Assessing the impacts of long-trucks on mode choice in freight transport and environment at European level

Stephan Kirsten[1], Carina Thaller[2] and Andreas Lischke[3]

[1] Deutsches Zentrum für Luft- und Raumfahrt e. V., Institute of Transport Research, Berlin, Germany
[2] Deutsches Zentrum für Luft- und Raumfahrt e. V., Institute of Transport Research, Berlin, Germany
[3] Deutsches Zentrum für Luft- und Raumfahrt e. V., Institute of Transport Research, Berlin, Germany

Abstract. Freight transport emits a high percentage of our global industrial carbon dioxide, which is a main factor of today's global warming. Any reduction of the carbon dioxide emission reduces negative effects on the global climate. Focussing on this challenge, we analyse the influence of new long-trucks (EMS1 and EMS2) on mode choice and environment at the European level. For assessing the impacts of these new truck types, we use a macroscopic freight transport model for Germany in the first step. The resulting freight transport performance is upscaled to European level. Finally, we calculate the carbon dioxide emissions for the three modes 'rail', 'road' and 'inland waterways' for whole Europe: with and without the long-trucks EMS1 and EMS2.

1 MOTIVATION AND OBJECTIVES

The European freight transport is challenged by several new situations: (i) increasing global economy, (ii) predominance of oil-depending transport means as well as (iii) its greenhouse gas (GHG) emissions. The aim of the European Union is affordable goods for all European citizens in a strong Single European Market as well as an ecological freight transport in Europe. For this reason, we will analyse two new long-haul heavy duty vehicle (HDV): European Modular System EMS1 – as a combination of a rigid, a new dolly application and a semitrailer with a length of 25.25 metres and up to XX tonnes in weight – and EMS2 – as a combination of a tractor, a new dolly application and two semitrailer with a length of 32 metres and up to XX tonnes in weight – and their impacts on European freight transport and environment in the framework of the research project 'AEROFLEX', funded by the European Union in HORIZON 2020. These truck types shall be used on specific European highways for a more efficient and more ecological-friendly transport. By our macroscopic freight transport model DEMO-GV, we show the impacts of the two truck types EMS1 and EMS2 in 2040.

2 GERMAN FREIGHT TRANSPORT MODEL DEMO-GV

First, we use our German macroscopic freight transport model 'DEMO-GV'. By this model, we calculate the freight transport demand in Germany differentiated into the transport modes 'rail', 'road' and 'inland waterways' (iww) in 2040. This model is a 4-step approach which includes freight generation, distribution, modal split and transport means split. Depending on the average transport costs on the three modes, we derive freight transport volume and performance between 431 German and 170 foreign European traffic cells. The freight demand is differentiated into commodity groups according to the classification NST 2007. The model 'DEMO-GV' can be configured by different transport costs on 'rail', 'inland waterways' and a flexible number of vehicles types for road freight transport. In the following, the 4-step approach of DEMO-GV will be explained in detail.

Step 1: Freight Generation

Depending on forecasted added values (in euros) for each traffic cell for the forecast year 2040, the supply and the use of each commodity in each traffic cell is calculated. Especially, value-density of each commodity is used [1]. In the end, there is the freight transport volume in every cell as source and sink.

Step 2: Distribution

The relations between the sources and sinks of the generated freight transport volume will be determined by an 'iterative proportional fitting', using the 'gravity model of trade' between source and sink.

Step 3: Modal Split

Based on the costs for an average delivery between source and sink of the three modes for a commodity, we calculate the utilities for all three modes (BVU [2]). The utility u represents the value of a freight transport from the origin (source) to the destination (sink) with the specific mode, corresponding to the logit model [3]:

$$p_i = \frac{\exp(u_i)}{\exp(u_{rail}) + \exp(u_{road}) + \exp(u_{iww})} \quad (1)$$

p_i is the probability for the transport of an average delivery between origin and destination cell for each mode i. If transport volume tv is the total mass which is transported between origin and destination of a commodity, tv_i is the mass which is transported with mode i between these two cells (modal split):

$$tv_i = tv \cdot p_i \qquad (2)$$

All utilities are calibrated by the modal splits of 2010.

