adjustments (e.g., tyre pressure) may be necessary to tow empty units.

As regards the modules and their frequency of use in trial cases **the length of EMS combinations makes them unsuitable for most of the CT services as a whole** [36, 35]. Examining the EMS combinations from Table 3, several compatibility considerations come to light:

- **Type 1:** While semi-trailers can be compatible to a large extent, it is essential for the trailer to be a chassis holding a standard loading unit. Even in this case, it is necessary to arrange a traction engine to collect a semi-trailer in the terminal so that the trailer can be removed from the terminal as a trailer combination.
- **Type 2:** Further difficulties arise for the so-called link semi-trailer: The modules are mostly compatible when they transport containers[12]. A rigid semi-trailer could also be loaded as a non-craneable semi-trailer, thereby implying capacity losses when filling a full pocket wagon space.
- **Type 3:** Compatible only in the rare case where the truck and the trailer are container chassis [19]. A rigid truck can be compatible with RoLa, although these operations usually take place in separate terminals (not container terminals) and the trains are independent, making the combination of two technologies impractical.

Table 3: Possible EMS combinations with their module composition. Their loading capacity and their frequency of use in national trials [37, 8, 7] is indicated. Not all combinations are allowed in the different Member States according to current legislation [38, 17].



Type	Module composition	Transport volume	Frequency in national trials
1	C + E + H	140 - 155 m³	37%, 16%, 1%
2	C + G + E *B-double*	140 - 155 m³	4%, 14%, 65%
3	B + I	140 - 155 m³	3%
4	A + D + E *A-train*	140 - 155 m³	58%, 63%, 33%
5	A + H + H *Road train*	135 - 150 m³	7%
6	C + E + D + E *Duotrailer*	180 - 200 m³	
7	C + F *Eurotrailer*	100 - 110 m³	8%

DE NL DK

[12] Link semi-trailers exist as chassis and rigid construction (see, e.g., https://pnorental.com/de/benefits-of-link-trailers/)

- **Type 4:** The most common combination in national field trials is only compatible in the case that the truck is a flatbed designed to carry standard containers. For rigid trucks, the same impracticability results as for Type 3.
- **Type 5:** The truck and both trailers must be container chassis, otherwise the combination is not compatible.
- **Type 6:** The combination with two semi-trailers consists of compatible modules but is only feasible for a limited number of terminals due to poor manoeuvrability, plus the dolly requires that a unit is also planned for pick-up or a separate truck is scheduled for collection of the dolly to be towed away.
- **Type 7**: The extended semi-trailer is predominantly not compatible, as mentioned above.

In general, the use of **EMS combinations on CT road legs is predominantly not suitable, as it is considerably more complex and requires more sophisticated transport planning** by terminals and freight forwarders, which might outweigh advantages such as volume efficiency.

1.1.3 Opportunities and capacity for EMS in CT

Compliance with the P400 profile was defined as a criterion for the compatibility assessment for the individual EMS modules. Despite not all railway lines in Europe being compatible – in 2017 only 34 % of the railway network complied with the P400 specification– the railway network is sufficiently dense, and further compliance evolution is planned in line with the revision of the TEN-T Regulation [39]. UIRR regularly produces a map on this topic showing the profiles of the European routes, which indicates the lines of the European rail network that offer a P400 profile[13].

Containers and craneable standard semi-trailers can be handled using standard techniques and equipment for vertical transshipment. Of the approximately 850 terminals in Europe, the vast majority are equipped with gantry cranes, mobile cranes or reach stackers for vertical transshipment. For horizontal handling (e.g., CargoBeamer, Modalohr) or vertical handling of non-craneable semi-trailers (e.g., Nikrasa, r2L VEGA), the number of terminals in Europe is smaller [21]. However, consultation with UIRR members showed that **many terminal operators own facilities that enable the transshipment of non-craneable semi-trailers or plan to employ such a solution**[14].

Concerning the wagon fleet, container wagons account for three quarters[15] of the CT operators' fleet [40]. The remaining quarter is comprised of pocket wagons for the transport of semi-trailers (many of which are also capable of carrying containers). Pocket wagons are suitable for CT-compatible semi-trailers (see Table 1). Just over half of the existing pocket wagons – according to the manufacturer's specifications – appear to be compatible with craneable extended semi-trailers. However, the requirements for CT, the restriction of the internal height to 2.76 m and craneability hinder the goals of extended semi-trailers, i.e., the efficient transportation of voluminous freight. Even with standard semi-trailers, the proportion of craneable units amounts to only 10 %. It can therefore be assumed that this proportion is even lower

[13] https://www.uirr.com/en/component/downloads/downloads/1778.html
[14] 62% of terminal members answered, that transshipment of non-craneable semi-trailers is possible in their facilities (n=13).
[15] Share of container wagons among the fleet of UIRR members.

for extra-long trailers. **Ultimately, extended semi-trailers are therefore to be regarded as predominantly not compatible.**

Another challenge and a potential cause of incompatibility of EMS vehicle combinations is the fact that terminals are often reachable from secondary roads, which do not necessarily meet the requirements in terms of tractrix curves and manoeuvrability for long trucks. Additionally, available parking space is often scarce on terminal sites as they are located in dense urban or industrial environments. In a consultation with UIRR terminal operators, **almost half of the terminals[16] stated that access, movement, or parking on the terminal site is not possible with overlong vehicles.**

1.2 Compliance check for additional weight

The authorisation of higher weights on CT road legs is proposed as a potential competitive advantage. However, the implementation of this measure can create challenges for both road and rail infrastructure, as well as for terminal equipment. Specifically, gantry cranes, reach stackers, intermodal wagons, and loading units may not be adequately designed to handle the increased weights, limiting the potential of the proposed measures.

CT and rail transport appear to require the application of standards to a greater extent than road transport – wagons, equipment, gauge profiles, etc. require compliance with standards in order to enable interoperability between the different transport modes. While the proposed measures to authorise longer vehicles are specifically aimed at road transport and pose challenges for CT as described above, the measures aimed at promoting CT include increasing the maximum authorised weight.

- **An extension of the definition of intermodal transport is intended to include non-containerised options**. In this way, more types of loading units such as semi-trailers and trucks should benefit from the incentives of the additional weight allowance of 2 t or 4 t for transport on intermodal road legs, depending on the vehicle combinations (see Annex 1 – point 2.2.2 (c) and (d) on articulated vehicles with five or six axles [3]).
- This weight allowance complements the incentives for ZEVs, for which an additional weight allowance is envisaged. **This means that ZEVs with a maximum weight of up to 48 t can be used on CT road legs** (and during the transition period also conventional internal combustion trucks).
- According to the new Article 4b(2), **Member States can also allow maximum weights exceeding 48 t** for vehicle combinations involved in intermodal transport operations. While 48 t is the maximum weight specifically set out in Annex I for a ZEV combination involved in intermodal transport for the vehicle combinations specified under point 2.2.2 (d), Member States can authorise even higher weights, with the provision that other requirements such as maximum axle loads still need to be met.

[16] 46 % of the members who participated in the consultation stated limitations for access for vehicles above 20 m or 25 m or limitations regarding length of storage spaces for units above 13.6 m (n=13).

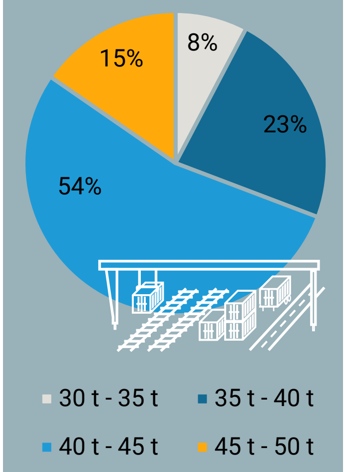


Figure 2: Distribution of weight restrictions for terminals due to equipment. Data collected in a survey with UIRR terminal operators.

The allowance of increased weight initially appears to be an incentive that makes CT particularly attractive for the efficient transport of heavy goods. However, this goal can be countered if the transport system is not designed to handle higher weights. Challenges may arise at various points in the transport chain, including road infrastructure, terminals and terminal equipment, rail wagons, the composition of freight trains, and loading units. Furthermore, it is necessary to ask for which market the incentive is relevant. These questions are analysed below.

Even when using the full weight allowances for CT, these heavy vehicles are not allowed to exceed the permissible axle loads (see Annex 1 – point 3). The use of road infrastructure should therefore not pose a problem in terms of authorisation. However, the wear and tear on the infrastructure is increased with higher vehicle weights and axle loads (see Section 3.3.1). In addition, it needs to be considered that terminals are often not located directly close to major highways but are accessed via secondary or proprietary roads. These roads can entail, e.g., bridge structures that may not have been designed for a traffic model involving particularly heavy vehicles (see Section 3.3.1), and therefore may not allow access to the terminals with vehicles with a higher total weight.

In terminals, challenges arise when heavy loading units are transhipped. For a 48 t tractor-trailer combination, it can be assumed that the loaded semi-trailer weighs up to 40 t[17]. If the unit is a container, the calculated weight could be up to 36-37 t[18]. If Member States choose to further increase the permitted weight limits for CT, these values could be even higher. However, these weights are already close to the limits of terminal equipment such as reach stackers and gantry cranes. Consultations with UIRR terminal members have shown **that for more than a quarter of the terminals, the limit for loading units for vertical transshipment is 40 t**[19]. For more than three quarters (see Figure 2), the limit is capped at 45 t, with several terminals, especially trimodal hubs, expressing a willingness to retrofit for higher weights. The limit for horizontal techniques such as Modalohr and Cargobeamer is also in this range at 37 t and 38 t respectively [31, 32]. It becomes evident that the usable network of terminals shrinks significantly as weights are increased, indicating that this measure may not be suitable for promoting the use of CT.

Rail wagons also have weight limits that must be complied with, which stand against an increase in weight. For pocket wagons, the pocket envelope structure is often designed for semi-trailers of up to 40 t, as evidenced by the loading schemes for the wagons – for example this is the case for the T5 wagon (compatibility class e [41]) or TWIN wagons (compatibility class g [42]). The loading schemes show that the maximum load of 40 t is divided into a maximum of 27 t aggregate load and 13 t load on the kingpin (see Figure 3). According to the loading scheme, this results in a load of almost 2 times 22.5 t on the middle bogie, which is the maximum axle load allowed on a railway wagons. **If the semi-trailers are unevenly loaded, there is therefore a risk of exceeding the permissible axle loads** for rail wagons. Besides, anchoring pins are

[17] Assuming a tractor unit of 8 tonnes (see Table 1).
[18] Assuming a combination of a tractor of 8 tonnes and a container chassis of 4-5 tonnes. Unladen weight range for 45' container chassis based on technical data sheets from manufacturers, e.g., S.CF 45' EURO, S.CF 45' EURO LIGHT.
[19] Answers from 13 terminal members were retrieved and evaluated.

Figure 3: Loading plan for an articulated pocket wagon (e.g., TWIN) with two semi-trailers and maximum load capacity.

usually designed for a maximum of 36 t, which represents the limit for the transport of containerised loading units [41].

