

CONTRIBUTION OF LHVS TO EU ENVIRONMENTAL POLICY

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Abstract

This paper describes the methodology used to estimate the likely effects of allowing Long Heavy Vehicles (LHV) in European cross-border freight transport on emissions of carbon dioxide (CO₂), nitrogen oxides (NO_x) and particulate matter (PM). This research is part of a study commissioned by the EC, Directorate for Transport and Energy, in the first half of 2008.

The methodology is based on the emission calculation tool COPERT IV as implemented in the European transport model TREMOVE. A disaggregated approach is used to allow for great detail in terms of vehicle type, vehicle technology, load factor, road type, region and time of day.

On the level of the individual vehicle, 25.25m/60t LHV can be up to 12.45% more fuel efficient compared to standard 18.75m/40t Heavy Duty Vehicles (HDV).

Overall, i.e. accounting for fleet uptake, distance driven and modal split changes, heavy freight transport can become 3.6% more fuel efficient.

Keywords: Long Heavy Vehicles, Europe, Emissions, Freight Transport, TREMOVE, COPERT

1. Introduction

1.1 General background

In December 2008, the EU Parliament and Council reached an agreement on a package to reduce greenhouse gas (GHG) emissions by 20% (compared to 1990 levels), as well as increase the share of renewables in energy use to 20% by the year 2020 [1]. While the main tool to reach these goals is the EU Emission Trading Scheme (ETS) for CO₂, the most prominent of GHG, a certain number of sectors are not included in the EU ETS. Road transport is among the leaders of the pack that is outside the ETS. For road transport as a whole, a separate target is set at a 10% reduction compared to 2005 levels by 2020.

As transport is vital in the logistic processes that support economic growth, limiting transport volume is not a favourable option. One of the pathways to follow is that of increased energy efficiency in transport. Broadly speaking, there two ways to achieve this: working towards the best modal mix, and improving the efficiency of every separate mode. A tool often described for the former is the internalisation of external costs: as all modes are held accountable for their full cost to society, end-user prices will determine the optimal outcome. This paper will focus on the latter, and in particular on freight transport and on how efficiency of road transport in Europe can be improved by introducing LHVs (Long Heavy Vehicles).

In the broader field of noxious emissions, the EU has taken a pioneer's role in setting up emissions standards: the EURO classes [2]. EURO V, in force since October 2008, further limits the exhaust of CO, HC, NO_x and PM for newly sold heavy duty vehicles, while similar standards exist for passenger cars and light duty vehicles. The Euro VI norm for Heavy Duty Vehicles (HDV) which will take effect for all new vehicles from January 2013 onwards, will further tighten limitations for HC, NO_x and PM.

Six effects of introducing LHVs in the EU were studied by a consortium of five partners (TML, TNO, Sétra, LCPC and RWTH Aachen) for the European Commission's DG Transport & Energy: LHVs' contribution to meeting future increases in demand, mode choice, road safety, infrastructure, energy efficiency and noxious emissions [3]. In a setup with a reference (Business-as-usual) scenario S1 with only "normal" 16.5/18.75 – 40t HDV road freight transport, three alternative policy scenarios were drafted:

- S2: "LHV Full Option": allowing LHVs of up to 25.25m – 60t on the entire primary road network (motorways) within the EU;
- S3: "Corridor": LHVs of 25.25m and 60t are allowed to cross borders, but only after prior agreement between neighbouring countries. As an example, a corridor of selected countries (Finland, Sweden, Denmark, Germany, the Netherlands and Belgium) allow them on their primary roads;
- S4: "Compromise": LHVs of up to 20.75m – 44t are allowed on the entire primary road network within the EU. This increase was chosen to reflect the wishes of the chemical and car transporting industries.

The evaluation was performed for the year 2020.

This paper describes in detail the methodology followed for estimating the effects on energy efficiency and noxious emissions, providing a more detailed look at how emission calculations were performed. First, the methodology to calculate emissions of individual

vehicles is discussed, followed by an overview of the main results and a sensitivity analysis. To complete the picture, we take a look at demand and modal split effects of introducing LHV, as both of them have a significant impact on the overall emission levels of transport.