Increasing the weight to 48 t or even more brings intermodal equipment and intermodal rail wagons to their limits – but the total weight limits of the units themselves are not sufficient either. For many semi-trailers, the technical maximum weight limit is approx. 39 t [43, 44], while the authorised weight limit for road transport is even lower, as the axle load limits still must be complied with. For tri-axles aggregate loads of maximum 21 to 24 t are possible (depending on axle spacing[20], see Annex 1 – point 3.3 [3]). For containers, the hypothetical weight of 36-37 t determined above is higher than the 30.5 t permitted for 40' or 45' ISO containers [24] or the 36 t for class A swap bodies [45]. This shows that a total mass of 48 t is unlikely to be achieved due to the weight limits of the loading units.

Another aspect of heavy loading units that brings the transport system to its limits is the composition of a longer train. Technically, 24 90'-wagons can be combined to form a 740-metre-long train. Assuming that each wagon is loaded with two class A swap bodies with their maximum permissible gross weight of 34 t, this would result in a train weight (including the locomotive) of 2,430 t[21]. This is much more than what is operationally feasible for heavy freight trains with a single locomotive on the current European railway infrastructure.

This clearly emphasises that a significant increase in weight is unlikely to open up further market segments for CT. It is rather questionable whether weight is a key factor in promoting CT, given that the average payload weight of a road transport journey in the EU is 14.4 t [46]. A large part of the transport sector therefore seems to involve large-volume goods and trucks that are not loaded to their maximum capacity.

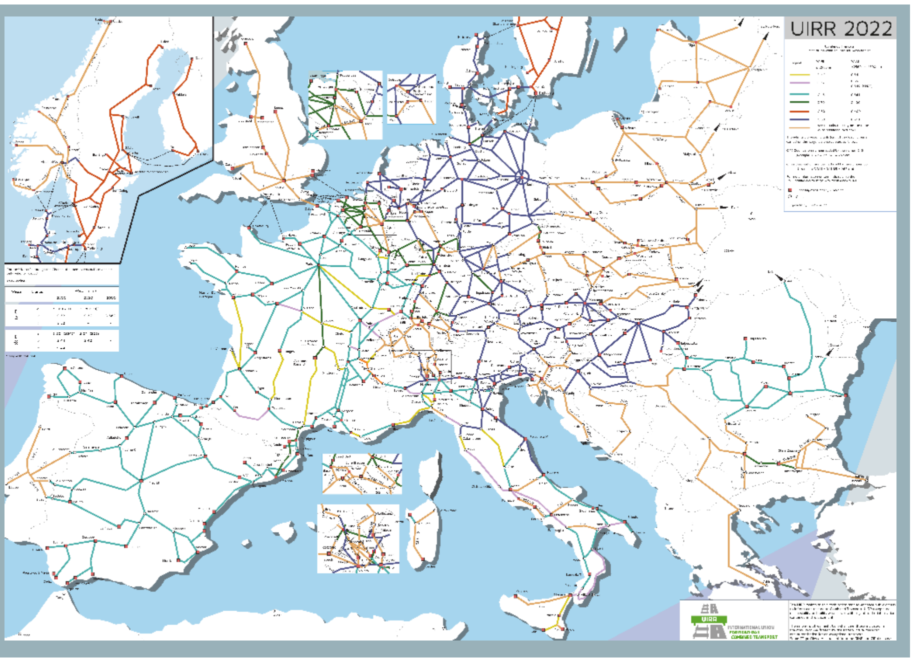
1.3 Potential of high cube containers

The proposed revision aims to promote the growth of intermodal transport by facilitating containerised transport on road legs. **For vehicles or vehicle combinations carrying high cube (HC) containers, the maximum height limit is intended to be increased from 4.00 m to 4.30 m**. This proposed amendment aims to make road transport a more seamless part of intermodal transport by allowing standard HC containers to move through the intermodal system without exceeding the height restrictions on the road leg and, thus, promoting the growth of CT.

Already today, HC containers are used extensively in CT without any extra height allowance on road. The potential of these containers and their current usage are analysed below to assess the benefits of this measure.

[20] If the spacing is higher than 1,4 m, the axle group is not considered as tri-axle and can reach up to a maximum aggregate load of 27 t.
[21] With a 90', 6-axle, Sggmrss freight wagon with length of 29.59 m and tare weight of 29.5 t.

Figure 4: CT map of the codified lines for swap bodies and containers. All lines not colored yellow or light purple are suitable for transport of HC containers. A map in high resolution can be retrieved from [97].



In maritime transport, HC containers are a widely used transport unit. They are similar in width and length to standard containers but have an increased height. The height of a HC container is approximately 9’6’’ (2.9 m), while standard containers have a height of approximately 8’6’’ (2.6 m) [24]. The operational advantage of HC containers is their increased storage capacity. They appear to be particularly useful for transporting voluminous goods that exceed the height limits of standard containers.

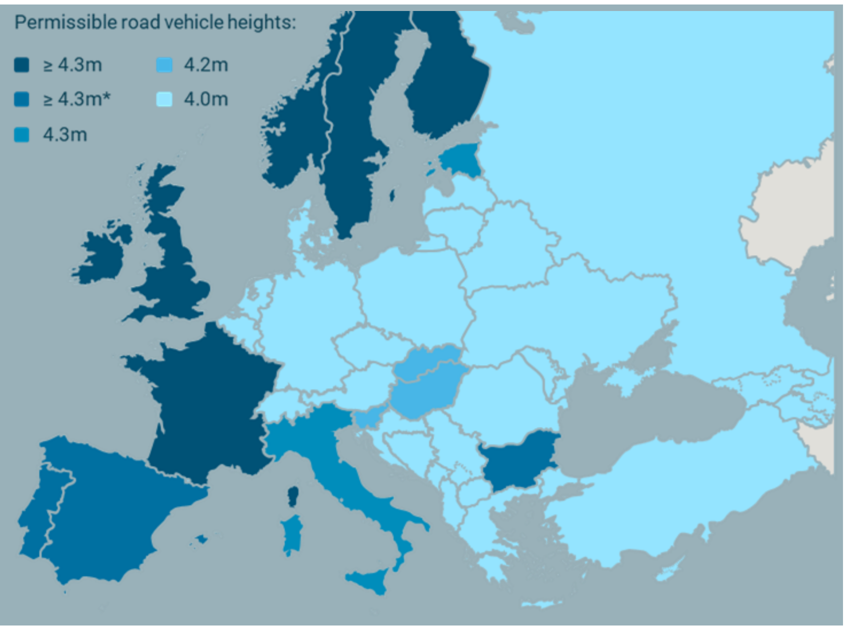
HC containers are already widely used today in CT operations. However, their market share depends strongly on the relation. Industry representatives[22] have indicated that hinterland connections in particular have higher shares of HC containers. There are relations on which almost all loading units are HC containers, e.g., those between Europe and China. Unfortunately, there are no recent European statistics on the market share of HC containers in CT. Even the impact assessment for the revision of the Weights and Dimensions Directive [47] based its market share figures on sources from 2008 on the market share of HC containers in hinterland transport from UK seaports [48] – at that time, 30 % of the transport on these relations was in HC containers in terms of volume. Feedback from individual CT operators has shown that the share of HC containers in their business in 2023 ranged from 32.5 % to over 50 % across all relations.

The high share of HC containers mentioned above is enabled by the fact that **the transport of HC containers by rail is unproblematic in vast parts of the network**. These containers require codification for transport by rail based on UIC IRS 592 [49] – due to their dimensions, they are issued with the C45 codification[23] [50]. As Figure 4 shows, almost the entire European rail transport network is designed to accommodate this profile – the transport of HC containers is therefore feasible using the fleet of standard container and pocket wagons.

[22] UIRR members technical group
[23] Confirmed by two codification bodies.

Figure 5: Map of the permitted vehicle heights for road vehicles in Europe. Data taken from [49, 103].

* Member States which allow heights of 4.3 m or above, except for containers.



Solutions have also been found for the transport of HC containers on road legs to comply with the maximum height of 4 m currently required in a large number of Member States. Low skeletal trailers and gooseneck trailers have a 30 cm lower loading height of 1.10 m instead of 1.40 m compared to standard skeletal trailers. Already 80 % of all HC containers are transported on such special trailers [47]. These are neither particularly rare nor excessively expensive. Leading trailer manufacturers have stated that almost all skeletal trailers produced nowadays are gooseneck trailers. Exceptions only apply for countries with less strict limitations of vehicle height for road transport, e.g., France, the UK, Scandinavia. Their price is about 1,000 EUR higher compared to standard skeletal trailers, which corresponds to about 5 % of the price. **It is therefore clear that HC containers are a viable solution for high-capacity transport in CT, but they are already widely used today and do not require any specific incentives for their transport on road legs.** Indeed, the proposed measure entails the risk that road structures such as tunnels and bridges in 21 Member States are not compatible as they are designed for the current maximum permissible overall height of 4 m and not for an additional 30 cm. Figure 5 illustrates that a large number of Member States currently require a maximum vehicle height of 4 m. This suggests that for a large part of the European road network, higher vehicles are not feasible without additional complexity in routing[24].

1.4 Potentials and risks for CT

As part of the proposal for the revision of the WDD, several measures were developed to promote CT [47]. Based on the analyses in the previous sections, the following chapter provides an assessment of the resulting potential for CT.

One policy measure is intended to extend the currently applicable allowance for additional weight in CT to all types of vehicles, including

[24] The progress report of the General Secretariat of the Council dated 27 November 2023 already indicates that a group of Member States cannot agree to increase the maximum height for vehicles carrying HC containers.

non-containerised goods. Although beneficial, this measure affects only a small proportion of CT, as containerised goods account for more than 80 % of the transport volume [40]. Nonetheless, this can make CT with semi-trailers more attractive. **However, using the full train length of 740 m is not operationally feasible if all units in CT use the maximum permissible weight,** as not every loading unit can carry a maximum load in order to observe the gross maximum train weight of 1,600 t. As shown in a modelling exercise for a heavy train of 2,000 t [51], the loading units may weigh only 25 t on average; for semi-trailer combinations this implies a gross weight of 32-33 t for each vehicle combination including the tractor – well below the current permissible maximum gross weight. Similarly, the additional weight allowance of plus 4 t for ZEV on CT road legs as well as the possibility of going even further should be considered. Terminal equipment, rolling stock and loading units themselves are not suited for an increase of vehicle gross weights. In this respect, it is also important to emphasise that **CT road legs are ideal for battery-electric trucks due to their typically short distances, which do not require trucks with excessively heavy batteries** [52]. In regional truck configurations with current battery ranges, typical road leg distances of around 70 km [53] are easily covered. Besides, allowing an additional 4 t would not incentivise better capacity utilisation given the fact that currently the utilisation of loading capacity for loaded trips[25] is below 50 % [54].

The allowance of 30 cm higher vehicles for the transport of HC containers on conventional chassis is intended to facilitate their transport on the road legs of CT. Indeed, HC containers on conventional chassis exceed the maximum authorised height (4 m) on the road legs. **However, for many years, road chassis have been developed with gooseneck tunnels that comply with the 4 m height limitation on road**.

The assessment of the opportunities presented by the use of high-capacity vehicle combinations, such as EMS, is more complex. In some cases, the individual units such as rigid trailers or extended semi-trailers are not or hardly compatible with CT. Some combinations, especially those consisting of CT-compatible standard units, offer the potential for using them for low-density, high-volume goods in CT, thereby increasing performance. However, these advantages do not come without challenges. Long truck combinations are difficult to manoeuvre in confined terminal areas, and even if they are made up of standard units, the combinations increase complexity by requiring equipment such as dollies to be towed back. **Ultimately, this is likely to limit the number of profitable applications for EMS in CT to a few special cases.**

The authorisation of long truck combinations in international transport can also entail the risk of undermining standards. There are currently specific standards for loading units, in particular for the length of semi-trailers. This standard could be diluted by the widespread trials of additional extended semi-trailers. Several existing pocket wagon types are designed according to the standard length of 13.60 m. The rail-road CT system is less flexible in this regard to adapt to this change in length. Regarding CT, extended semi-trailers offer little potential due to significant incompatibility risks. Their actual potential for unimodal road transport is also still unclear – they allow additional volume for the transport of low-density goods, but longer EMS combinations are even better suited for fully exploiting this potential.

[25] Empty trips are not included.

2. Impact of measures on rail transport

The single wagonload (SWL) market, which has already come under significant financial pressure in recent years, could also be severely affected by the authorisation of longer and heavier vehicles (LHVs) such as EMS truck combinations. **Their flexibility could lead to a decline in SWL, particularly for low-density freight.** The full train load (FTL) market appears to be less vulnerable but could face **indirect losses due to the lower network utilisation.**

Key findings	
Key findings	▪ Low-density cargo freight is prone to shifting to LHVs which allow economic savings for transport operators and increased flexibility. ▪ Captive markets on short distances and for heavy cargo freight appear less suited for LHVs. ▪ Reverse modal shift threatens the achievability of climate targets.

2.1 Impact of EMS on rail products

The introduction of LHVs also impacts conventional rail transport. The implications and risks for the two pure rail products are different, as different freight types and markets are affected. The following section analyses the extent to which market share can be captured or lost.

2.1.1 Impact on single wagonload

Single wagon load (SWL, also full wagon load, less-than-train load): any consignment requiring the exclusive use of a wagon throughout its journey whether the full loading capacity is utilized or not; wagons are merged into a full train and separated at the destination.

Full train load (FTL, also block train): any consignment comprising a train of several wagon loads transported for a single consignor with no change in train composition from single point of loading to single point of unloading.

SWL transport plays an important role in Europe, accounting for about 27 % of total rail freight transport performance [55]. The share is similar to the proportion of intermodal transport (30 %[26], [56, 57]), although the underlying statistics presumably overlap with SWL, as intermodal loading units may be used likewise. SWL is **commonly used for transporting bulk commodities,** such as heavy industry and chemical products, as well as for the shipment of foodstuff, agricultural goods and various other types of general goods [58]. An analysis of different transport corridors shows that, depending on the freight composition typical of the corridor, SWL can achieve an even higher market share than intermodal rail freight [59]. The relevance of the SWL production system is high for particular types of consignments – the rail freight sector, such as the Rail Freight Forward coalition, expresses its interest in the SWL segment and works on an action plan to promote this production system.

Freight segments at risk

LHVs like EMS can offer advantages in flexibility compared to rail freight transport through the possibility of unimodal point-to-point transport, provided that the vehicle combinations meet the requirements on volume and weight capacity. As a consequence, there is a risk of a reverse modal shift for several segments of the SWL market. In particular, low-density goods transported by SWL seems highly vulnerable, as LHVs are suitable and competitive and might even offer significant

[26] Share of rail transport in intermodal transport units in total rail transport for 2022.

cost savings for transport operators since current prices do not reflect the lower energy efficiency and externalities. In combination with the high fixed cost intensity of SWL, even small reductions in volumes can impact economic viability and achievability of climate targets. **Permitting longer EMS combinations for cross-border transport can thus further exacerbate the financially challenging situation for SWL.** In comparison to intermodal rail freight, SWL was found to have higher elasticities, meaning volumes are more responsive to the cost advantages of EMS [59].

Lower-risk segments

Heavy bulk freight appears to be less suitable for a shift to EMS, as their payload capacity of approximately 25 t does not allow for efficient transport. Captive markets where rail is the only option are considered less at risk, similar to SWL routes under 200 km, as these are mostly specific intra-industry rail freight services, i.e., a conquered market. Furthermore, parts of the bulk goods market that require the transport of dangerous or hazardous materials may be less prone to shifting due to higher safety and reliability needs that favour rail [58].

Overall effects

The market share of SWL in the transport sector may decrease due to the introduction of EMS. The analysis of different rail freight transport corridors in Europe **predicts potential losses in tonne-km ranging from 14 to 40 %** [59] This is mainly driven by the share of low-density goods and transport distances along the corridors, as low-density goods and SWL consignments transported over longer distances are especially prone to shifting to EMS.

At the same time, the transport of containerised consignments by rail-only transport, such as new, particularly heavy tank containers is emerging [60]. This market is not shiftable to road transport, as the weight of these units is up to 75 t.

2.1.2 Impact on full train load

FTL transport plays a major role in the rail freight segment, **carrying high volumes of bulk goods** like coal, ore, oil and steel over long distances [58]. Block trains are acknowledged to have strong cost advantages over road, which acts as a protection against effects of reverse modal shift. However, cases of special train services established on short distances (e.g., household waste to recycling facilities) might still be vulnerable.

Freight segments at risk

Similar to SWL, finished consumer goods, agricultural and food products and semi-finished goods, with lower densities are compatible with the payload and volume capacity of EMS combinations. The usually high demand for flexibility and reliability of these products could make them susceptible to switch to road transport [58].

Lower-risk segments

Industrial bulk commodities like coal, ores, oil and timber that move in very large volumes are less prone to shifting as EMS combinations cannot match the scale and efficiency of full trains [58]. Special block train services over short distances may also be captive markets for rail.

Overall effects

Analyses suggest that the FTL market is shielded to a greater extent by cost competitiveness. However, the market analyses cited point out that if rail loses volumes in other segments, the viability of bulk unit trains could also be threatened in the long-term due to lower network utilisation [58] which consequently can also threaten the attainment of climate targets.

3. Impact of measures on road transport

Allowing heavier and longer vehicle combinations can offer efficiency gains for both typical segments: heavy goods and voluminous freight transport. However, the efficiency gains in terms of energy consumption are marginal compared to what is achievable with door-to-door CT and rail freight transport. While the use of EMS offers an economic savings potential for transport companies, there are risks in terms of externalities such as road degradation and fatalities.

Key findings

- EMS offers emission savings potential of below 10 % when utilising full weight or volume capacity – the impact is marginal compared to the potential of door-to-door CT and rail freight transport.
- For transport operators, EMS hold a cost savings potential of 7 % to 25 % per tonne or m^3.
- The effect on road deterioration is complex. More axles potentially reduce the stress on road infrastructure while higher unladen weight results in worse energy efficiency.
- Higher total weight bears the risk of overloading.

3.1 Energy efficiency and decarbonisation impact

Weight-limited case: analysis of a vehicle filled to its maximum permissible laden weight. The volume capacity is not necessarily fully utilised.

Volume-limited case: analysis of a vehicle (combination) filled to its maximum volume capacity. The maximum permissible laden weight is not necessarily reached.

Enabling heavier vehicles should pave the way for ZEVs. At present, 44 t trucks are already more efficient than 40 t trucks as they reduce energy demand per tonne-kilometre. An ISO 14083-compliant emissions calculator[27] was used to calculate the energy requirements and emissions for the different transport options (see Figure 6).

In the **weight-limited scenario**, the energy consumption of a 44 t vehicle is 8,2 % lower than that of a 40 t vehicle– in terms of CO_2 emissions, 7,9 % can be saved per tonne-kilometre. However, compared to door-to-door CT and unimodal rail freight transport, these percentages are marginal. Door-to-door **CT allows savings of between 60 % and 75 % in energy and up to 90 % in CO_2 emissions.**

Looking more closely at the maximum allowed gross weight of EMS combinations being increased from 40 t to 44 t, it becomes clear that the efficiency gains are offset by the higher unladen weight of the longer combinations[28]. Figure 6 shows that **for the weight-limited case, the energy consumption and emissions are highest for EMS combinations**.

[27] Calculations performed using EcoTransIT. Parametrisation of heavy-weight road transport (40-50 t truck, total weight: 50 t, empty weight: 15 t, payload capacity: 35 t (100 % load factor); for 40 t truck: payload = 25 t, load factor: 72 %; for 44 t truck: payload = 29 t, load factor 83 %; error bars stem from different road properties in different countries and use of different vehicle combinations which allow different amounts of payload depending on the tare weight. Parametrisation for the EMS combination (50-60 t truck, total weight 60 t, empty weight: 20 t, payload capacity 40 t (100 % load factor); for 40 t EMS combination: load factor 50 %, for 44 t EMS combination: load factor 60%. For the volume limited case, a cargo density of 72 kg/m^3 is assumed. Used vehicle parametrisations: standard (100 m^3, 26-40 t truck, load factor: 28 %), EMS (155 m^3, 50-60 t truck, load factor: 28 %). Energy consumption and emissions for CT and rail transport are taken and derived from the study "Combined Transport: carbon footprint and energy efficiency" utilising the heavy-weight and statistical scenario [53]

[28] For a tractor semi-trailer combination, a tare weight of 15 t is assumed, for the most common EMS combination (rigid truck + dolly + semi-trailer), a tare weight of 22.5 t is used [14].