1.2 Types of emissions and their impact

Energy efficiency of freight transport is measured in terms of energy consumption per tonne-km. For road transport, this is generally equivalent to fuel consumption, more specifically diesel fuel for the freight market. As such, improving energy efficiency contributes to decreasing operational costs. CO₂ emissions are directly related to fuel consumption. For each litre of diesel fuel that is consumed, approximately 2.62 kg of CO₂ are emitted into the air.¹ CO₂ is a greenhouse gas, likely the most important anthropogenic contributor to the greenhouse effect, which has been linked to global warming.

NO_x is a generic term for mono-nitrogen oxides (NO and NO₂). Ground-level (tropospheric) ozone (smog) is formed when NO_x and volatile organic compounds (VOCs) react in the presence of sunlight. Children, people with lung diseases such as asthma, and people who work or exercise outside are susceptible to adverse effects such as damage to lung tissue and reduction in lung function. Ozone can be transported by wind currents and cause health impacts far from original sources. Other impacts from ozone include damaged vegetation and reduced crop yields.

PM or particulate matter are tiny particles of solid or liquid suspended in a gas. It is generally classified based on its diameter, ranging from 10 µm to smaller than 0.1µm. PM has an impact on human (and animal) health. Inhalation of the bigger particles (between 2.5 µm and 10 µm) can cause pulmonary diseases such as asthma or lung cancer. Emissions of traffic are mainly PM below 2.5 µm. Inhaling particles of that size can also lead to cardiovascular problems. The road transport sector contributes with both vehicle exhaust particles and resuspension of road dust.

2. Methodology

To calculate emissions and fuel consumption, the COPERT IV [4] methodology was used, in accordance with its setup within the TREMOVE model [5]. TREMOVE is a policy assessment model, designed to study the effects of different transport and environment policies on the emissions of the transport sector.

The key variables in the calculations are:

- truck type,
- truck technology,
- region (urban/motorway/rural road),
- timing (peak/off peak),
- load factor.

¹ Formula: $[CO_2] = \frac{44.011 * DENS * FC_v}{12.011 + (1.008 * RHC)}$,

with [CO₂] = the weight of CO₂ exhausted, DENS = fuel density (g/l; for diesel, this is 835), FC_v = fuel consumption in liter, and RHC the ratio of hydrogen and carbon atoms in the fuel (for diesel, this is 2).

These variables will be discussed in the following paragraphs.

HDVs are split in TREMOVE based on their Gross Vehicle Weight (GVW). In the standard model, four types exist:

- 3.5 t - 7.5 t (HTD1²)
- 7.5 t - 16 t (HTD2)
- 16 t - 32 t (HTD3)
- 32 t - 40 t (HTD4)

While this is sufficient for the base case, the other scenarios require modelling greater gross vehicle weights. Therefore, two types are added:

- 40 t - 50 t (HTD5)
- 50 t - 60 t (HTD6)

COPERT IV works with a different set of truck types. These are:

- | | |
|---|---|
| <ul style="list-style-type: none">• Rigid- 3.5 t - 7.5 t (HDT_RIGID1)- 7.5 t - 12 t (HDT_RIGID2)- 12 t - 14 t (HDT_RIGID3)- 14 t - 20 t (HDT_RIGID4)- 20 t - 26 t (HDT_RIGID5)- 26 t - 28 t (HDT_RIGID6)- 28 t - 32 t (HDT_RIGID7)- 32 t + (HDT_RIGID8) | <ul style="list-style-type: none">• Articulated- 14 t - 20 t (HDT_ARTIC1)- 20 t - 28 t (HDT_ARTIC2)- 28 t - 34 t (HDT_ARTIC3)- 34 t - 40 t (HDT_ARTIC4)- 40 t - 50 t (HDT_ARTIC5)- 50 t - 60 t (HDT_ARTIC6) |
|---|---|

A link exists between these classifications. The column “proportion” shows the share of the COPERT type in the TREMOVE type:

² HTD: Heavy Truck - Diesel, TREMOVE's code for HDVs.