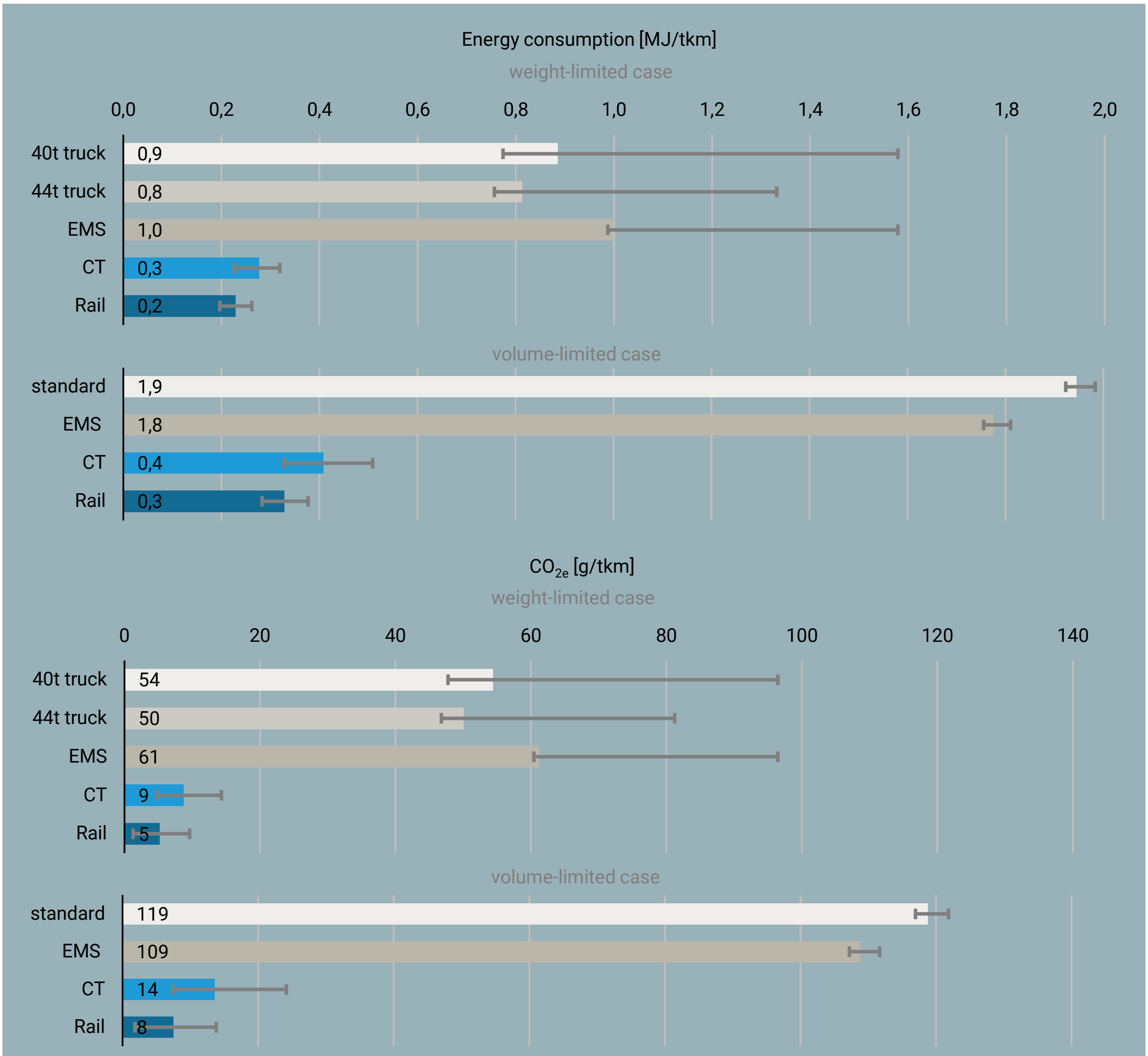


Figure 6: Energy consumption and emissions per tkm for a weight-limited scenario: fully loaded 40 t and 44 t vehicle combinations (standard semi-trailer or EMS combination) and for EMS combinations (tare weight 20 - 22.5 t [14]) with a load of 40 to 44 t as well as for CT and rail transport using a long, 2.000 t -freight train. Results are also shown for a volume limited case (density 72 kg/m³) for a standard mega truck (100 m³) and a typical EMS combination (155 m³), as well as statistical average transport for CT and rail. To take into account different local conditions for road transport and rail power mixes for the energy and emissions calculation, a set of typical European transport relations was considered. The calculations were performed with EcoTransIT.

It is often argued that efficiency gains and emission savings favour EMS combinations. Yet, this holds true only for **a volume-limited case**. Figure 6 shows the calculation for the volume-limited case of transporting goods with a density of 72 kg/m³ in a semi-trailer (100 m³, mega trailer) or in an EMS combination with a volume of 155 m³ [61]. **In this case, the EMS allows for 8-9 % better efficiency and lower emissions.** For comparison with door-to-door CT and rail freight transport, energy consumption and tonne emissions are also shown for an average transport scenario for these modes.

Even if this analysis of emissions initially appears to argue for higher total weights in the weight-limited case and for longer combinations in the volume-limited case, the connection with a potential reverse modal shift and the additional emissions resulting from the transport volumes shifted to road is relevant. This will be analysed in a second phase of this study.

3.2 Economic savings potential

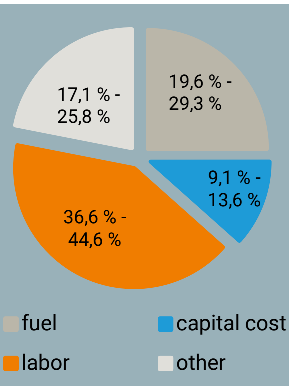


Figure 7: Road haulier cost structure in European countries for Austria, Belgium, Denmark, France, Germany, Great Britain, Italy, The Netherlands, Norway, Spain, and Sweden [67].

The recitals in the analysis of the proposal for the WDD the European Parliamentary Research Service already indicate that **transport operators will achieve cost savings, although this was not initially specified as an objective of the revision** [62].

The loading capacity of trucks is limited by either weight or volume, depending on the goods type. Longer vehicle combinations offer a potential for economic savings as they allow more freight volume to be transported per trip compared to standard trucks. This argument also applies analogously to the case of weight-limited transport due to the increase in the weight allowance – **more freight per journey is possible**. This reduces the number of trucks and drivers needed to move a given quantity of freight.

Cost modelling shows that LHVs allow for lower costs per t and volume for both the heavy weight scenario and the low-density (volume) scenario (see Table 4). This modelling includes assumptions for the ratio of the cost factors in road transport (see Figure 7) for LHVs and currently permitted standard trucks. Operational costs other than fuel and capital costs are 5 % higher for LHVs [59]. Fuel costs were determined according to the emissions modelling described in Section 3.1. For capital costs, it was assumed, in line with literature, that LHVs have a 25 % higher purchase price, with an additional 3 % cost for safety features [59]. This is in line with the procurement and maintenance costs reported in various European field trials reports [19].

The result shows a **cost advantage of 7 % per t for heavy vehicles weighing 44 t** and for long vehicle combinations **with a loading volume advantage in a cost advantage of up to 25 % per m³**. This is consistent with literature values that indicate a cost advantage of 22 % per pallet space for LHVs [59] or cost advantages of 20-25 % [63].

Table 4: Cost indices for a 40 t and 44 t as well as for a standard mega truck and an EMS combination in a weight-limited and a volume-limited scenario. Estimates for cost indices for operating costs and purchase price according to [59].

weight-limited case

	payload	payload gain	operating costs	CO_{2e} per km	fuel costs	purchase/ capital costs	**cost index per tonne**
40 t	**25 t**	100 %	100 %	1.36 kg	100 %	100 %	**100 %**
44 t	**29 t**	116 %	105 %	1.45 kg	107 %	128 %	**93 %**

volume-limited case

	volume	volume gain	operating costs	CO_{2e} per km	fuel costs	purchase/ capital costs	**cost index per m³**
standard	**100 m³**	100 %	100 %	0.85 kg	100 %	100 %	**100 %**
EMS	**155 m³**	155 %	105 %	0.21 kg	142 %	128 %	**75 %**

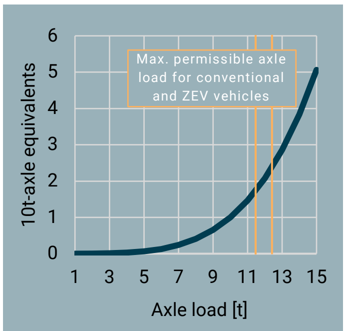


Figure 8: Illustration of the fourth power law relationship between axle loads and damage indicator expressed in 10 t-axle equivalents. Max. permissible axle loads for conventional (11.5 t) and proposed value for ZEV (12.5 t) are indicated (orange).

Looking at the costs per journey, as in Table 4, operating costs for LHVs are higher, but they are offset by the weight and volume advantage. Looking at the operating costs from the perspective of a freight forwarder and assuming the same amount of freight to be transported, the arguments are reversed – in the bigger picture, the **operating costs are lower due to the potential need for fewer journeys and vehicles**.

- Labour costs are lower since fewer driver hours are needed with fewer journeys.
- Fuel consumption per tonne or cubic metre transported is lower. The European trials show 15-18 % lower fuel costs [19], i.e., the assumption based on emissions modelling, which suggests lower fuel consumption of 8-15 %, is still a conservative estimate.
- Reduced capital costs – fewer trucks and trailers are needed for the same volume of transport performance, while they are expected to have higher purchase prices. However, this represents the final situation after a fleet transformation.

From a macro perspective, savings potential can also be made by reducing the vehicle kilometres travelled [58]. However, this effect can be counteracted in various ways – the reverse modal shift potential is analysed in the second phase of this study. In addition, lower transport costs could have consequences such as changes in depot relocation, shipment size, load consolidation, change of supplier and customer base, and relocation of production operations, which could result in longer or more journeys.

3.3 Impacts on road infrastructure

Given that the existing road infrastructure in Europe is designed for the existing vehicle weight standards, a thorough evaluation of the effects on infrastructure deterioration is critical to assess the risk of accommodating heavier vehicles. Evaluation of the impacts on accident rates and other externalities is also essential to assess the impact on road safety and societal implications.

3.3.1 Deterioration of road infrastructure

In the 1950s, several experiments[29] showed that the stress exerted by vehicles on the road increases in proportion to the fourth power of the axle load (see Figure 8). This implies that damage to the road infrastructure increases exponentially with the axle load. The configuration of the axles is of major importance in this regard [64].

The German Federal Highway Research Institute has carried out a study for various long and heavy vehicle combinations (LHVs like EMS) based on actual axle loads [14]. Using the layout for a standard 6-axle 40 t truck, the corresponding values for a maximum weight of 44 t were derived. Figure 9 shows that a heavier truck results in a considerably greater stress on the infrastructure comparing single trucks. Although heavier trucks have the potential to reduce the number of vehicles required, they cause disproportionately more damage.

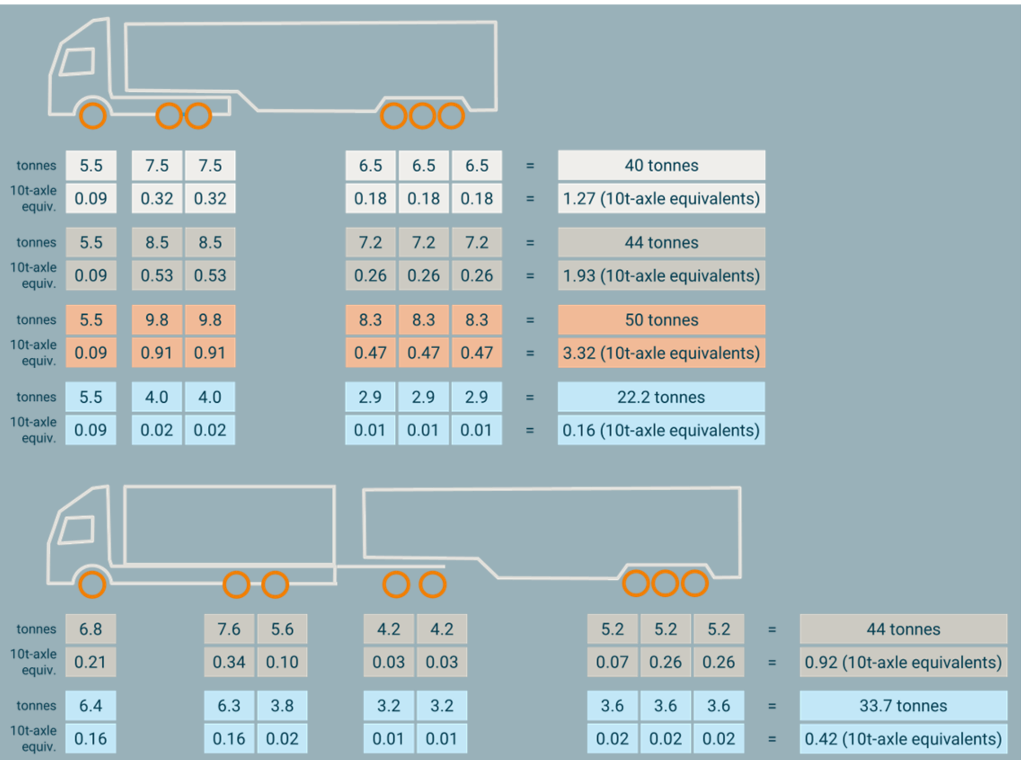
For the concrete weight-limited transport scenario, the payload of a typical freight train carrying 725 t of goods can be distributed in two

[29] AASHO-Road-Test

Figure 9: Axle loads and resulting material road damage in equivalent 10 t axles.

Top: for a 6-axle articulated truck with 40 t and 44 t gross weight and for an overloaded scenario with 50 t as well as a volume-limited scenario with 7.2 t payload (density 72 kg/m³).

Bottom: for the most frequent EMS combination with 44 t gross weight and the volume-limited scenario with 11.2 t payload (density 72 kg/m³).



ways: either as the equivalent of 25 trucks of 44 t (with a 29 t payload) or as 29 trucks of 40 t (with a 25 t payload). This number of 44 t trucks results in damages corresponding to 48 10 t-axle equivalents. Conversely, the same operation with 40 t trucks would correspond to “only” the impact of 36 10 t axle equivalents on the road. In other words, **transporting the same freight quantity in fully loaded lighter trucks causes less stress on the infrastructure than using fewer, fully loaded heavy trucks**.

It is essential to acknowledge that as the number of axles increases, the stress exerted on the infrastructure decreases, i.e., a 6-axle 40 t truck has less impact in terms of 10 t-axle equivalents than a 5-axle truck of the same gross weight. As six axles are required for 44 t trucks and they could be allowed to carry a heavier load in international traffic, Figure 9 compares the same vehicle configuration with different payloads and includes the most frequent EMS combination.

It is often claimed that EMS combinations are advantageous due to the distribution of weight they offer over an increased number of axles, which reduces road deterioration. **This is only true for the weight-limited case**: with a gross weight of 44 t, the most common EMS truck combination generates around half the damage of a 6-axle 44 t truck. In the volume-limited scenario (see emissions assessment in Section 3.1 for parameterisation), the significance of the payload decreases while that of the vehicle weight increases. This translates into lower axle loads also for a volume-full 6-axle combination, in this case, the shorter vehicle causes less than half as much damage. Again, a different number of vehicles are required for the same amount of goods: 3100 m³ of goods can be transported in 31 6-axle mega trailers or in 20 EMS truck combinations. In this case, 31 mega trailers would cause road deterioration corresponding to five 10t-axle equivalents, while the 20 EMS combinations would result in an impact of 8.4 10 t axle equivalents[30].

While the figure may seem small in comparison to the weight-limited case, it is evident that **the scenario used to support the emissions advantages does not translate into benefits in terms of road deterioration**. Overall, the impact of vehicles must be considered in the broader context of potential changes in traffic volumes which will be analysed in the second phase of this study.

The maximum authorised axle weight for single axles is currently in the range of 10 t to 11.5 t (steered axle) – the proposal for the revision of the WDD entails an increase to 12.5 t for ZEVs and thus also for conventional vehicles for the duration of the transition phase. For double axles, the maximum permissible weight depends on the axle spacing and varies between 11 t and 19 t depending on the spacing and configuration including steered axles. Although an increase in the permissible total weight will still allow compliance with these limits for common tractor-trailer combinations, it can be expected that the average axle weight will continue to increase with the total weight - in one national trial, axle loads of up to 13 t were reported [7].

Heavier trucks also have a significant influence on bridges, particularly by inducing mid-span bending moments. This effect intensifies with increasing gross vehicle weight and axle loads and decreases with a shorter wheelbase. The ratio of gross vehicle weight to vehicle length (equivalent uniformly distributed load), predominantly governs the impact of a single vehicle on a bridge span. The stresses induced by single vehicles crossing a span are also subject to dynamic factors that escalate with velocity, gross vehicle weight, and pavement roughness [65].

For long-span bridges (exceeding 80 to 100 metres), the maximum stress levels are primarily dictated by a number of heavy vehicles travelling in proximity, as observed in congested traffic scenarios. Moreover, steel bridges are particularly susceptible to fatigue resulting from the cumulative impact of stress cycles induced by vehicle crossings. The extent of damage incurred is roughly proportional to the power of 3 to 5 of the stress amplitude and directly proportional to the number of cycles endured [65]. Applying the same rationale as for the fourth power law in the case of road deterioration, it can be assumed that the **effect of the higher axle load prevails over the reduced number of vehicles** due to the higher permissible gross vehicle weight.

The disproportionate increase in heavy traffic in recent decades, in terms of total vehicle weights, axle loads and frequency, has been putting pressure on bridges, necessitating measures to maintain their load-bearing capacity. As a result of formerly lower permissible total weights, lower standard load-bearing capacities were required. The load-bearing reserves of bridges that were planned up to the mid-1960s using the traffic model of that time are exhausted for the proposed heavy vehicles. These bridges will have to be substantially reinforced or completely rebuilt – in Germany, **this affects over 50 % of the bridges on federal highways** [66].

Another aspect shows that weight is a significant factor in road deterioration. Analyses of overloading show that even when only a small

[30] The transport of the same amount of volume goods in 5-axle mega trailers is at a similar level with 9.7 10 t-axle equivalents.

proportion of trucks are overloaded (from less than 10 % to 20 %, [67, 64]), as is the case in Europe, these instances contribute significantly to the overall damage impact [64]. For the Rhine bridges in Germany, almost all damages were found to be the consequence of excessive local stress due to high axle loads [66]. Further analyses indicate that axle load and overloaded vehicles are particularly damaging [68].

Longer vehicle combinations are more **susceptible to overloading.** If the volume of an extended semi-trailer is used to produce an overload of 14 % (50 t), the damage in axle equivalents increases by 73 % (see Figure 9). However, due to the ratio of total weight to the number of axles, long combinations are not expected to exceed individual axle loads as they typically have more axles than conventional shorter vehicles with the same permissible gross weight [7].

3.3.2 Impact on accidents and externalities

In the impact assessment, the regulator used the CARE[31] database, statistical methods, and post-hoc analyses to derive the impact of increased length and weight on the risk of road fatalities – some of which indicate an increase in risk, others a decrease. For the different policy options, a 0.5-1 % rise in risk is considered for an increase in total weight from 40 t to 44 t. However, if the introduction of 44 t vehicles translates into fewer HDVs on the road, overall risks could eventually decrease. [47]. Further **accident surveys indicate that accidents involving 44 t vehicles are particularly serious – the risk is increased both by the length and especially by the higher weight** [69]. In particular, it is observed that heavier trucks have longer braking distances, which means that the impact speed could be higher when a crash occurs, thus increasing the impact force. The weight is not expected to increase the risk for accidents, but rather the severity and fatality rate of accidents [70]. Moreover, longer vehicle combinations would be more likely to fully block traffic lanes in the event of an overturning in an accident, thus increasing the risk of secondary collisions.

The European Transport Safety Council and the European Association of Operators of Toll Road Infrastructures also note that the safety-relevant infrastructure such as lay-bys, crash barriers and truck safety features like runaway ramps and breakout bays in tunnels [71] are not designed to accommodate vehicles above the current weight and length limits, which can lead to further risks. The same applies to the design of level crossings and the times required for clearance. Longer vehicles are likely to require more time to clear the crossing [72], thus causing additional risks at these sensitive points. Other risks can arise because of road stress and bridge damage if this requires the installation of additional construction sites [73].

It is significant that in the area surrounding the (un)loading sites and in (sub)urban regions, the greater size of these trucks reduces visibility and manoeuvrability, posing heightened risks to vulnerable road users such as pedestrians and cyclists [73].

Regarding parking spaces, longer EMS combinations appear to be incompatible with the standard angled parking spaces due to their length and wide towing curves. Long trucks with extra-long semi-trailers with a total length of up to 17.8 m fit well into the standard 21.96 m long diagonal parking stalls. Combinations up to 25.25 m cannot use these

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[31] https://dashboard.tech.ec.europa.eu/qs_digit_dashboard_mt/public/extensions/MOVE_CARE_public/MOVE_CARE_public.html

diagonal parking stalls but require lengthwise parking stalls. In addition, a comparatively wide towing curve poses a challenge to the accessibility of parking areas. This means that with the increased use of long trucks, the demand for parking spaces of adequate length in Europe may exceed the available capacity in rest areas along the highway [74].