Table 1 - TREMOVE-COPERT link for vehicle types

TREMOVE	TREMOVE description	COPERT	COPERT description	proportion
HTD1	heavy duty truck 3.5-7.5t - diesel	HDT_RIGID1	RT <=7.5t	1
HTD2	heavy duty truck 7.5-16t - diesel	HDT_RIGID8	RT >7.5-12t	0.25
HTD2	heavy duty truck 7.5-16t - diesel	HDT_RIGID2	RT >12-14t	0.25
HTD2	heavy duty truck 7.5-16t - diesel	HDT_RIGID3	RT >14-20t	0.25
HTD2	heavy duty truck 7.5-16t - diesel	HDT_ARTIC1	TT/AT >14-20t	0.25
HTD3	heavy duty truck 16-32t - diesel	HDT_ARTIC1	TT/AT >14-20t	0.1
HTD3	heavy duty truck 16-32t - diesel	HDT_ARTIC2	TT/AT >20-28t	0.16
HTD3	heavy duty truck 16-32t - diesel	HDT_ARTIC3	TT/AT >28-34t	0.16
HTD3	heavy duty truck 16-32t - diesel	HDT_RIGID3	RT >14-20t	0.1
HTD3	heavy duty truck 16-32t - diesel	HDT_RIGID4	RT >20-26t	0.16
HTD3	heavy duty truck 16-32t - diesel	HDT_RIGID5	RT >26-28t	0.16
HTD3	heavy duty truck 16-32t - diesel	HDT_RIGID6	RT >28-32t	0.16
HTD4	heavy duty truck >32t - diesel	HDT_ARTIC4	TT/AT >34-40t	0.5
HTD4	heavy duty truck >32t - diesel	HDT_RIGID7	RT >32t	0.5
HTD5	heavy duty truck >32t - diesel	HDT_ARTIC5	TT/AT >40-50t	1
HTD6	heavy duty truck >32t - diesel	HDT_ARTIC6	TT/AT >50-60t	1

Truck technology corresponds to the EURO classes as described before.

Region and timing are determinants for the speed, a key parameter in exhaust emission calculation. Average speeds were derived from TREMOVE, which in turn used SCENES [6], a European transport network model, as its source.

The effect of load factor [average payload]/[maximum vehicle capacity] on fuel consumption can work in 2 ways: (1) the engine of a vehicle with a heavier load has to generate more power; and/or (2) vehicles normally carrying a heavy load may be equipped with a bigger engine (as a rule of thumb, 10 hp for every tonne of GVW). The maximum vehicle capacity was set at 26 tonnes for HDVs. Capacity of the heaviest LHV class for scenarios S2: “Full option” and S3: “Corridor” was set at 39.5 tonnes, while LHVs used in the S4: “Compromise” scenario has a capacity of 29 tonnes.

The average load factor in terms of weight is typically close to 50% on average for all trips. The average payload is derived from baseline freight demand in TREMOVE, and calculated as [number of tonne-km]/[number of vehicle-km] (tonne-km and vehicle-km data were also derived from SCENES). Payload in terms of volume was not calculated, but it could be argued that only weight has a significant influence on fuel consumption. The same load factor was assumed for standard 40t HDV and 60t LHV.

Based on these variables, COPERT then provides a set of calibrated formulas and parameters to calculate real world emissions for an empty truck, a half-loaded truck and a truck at maximum capacity - in terms of weight. The load factor is then used to determine the actual emissions by linear interpolation.

As an example, the five formulas for fuel consumption of LHV classes (HTD5 and HTD6) are:

$$\bullet \quad FC = e + a * \exp(-b * v) + c * \exp(-d * v); \quad (1)$$

- $FC = \frac{1}{a + (b * v)}$; (2)
- $FC = c + a * \exp(-b * v)$; (3)
- $FC = c + a * \exp(b * v)$; (4)
- $FC = a * v^2 + b * v + c$; (5)

where v is speed and $[a-e]$ are coefficients, which depend on the combination of vehicle type, EURO class and load factor. For empty and half loaded vehicles, formula (1) is valid. For a full HDV, all five are possible.

For formulas for NO_x, PM and other pollutants, we refer to [4].