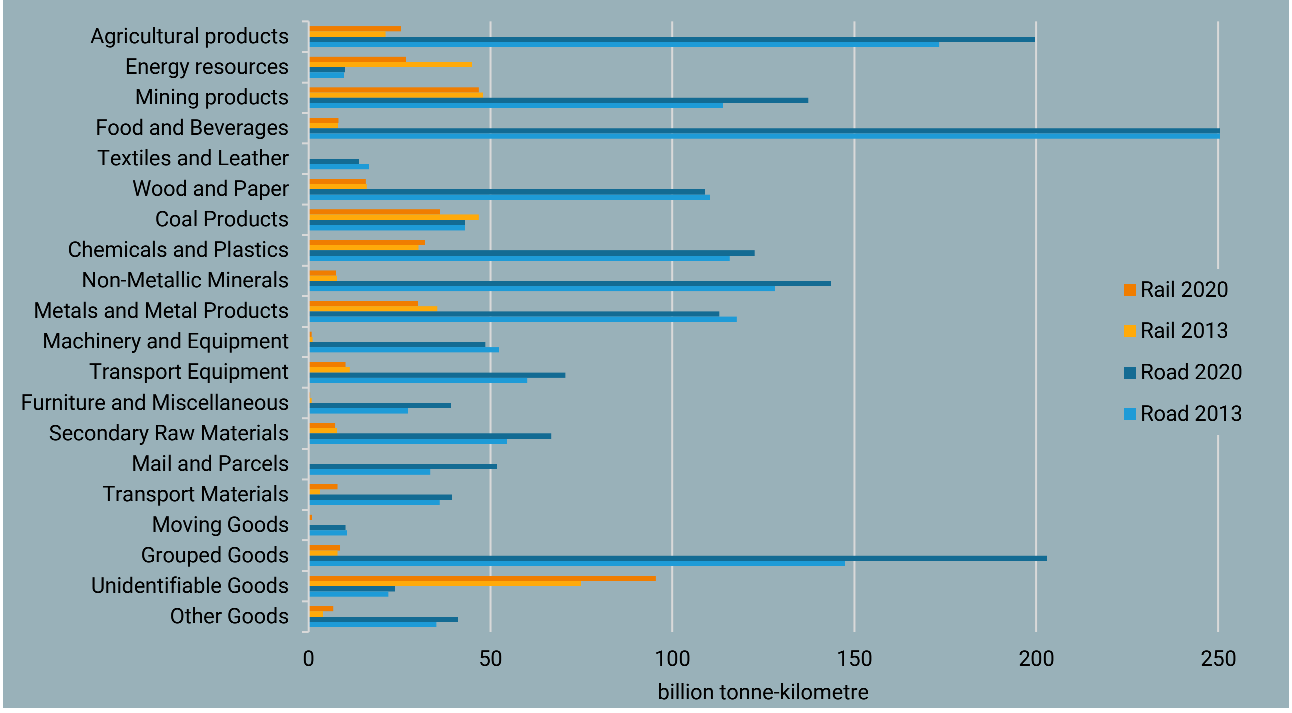
In conclusion, it also needs to be mentioned that measures may be necessary to counter these risks of fatalities and overloading, e.g., through the mandatory use of intelligent transport systems (ITS) [65] and further technologies.

3.4 Market segments of long-distance road freight transport

Road freight transport dominates for distances under 250 km, as its flexibility plays off. Rail transport only accounts for 5 % of these distances and increases to 30 % for distances between 1,000 and 3,000 km [75]. The transport sector in the EU has grown significantly in the past decade and is expected to continue to grow [76]. Road transport is the main driver of this growth. Between 2000 and 2020, transport volumes increased by approximately 10 % while rail transport volumes stagnated (see Figure 11, left), although the intermodal segment recorded some growth.

Figure 10 shows recent developments in freight transport for different market segments according to the NST 2007 categories[32], revealing road transport volumes increased in almost every category [77]. While some expectedly heavy bulk categories such as minerals and mining products also increased, the strongest growth is dominated by lighter categories and presumably palletised goods like grouped goods, agricultural products, and secondary raw materials. Rail freight transport stagnated for

Figure 10: Development of market segments in rail- and road freight transport in the EU-27 between 2013 and 2020 according to NST 2007 categories. Data taken from Eurostat [87, 99].



[32] Missing data for Belgium (Rail) and Italy (Rail 2013).

all categories except unidentifiable goods, probably a sign for unspecified goods, as often declared in CT consignment notes.

Light, high-volume freight such as palletised goods benefit in particular from the advantages of road transport and the introduction of EMS, as the high transport volumes offer savings potential and efficiency gains. Projections of the development of the different freight categories until 2050 show that high-volume freight such as manufactured goods is growing particularly strong (see Figure 11). This provides evidence that the existing trend is likely to continue unless measures to promote more efficient modes of transport are implemented.

In addition, transport statistics show that precisely these high-volume goods are also transported over particularly long distances by road (see Figure 12). However, these transports are those that are suitable for the more efficient mode of rail transport, as road transport's flexibility advantages are less pronounced on long distances. Despite potential for rail transport and despite the European goals set out in the Whitepaper on transport and mobility [78, 79] and in the Smart and Sustainable Transport Strategy [80] of reaching 50 % of efficient modes of transport (rail and IWW), the introduction of EMS combinations for cross-border transport is likely to prevent rail-based transport options from being chosen. The effects and shift potentials are analysed in Chapter 4.

Figure 11: Left: Development freight transport volumes within the EU. Data from [76]. Right: Projections for freight transport volumes for different market segments from until 2050 (base year 2020) [77].

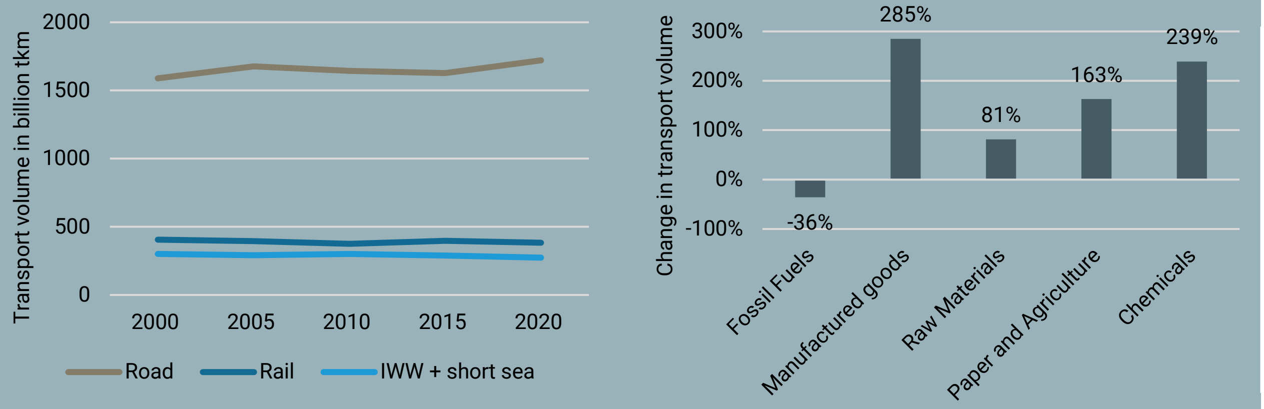
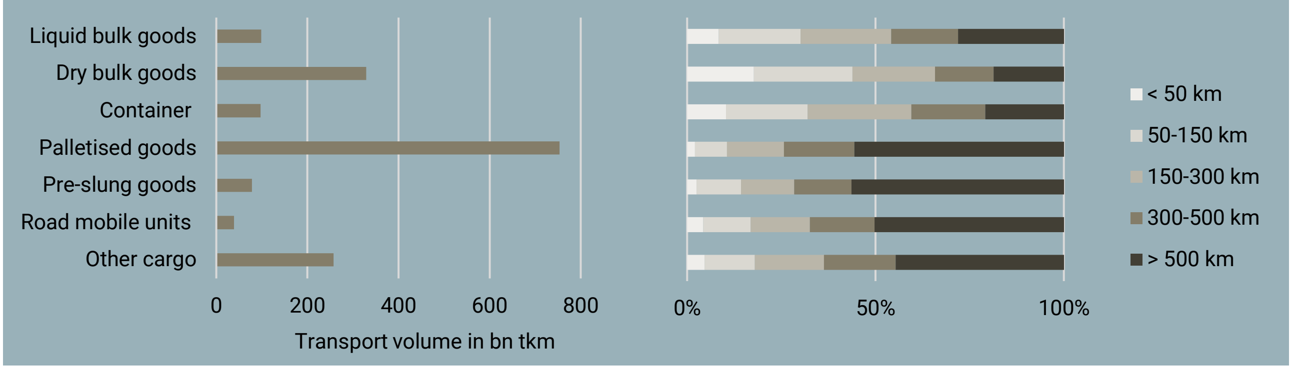


Figure 12: Road freight transport statistic for different types of goods (left) and distance classes (right) in the year 2020. Data taken from [98].



4. Impact of measures for road transport, CT, and rail transport

The increase in the permissible gross weight and the authorisation of EMS may lead to a reverse modal shift. This depends to a large extent on whether the freight segments are predominantly heavy or light. The analysis shows that, on average across all rail transport segments, up to 21 % of the volume would be susceptible to a reverse modal shift. For CT, the proportion is 16 %. The disproportionate growth in light freight segments could exacerbate this situation in the future. The shift is not without consequences for the road sector - it can result in additional truck journeys, emissions, and external costs.

Key findings	

	▪ Across all rail transport segments, on average up to 21 % of the volume is susceptible to a reverse modal shift. For CT, the proportion is 16 % on average.
	▪ Reverse modal shift leads to additional:
	  ▪ 5.3 to 10.5 million truck journeys
	  ▪ 3.5 to 6.6 million t CO_2 emissions
	  ▪ Three times higher external costs

4.1 Reverse modal shift potential

As modelled in the previous chapter, heavier trucks provide efficiency gains and cost advantages for the transport of bulk goods, as do longer vehicle combinations for high-volume goods. The lower cost of road transport strengthens the competitive position of this mode, which is at risk of a reverse modal shift. This modal shift potential is quantified below.

Methodology

The transferability of different goods to road transport varies, resulting in various degrees of modal shift potential for each category. This relationship is quantified by cross-price elasticities, which measure the responsiveness of CT and rail transport demand to changes in road transport.

Such tabulated cross-elasticities exist for both, CT and rail freight transport as a whole, with a different breakdown by freight segments. In the following, the modelling of the reverse modal shift potential is performed separately for CT and rail freight transport in general. It should be noted that CT rail legs are also counted in the rail freight transport statistics, so the results of the two modelling approaches should not be added, but CT is also included in the modelling for rail freight transport in general.

Data collection for CT

CT can be divided into eight categories according to its characteristics: domestic and international, hinterland and continental, and light and heavy transport. Transport volumes are reported according to these categories [57, 81, 82, 83]. The share of heavy and light consignments per category can be derived by a linear combination of empty trips[33], light consignments[34], and heavy consignments[35] per type of transport unit, i.e., semi-trailers and containers, to represent the average consignment weight. For domestic transport, this results in a distribution of 31 % heavy and 69 % light consignments and for international CT the modelling shows 52 % heavy and 48 % light consignments. The resulting distribution[36] as well as elasticities for these categories are shown in Table 5. Literature values from various sources for rail-road cross-elasticities for containerised transport [59, 84] are in good agreement, although providing different breakdowns, e.g., by weight or transport distance. Light consignments in particular are more susceptible to shifting, as is the hinterland transport of maritime units.

Data collection for rail freight transport in general

For rail transport, goods are commonly classified according to the NST-2007 categories [85]. This categorisation is well suited to differentiate between light and heavy goods with different cross-elasticities[37]. There is a relatively wide range of elasticities in the literature due to the way they are modelled. In this analysis, a range between rather low cross-elasticity values [86] and high [87] values is considered[38]. The values used in the Fraunhofer Institute modelling [59] fall within this range. The impact assessment [47] does not differentiate between freight categories for rail transport but gives a single rail-road cross-elasticity of

Table 5: Transport volumes and elasticities for CT market segments and calculated volumes prone for a reverse modal shift to road transport. Transport volumes taken from [83, 57], elasticities from [59].