This methodology then allows comparing fuel consumption and emissions between truck classes and so estimating the efficiency gains possible for freight transport with LHVs as opposed to only using “normal” HDVs.

In addition to exhaust emissions, the EC project also calculated well-to-tank emissions, using TREMOVE methodology³. This was needed to provide a solid base for comparison between different transport modes using different energy sources. For diesel fuel, the source is the production and transportation of the fuel.

3. Results of calculation

3.1 Fuel consumption

“Normal” HDVs have an estimated average fuel consumption of 30.28 l/100 km. Fuel efficiency is at 25.7 l/1000 tonne-km. This is equivalent to 67.2554 g of CO₂ emitted per tonne-km. Well-to-tank emissions add another 19.4% to this (for all diesel fuel).

The fuel efficiency for LHVs of 25.25m and 60t was calculated to be 22.62/1000 tonne-km for the S2: “Full option” scenario. This equals a gain of 12.45% in fuel consumption and in CO₂ emissions compared to “normal” HDVs (HTD4). The fuel consumption per distance travelled is of course higher, and stands at 40.65l/100 km. The efficiency gain for LHVs in the “corridor” scenario is marginally lower due to slightly lower load factors.

A 44t LHV was demonstrated to have a fuel efficiency 0.31% worse than normal HDVs. This is likely due to the very moderate extra load that can be carried relative to the bigger vehicles assumed to be needed. Because of the small margin, the statistical significance of this loss of efficiency may not be very robust.

3.2 Nitrous oxides

The results for NO_x follow a very similar pattern, as NO_x is also closely related to fuel consumption. However, as the introduction of LHVs may cause transporters to buy new, more powerful lorries, a relatively higher share of LHVs will have the latest EURO VI technology

³ For CO₂, the source was the joint CONCAWE/EUCAR/JRC report [9]. For NO_x and PM, the ECOINVENT database was used [10]

on board. As a result, the decrease of NO_x will be slightly higher for 60t LHVs, relative to CO₂, and reach up to 13.2% per tonne-km.

In 44t LHVs, NO_x emissions per tonne-km will likely remain almost constant, as was the case for CO₂.

3.3 Particulate matter

Particulate matter emissions decrease for a combination of three reasons: better fuel efficiency, technological improvements due to the higher share of EURO VI, and a decrease in vehicle-kms driven. The former two have been clarified before. The latter is explained by the fact that a significant part of what is measured as PM emissions, is actually road dust, from mechanical abrasion of the vehicle on road pavement, which is resuspended into the air by vehicles driving by. As fewer longer and heavier trucks vehicle-km are needed to transport the same amount of cargo, this keeps total PM emissions down. The PM emissions decrease per tonne-km of LHVs vs. HDVs can be up to 25%.

For 44t LHVs, the lower amount of vehicle-km needed works as it did for 60t trucks: total PM emissions per tonne-km are expected to decrease by almost 7%.

3.4 Sensitivity

Sensitivity has been investigated for S2: “Full option” and S3: “Corridor”, where not 60t but 50t would be the maximum weight, given that the case is commonly made that a volume increase is more needed than a weight increase. For scenario 4, an evaluation was made for using 48 t instead of 44 t, as for some sectors, including the chemical industry, extra capacity in terms of weight is the main requirement.

With the modified load factors, CO₂ emissions for the 25.25 m / 50 t truck (S2 and S3) decrease by 5.09 % per vehicle-km. However, per tonne-km, they increase by 13.72 %. Under simplified assumptions, LHVs of those dimensions could even be more expensive per tonne-km than classic HDVs (on average 1.72 %).

The LHV of max 20.75 m/48 t (S4) would emit 6.02 % less CO₂ per tonne-km than the 44 t variant. This type of LHV is 4.64 % more fuel efficient per tonne-km compared to classic HDVs.

For NO_x and PM, similar trends were found.

A very important caveat of the previous analysis is that, as load factors are based on weight, volume goods do not quite fit within the logic described above: the capacity increase of 25% that 50t LHVs provide (down from the 50% of 60t LHVs), would not be valid. Interviews with experts have shown that 50-70% of all transports are limited by volume rather than weight. Hence, the efficiency gain in comparison to 40t HDVs would likely be closer to the 12.45 % mentioned in 3.1, as the volume capacity increase remains at 50%.