			Cross price elasticity	CT volume 2021 in bn tkm	Reverse modal shift fraction	Reverse modal shift volume 2021 in bn tkm	Projected CT volume 2050 in bn tkm	Reverse modal shift volume 2050 in bn tkm
Hinterland	Domestic	heavy	0,5	5,9	4%	0,2	9 - 11	0.3 - 0.4
		light	1	13,1	25%	3,3	20 - 24	5.0 - 6.0
	International	heavy	0,4	24,9	3%	0,7	67 - 81	1.9 - 2.3
		light	1	22,9	25%	5,7	62 - 74	15.4 - 18.6
Continental	Domestic	heavy	0,9	3,7	6%	0,2	6 - 7	0.3 - 0.4
		light	1,5	8,3	38%	3,1	12 - 15	4.6 - 5.6
	International	heavy	0,8	49,5	6%	2,8	128 - 154	7.2 - 8.6
		light	1	45,7	25%	11,4	118 - 142	29.5 - 35.6
Total				**174**		**27,5**	**421 - 508**	**64.2 - 77.5**

[33] Tare weight of 4 t assumed for 40’ containers and of 7.6 t for semi-trailers.
[34] For the light consignment, a mean density of 113 kg/m³ is assumed up to which EMS combinations can be loaded volume-full [63]. The cargo weight is calculated for a volume of 90 m³ for semi-trailers and for 67.5 m³ for 40’ containers.
[35] Heavy consignments are modelled as containers and semi-trailers loaded to 95 % of their permitted payload. The gross weight of the modelled heavy consignments is 30 t for 40' containers and 30.3 t for semi-trailers.
[36] The breakdown into hinterland and continental transport for domestic and international CT is based on the 2022 Report on Combined Transport in Europe [85].
[37] However, common analyses for cross-elasticities are available in the older classifications according to NST/R freight classes, which were transformed to the currently used NST-2007 classes using a corresponding mapping [101].
[38] The higher values stem from a recent publication that differentiates between different influencing demand factors in the modelling – costs and transport time. This distinction can prevent overlapping of influential effects and thus result in higher elasticity values.

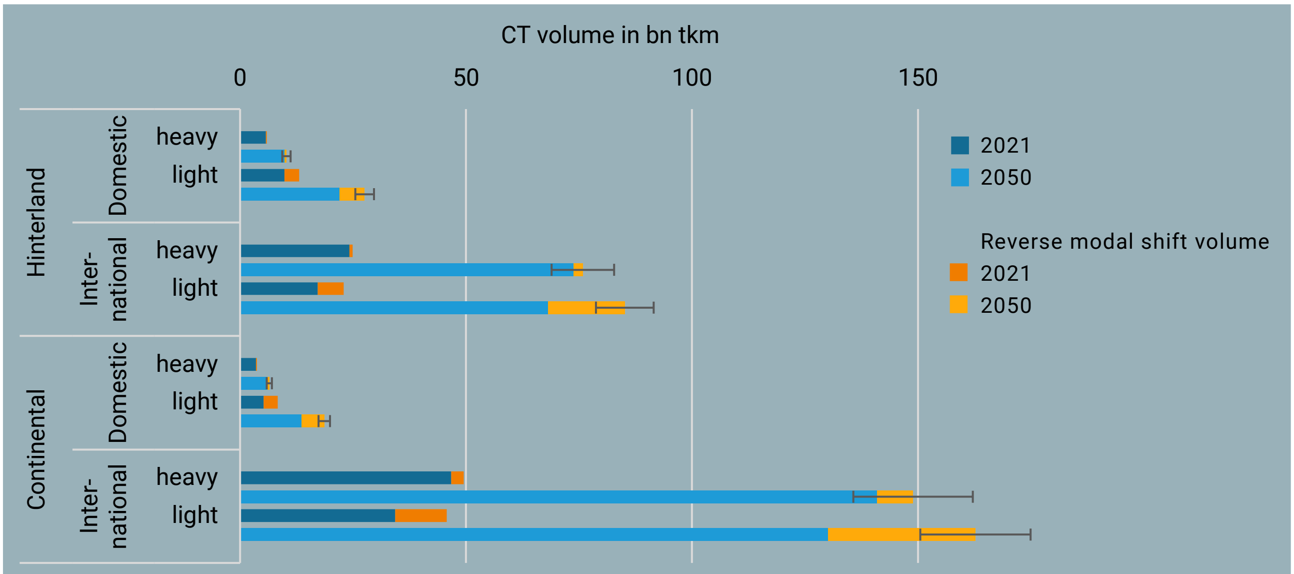


Figure 13: Transport volumes for CT market segments for 2021 (darker colours) and projection for 2050 (lighter colours). Calculated volumes prone for a reverse modal shift to road transport (orange and yellow for the respective years). Transport volumes taken from [85, 100]

0.5[39]. This value is at the lower end of the range assumed here for some groups of goods, and for some it is even lower. The predominance of heavy or light consignments in the commodity groups was determined on the basis of the median shipment weights in these groups[40] [88]. Table 6 shows the rail freight transport volumes and elasticities.

CT – Results for the reverse modal shift

Based on the cost saving potentials (see Chapter 3.2) for the transport of heavy and light freight in LHVs, the share of the transport volume susceptible to a reverse modal shift is calculated for the CT segments. This share at risk ranges from 3 % to 38 % (see Table 6), which is well in line with previous studies [59, 89]. Actual cases from the industry also confirm that these percentage shifts are realistic[41].

Between 2011 and 2021, international CT recorded significantly higher growth rates than domestic CT [83]. This is primarily driven by continental transport, which has a comparatively higher share of heavy consignments. In order to assess the situation in 2050, linear growth was assumed to determine the shares for the individual CT segments. The total volume was calibrated assuming a realistic CT share of 58-70 %[42] of the rail transport projected in the EU reference scenario [76]. Consequently, it is clear that the relative share of CT that is susceptible to a shift to LHV remains almost constant. However, as the CT volume increases, the absolute volume that could be shifted to road transport increases from 27 billion tkm in 2021 to 64 – 77 billion tkm in 2050.

[39] In the support study accompanying the impact assessment from 2008 [93], values for elasticities from the years 1970 to 1999 are cited for various European or non-European regions, which also lie predominantly within the range assumed in this study.
[40] For unidentifiable goods a 50:50 distribution of heavy and light consignments is assumed.
[41] Following the authorisation of LHVs for road transport in France, the RoLa relation between Luxembourg (Bettembourg) and Spain experienced a loss of 13% in volume.
[42] The range of CT shares is in accordance with with industry targets [102] and targets that would be necessary to achieve European climate targets [96].

Total rail freight– Results for the reverse modal shift

For rail transport, the reverse modal shift risk in the freight segments range from 1% to 47% (see Table 6). Again, this is in line with previous studies. Freight classes with negligible modal shift potentials are heavy and have low elasticities – these are typical FTL freight segments. The lighter segments are likely to be predominantly SWL and CT segments.

A very recent projection of annual growth rates of transport up to 2050 per NST-2007 category is available for Germany [90]. These growth rates were applied to the current European rail transport volume and calibrated with the rail transport volume projected for 2050 in the EU reference scenario [76]. While the relative shares and the corresponding absolute volumes of 41 to 77 billion tkm are already significant for 2020, the projection for 2050 suggests that freight segments with

Table 6: Transport volumes and elasticities for rail transport in general classified according to NST-2007 freight segments and calculated volumes prone for a reverse modal shift to road transport. Transport volumes taken from [85] and elasticities taken from [86, 87].

** Mail and parcel as well as other goods are merged with the unidentifiable goods as no elasticities were available for these categories*

	Cross price elasticity	Volume 2020 in bn tkm	Reverse modal shift fraction	Reverse modal shift volume 2020 in bn tkm	Projected volume 2050 in bn tkm	Reverse modal shift volume 2050 in bn tkm
Agricultural products	0.64 - 1.32	25.4	4% - 9%	1.1 - 2.4	51.8	2.3 - 4.8
Energy resources	0.19 - 0.73	26.8	1% - 5%	0.4 - 1.4	0.0	0.0 – 0.0
Mining products	0.49 - 1.33	46.8	3% - 9%	1.6 - 4.3	95.5	3.3 - 8.9
Food & Beverages	0.99 - 1.47	8.2	25% - 37%	2.0 – 3.0	18.2	4.5 - 6.7
Textiles & Leather	0.66 - 1.31	0.1	17% - 33%	0.0 – 0.0	0.3	0.1 - 0.1
Wood & Paper	0.77 - 1.29	15.7	19% - 32%	3.0 – 5.0	34.8	6.7 - 11.2
Coke & petroleum products	0.28 - 1.87	36.1	7% - 47%	2.6 - 16.9	12.5	0.9 - 5.9
Chemicals & Plastics	0.74 - 1.37	32.0	18% - 34%	5.9 - 11	65.2	12.0 - 22.4
Non-Metallic Minerals	0.75 - 1.02	7.6	19% - 26%	1.4 - 1.9	19.5	3.7 – 5.0
Metals & Metal Products	0.47 - 1.27	30.2	3% - 9%	1.0 - 2.7	63.2	2.1 - 5.6
Machinery and Equipment	0.98 - 1.23	0.8	25% - 31%	0.2 - 0.2	2.2	0.5 - 0.7
Transport Equipment	0.98 - 1.23	10.1	25% - 31%	2.5 - 3.1	25.4	6.2 - 7.8
Furniture & Miscellaneous	0.98 - 1.23	0.4	25% - 31%	0.1 - 0.1	1.0	0.3 - 0.3
Secondary Raw Materials	0.33 - 1.75	7.3	2% - 12%	0.2 - 0.9	14.0	0.3 - 1.7
Material f Goods-Transport	0.98 - 1.23	7.9	25% - 31%	1.9 - 2.4	19.8	4.9 - 6.1
Moving Goods	0.98 - 1.23	0.9	25% - 31%	0.2 - 0.3	3.0	0.7 - 0.9
Grouped Goods	0.98 - 1.23	8.6	25% - 31%	2.1 - 2.6	27.2	6.7 - 8.4
Unidentifiable Goods *	0.98 - 1.23	102.4	16% - 20%	16.1 - 20.2	272.2	42.7 - 53.6
Total		**367**		**42.3 - 78.5**	**726**	**97.8 - 150.0**

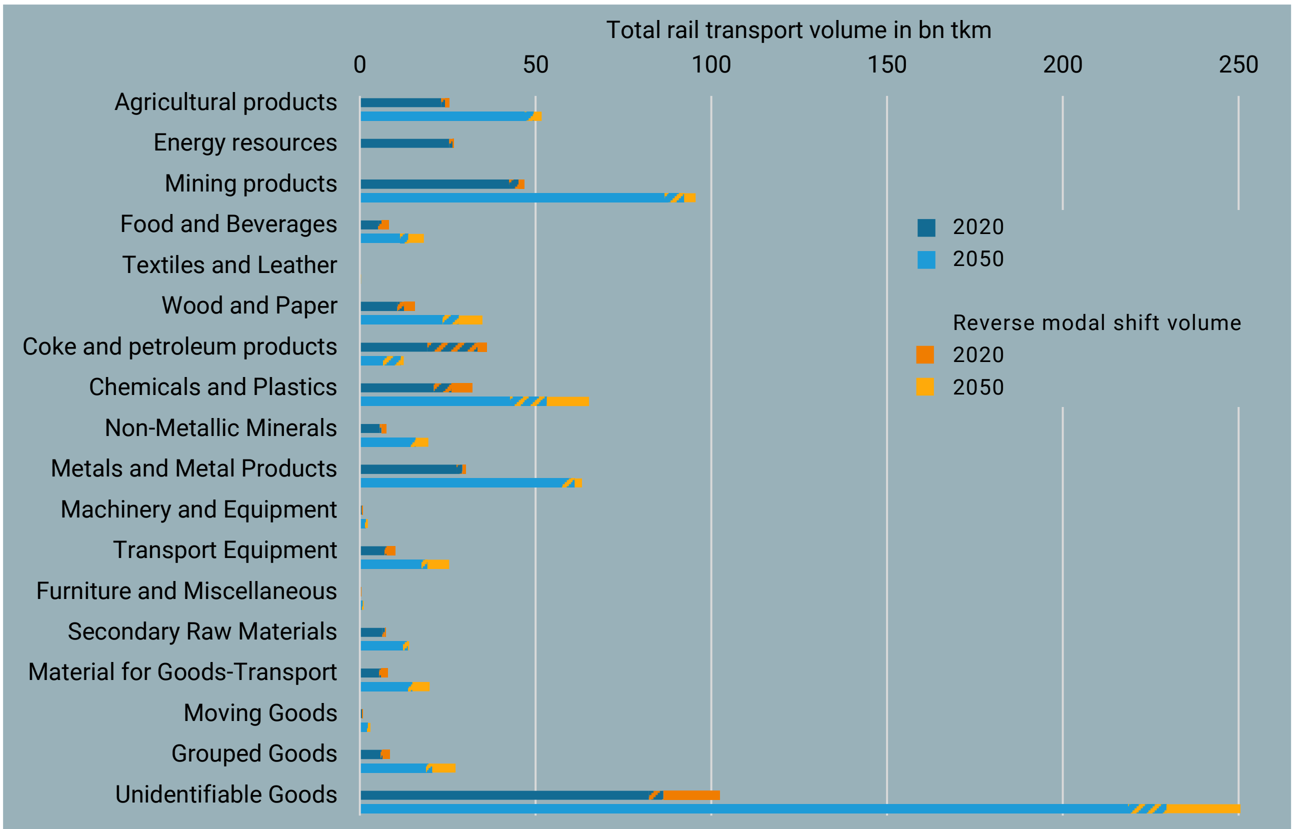


Figure 14: Transport volumes for rail freight transport according to NST-2007 segments for 2020 (darker colours) and projection for 2050 (lighter colours). Calculated volumes prone for a reverse modal shift to road transport are indicated (orange and yellow for the respective years). Transport volumes taken from [87]

rather light goods might grow more strongly than heavy, less elastic segments, which may even decline sharply (e.g., energy resources and coke and petroleum products). For 2050, the volume that could be subject to a reverse modal shift is between 95 and 146 billion tkm.

Interpretation

Rail freight transport figures also include CT data. The rapidly growing proportion of unidentifiable goods is presumably largely attributable to CT – consignment notes in which the goods are not classified in detail, as is often the case in CT, fall into this category. Another segment with a particularly high potential for reverse modal shift are chemical products. By comparing the vulnerable volumes calculated for CT only, it becomes clear which volumes are to be attributed to the other rail products. As mentioned above, the major portion of this falls to SWL.

In comparison, the reverse modal shift figures given in the impact assessment (4.9 billion tkm in 2030 and 5.5 billion tkm in 2050, [47]) are much lower. This might be due to several reasons. Firstly, the modelling in the impact assessment does not explicitly include the use of EMS, as this requires authorisation from the individual Member States. Furthermore, the assumed savings could be lower provided that the additional weight is accounted for by the zero-emission propulsion technology rather than by additional cargo, which however is possible during the transition phase. Another aspect might be, similar to the accompanying study from 2008 [91], the assumption that only part of road transport, i.e., that which is handled in LHVs or zero-emission LHVs, serves as the target of the shifted transport volume. No such assumption is made in this study as conventional trucks can also be used during the transition period and a total weight of 44 t is possible for a typical 6-axle truck. Furthermore, EMS combinations consist of common modules that can easily be combined into longer modules once this is allowed, so that the road transport market should not be limited to the current segment of LHVs. Moreover, the impact assessment also identifies effects that could lead to price reductions per volume in CT, such as the use of HC containers, which should therefore result in a shift towards CT. However, as HC containers can already be regarded as established (see Chapter 1.3), the effect on this segment is not considered in this study. One effect that may become relevant is the extension of the CT weight allowance to semi-trailers. For this measure, the impact assessment projects a shift potential from road transport to CT of 21 billion tkm in 2030 and 26 billion tkm in 2050. It is questionable whether the potential is actually that high, given that only about one tenth of semi-trailers are craneable and that the network of horizontal terminals in Europe for transshipment of non craneable semi-trailers is less dense. Furthermore, semi-trailers currently account for about 21 % of the volume of CT [83], which corresponds to about 35 billion tkm. Overall, the additional volume of CT in semi-trailers estimated in the impact assessment would represent a 60 % growth of this segment.

4.2 Effect of reverse modal shift on externalities

The number of consignments that are likely to be shifted from rail and CT to road, as calculated above, is only one side of the coin – the authorisation of LHVs has further effects. On the one hand, there is an intrinsic elasticity of demand for road transport of about -0.4[43] [47]. With a road transport volume of 1,913 billion tkm in 2022 [92], this would lead to an additional demand of 150 billion tkm[44]. On the other hand, the introduction of LHVs not only has a modal shift effect, but also means that more freight can be transported in fewer trucks. Assuming that all road freight traffic is transported in LHVs that are best suited for full capacity utilisation of the respective freight segment, the number of trucks could be reduced by 27 %. However, given the fact that the current average payload of 14.4 t [46] indicates that truck capacity is not being fully utilised, it is unlikely that this reduction will be achieved.

This effect of the reduced number of HGVs is offset by the fact that 5.3 to 10.5 million LHV journeys could be added due to the reverse modal shift from CT and rail and possibly a further 39 million due to the own price elasticity.

The impact assessment for the revision of the Weights and Dimensions Directive [47] states that the policy measures will require additional infrastructure investment, while external costs will decrease. This result is mainly driven by the measures to authorise additional weight for ZEVs, as they allow to reduce external costs for air pollution, climate, and emissions. The following section analyses the externality effects for the reverse modal shift due to the authorisation of LHVs modelled in this study.

4.2.1 Deterioration of road infrastructure

On the one hand, the number of vehicles in circulation influences the stress on the road infrastructure, but the total weight and axle load of

[43] Own price elasticity of -0.3 to which additional 0.1 should be added due to the rebound effect of switching to more efficient vehicles.
[44] Assuming the same distribution of heavy and light goods for the NST-2007 categories as introduced above.

Table 7: Overview of external costs for the transport of the freight volume of rail transport (2020) in general, i.e., including unimodal rail and CT, prone of shifting to road transport. External costs taken from [93].

External costs in million €

	Accidents	Air pollution	Climate	Noise	Congestion	WTT	Habitat	total
LHVs	536 - 1,003	330 - 617	206 - 386	206 - 386	330 - 617	82 - 154	82 - 154	**1,772 - 3,317**
Rail	41 - 77	82 - 154	25 - 46	247 - 463	0	82 - 154	82 - 154	**560 - 1,049**

these vehicles are equally relevant. A smaller number of vehicles with a higher axle load can cause more damage than a larger number of vehicles with a lower axle load (see Chapter 3.3.1). Even the calculated possibility of reducing the number of HGVs by 27 % would lead to a 42 % increase in wear and tear on the road infrastructure assuming fully utilised LHVs.

In addition, the road infrastructure will be subjected to strain by the additional vehicles due to the reverse shift and the elasticity inherent to road transport. The 5.3 to 10.5 million LHV journeys caused by the shift from CT and rail to road would result in additional wear and tear equivalent to 3 % of the current road wear and tear - a further 7 % should be added due to the inherent elasticity of road transport.

4.2.2 Impact on accidents and externalities

In terms of emissions, it is again worth looking at the overall picture. By completely shifting current road transport to optimally utilised LHVs, the efficiency potential of these vehicles could be exploited, and emissions reduced by 8 %.

However, the reverse modal shift balance works the other way round – it is a shift from a highly efficient mode of transport to a less efficient one. Instead of 0.3 to 0.6 million tonnes of CO_2e emitted in rail transport or CT, 3.8 to 7.2 million tonnes of CO_2e – more than 10 times as much – are emitted for transporting the same quantity of goods on road. Further emissions also arise from additional transport demand for LHVs due to the cost elasticity of road transport.

A common method of assessing externality impact is to calculate external costs. The effect of the reverse shift can be calculated on the basis of the values in the Delft Handbook [93] assuming tabulated average values for HGVs and rail transport (see Table 7). Overall, the external costs are more than three times higher. The reverse modal shift generates particularly higher costs for accidents and congestion. This does not yet take into account that the use of EMS increases, e.g., the severity of accidents, as this differentiation of vehicle categories is not yet available in terms of external costs.

5. Recommendations

This study analyses in detail the various measures proposed as part of the revision of the Weights and Dimension Directive. The overarching aim of these measures is to decarbonise transport and enable efficient transport options. However, the analysis has shown that these measures, as proposed, are not necessarily suitable for achieving these objectives.

The introduction of EMS in road transport does provide a more energy efficient option for high-volume road transport. Meanwhile, transport from an even more efficient segment, CT and rail transport, will be cannibalised through reverse modal shift. Allowing additional weight for the use of ZEVs is also well-intentioned, but the extended transition period spanning until 2035 poses the risk that conventional vehicles will render ineffective the weight advantages for the more energy-efficient option of CT. A further increase in the permissible weights in the CT in order to maintain the weight advantage is not necessarily practical or suitable. There are operational limits to the weight of loading units and for a many freight segments, especially high-volume goods, it is not required. In this regard, it is important to recognise that, alongside zero emission targets, energy efficiency is a key factor in achieving the climate targets for the transport sector.

The impact of the measures proposed for CT, such as increasing the permissible height to 4.30 metres, is limited as appropriate solutions and vehicles are already available on the market for the transport of HC containers.

Irrespective of the introduction of the EMS, standard lengths for loading units should be maintained in order to sustainably ensure compatibility with different transport modes. The rail freight transport system is less flexible when it comes to deviations from standards, e.g., semitrailers that exceed 15 m cannot be transported on any pocket wagon.

The modelling shows that the proposed measures entail the risk of a reverse modal shift in the range of 16-20 % for CT and rail freight transport. This is due to cost savings in road transport that can be realised by introducing longer or heavier vehicles. However, while transport costs could be reduced, this reverse modal shift would lead to a drastic increase in external costs. It would be therefore advisable to take this into account when developing the measures, in order to favour transport modes such as rail, which offer significant advantages in terms of external costs.

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