4. Completing the picture

4.1 Demand effects

Given the lower fuel consumption per tonne-km, as well as the need for fewer drivers and lorries needed to transport the same amount of freight, a drop in road freight transport price was assumed. Common economic logic predicts this will likely result in an increase in demand for freight road transport.

While not the main subject of this paper, the study [3] did investigate what the effect would be, using the European transport network model TRANS-TOOLS [11]. A number of assumptions were used to establish the generation effect the price decrease would have: on average, the cost discount for using LHVs was set at 20%. Based on expert judgment, the uptake of LHVs in total road freight transport with heavy vehicles (thus not including smaller truck classes) is around 30%, depending on commodity type and trip distance.

Results of the analysis showed that total road freight vehicle-kms would decrease by 12.9% in the S2: “Full Option” scenario, while total tonne-kms would in fact increase by 0.99%. This slightly compensates the efficiency gains from using LHV when looking at the effect on total emissions of road freight in Europe.

Another study on the same subject conducted by the EC’s JRC-IPTS [7] showed a more moderate decrease in road freight vehicle-kms (-2.3%), mainly due to a lower assumed uptake. Still, environmental impact under these circumstances would be positive.

4.2 Other modes

The extra demand in road freight would not only be due to its lower absolute price, but also by its lower relative price compared to rail and inland waterway transport. These modes are generally accepted to provide more energy efficient transport than road, even with LHV transport available, albeit with restrictions related to the availability of infrastructure.

While it is debatable to which extent the markets for transport by road vs. rail and inland waterways (IWW) overlap, there is no doubt that these modes will experience some decrease in market share and overall transport volume. As a higher share of total freight will be transported by road, again some of the efficiency gains caused by shifting to LHV could be lost. Output from the TRANS-TOOLS model indicates volume for rail could decrease by some 3.8%, while IWW transport could stand to lose 2.9% of its volume.

However, this also implies these modes will in turn consume proportionally less energy in absolute figures.

The risk of introducing LHVs in Europe lies in those markets where rail or specifically combined rail-road transport operates with very small profit margins. A cost advantage for road could push its competitors out of the market entirely, with far-reaching consequences for rail on specific trajectories. If introducing LHVs is to have a favourable contribution to the EU’s environmental policy, this aspect has to be managed closely.

4.3 Results in absolute figures

Rolling out 60t LHVs in the entire European Union (as in S2: “Full option”) could save up to 5.2 million tonnes of CO₂ annually (3.8 of which come from the efficiency improvements in road), about 3.6% of total emission of heavy freight transport in Europe. When applied on a smaller scale as in the S3: “Corridor” scenario, about 1 million tonnes of those savings remain. Extending dimensions of modules to 44t and 20.75m is not favourable in terms of emissions, as about 0.3% more CO₂ would be emitted.

For NO_x, savings could reach up to 27 278 tonnes annually, 3.7% of total NO_x of heavy freight. For PM, 5% of total heavy freight emissions or 1 738 tonnes can be saved.

5. Conclusions

On a “per tonne-km” basis, LHVs can have an important contribution to the improvement of environmental performance of road freight. For global (CO₂), regional (NO_x) and local (PM) pollutants, significant benefits can be reaped in a well-conceived transportation system. Gains for these pollutants range from 12 to 25%, for LHVs of 25.25m and 60 tonnes.

On the other hand, it should be duly noted that for the total freight transportation market, the final effect of introducing LHVs highly depends on the uptake and shifts in modal balance. The lower operational cost of LHV freight transport can pull market share away from still less-polluting modes like rail and inland waterway transport. Reference [3] provides a detailed analysis on other determinants of the eventual outcome of introducing LHVs in the EU.

Under the cautious assumptions made for the study [3] underlying this paper, the 3.8 million tonnes of CO₂ coming from the efficiency improvements in road, would account for 0.4% of 2006 EU road emissions [8]. In light of the 10% improvement sought by 2020, the introduction of LHVs would be a useful (yet not overwhelming) contribution to achieving this goal, as long as the interaction with other modes is closely monitored.

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