Step 4: Mean Split
The transport volume tv_{road} which is transported on the road can be differentiated into different truck types. We use EUROSTAT data [4] for estimating the parameters for each truck type for a maximum likelihood model (probability p_{mean}). This probability provides the transport volume tv_{mean} which is transported by a specific truck type (mean split) between origin and destination cell:

$$tv_{mean} = tv_{road} \cdot p_{mean} \qquad (3)$$

3 UPSCALING TO EUROPEAN LEVEL

The modal split and the means split on the road of 'DEMO-GV' have to be upscaled to European level. First, we calculate the freight transport performance tp at German level, multiplying the transport volume tv by the distance d between the cells at German level. The unit is tonne-kilometre [tkm]:

$$tp = tv \cdot d_{Germnany} \qquad (4)$$

The next step is an extension on the freight transport performance tp which exists at European level. For this reason, we assume:

$$\frac{tp_{German,c,i}}{total\ tp_{German}} = \frac{tp_{EU-28,c,i}}{total\ tp_{EU-28}} \qquad (5)$$

$tp_{German,c,i} =$ Freight transport performance at German level for commodity c with mode i [tkm]
$total\ tp_{German} =$ Total freight transport performance at German level [tkm]
$tp_{EU-28,c,i} =$ Freight transport performance at European level for commodity c with mode i [tkm]
$total\ tp_{EU-28} =$ Total freight transport performance at European level [tkm]

We assume the European territory as the territory of the EU-28. The assumption (5) is the result of the same mode ratios in Germany and the EU-28 (EUREF 2016 projection [5]). Based on equation (5) and the total projected freight transport performance in EU-28 of EUREF in 2016, a disaggregated freight transport performance in EU-28 in 2040 is derived. The freight transport performance is disaggregated by NST-2007-classification and the three modes.

Our projection of freight transport performance at European level in 2040 can be extended by new truck types, like EMS1 and EMS2 with their specific vehicle characteristics (i.e. payload, transport costs) for each commodity group.

4 CO_2 EMISSIONS AT EUROPEAN LEVEL

The projection of freight transport performance for each country is used for the mileage m performedper mode. m is calculated by standard vehicle loads, depending on distance, mode, vehicle-type and commodity:

$$m\ [km] = \frac{tp\ [tkm]}{vehicle\ load\ [t]}$$

m is multiplied by fuel consumption per km fc_{km} to derive the total fuel consumption per year for each mode fc. Afterwards, we calculate CO_2 emissions per year for each mode based on the product $fc\ \beta_e$. In this case, β_e are the specific CO_2 emission factors for each mode

5 SCENARIO DEVELOPMENT AND EXPECTED RESULTS

Baseline scenarios for the baseline year 2010 and the forecast year 2040 already exist. In the framework of this project, we develop four scenarios for the forecast year 2040: (i) EMS 1 without any restrictions, (ii) EMS 1 und 2 without any restrictions, (iii) considering external costs for the three transport modes and (iv) EMS 1 und 2 for selected commodity groups. Based on this, DEMO-GV will be prepared and parametrized to carry out the simulations for the baseline and the four future scenarios. Afterwards, the steps described in chapter 3 and 4 are conducted to show the transport-related and ecological impacts of long-trucks EMS 1 and 2 at European level in comparison to the baseline scenario.

References

1. Stephan Müller, Axel Wolfermann, Sandra Burgschweiger:
Analysing the connection between gross value added of industries and freight transport demand, at: *ICPLT*, (2015)
2. BVU Beratergruppe Verkehr+Umwelt GmbH: Entwicklung eines Modells zur Berechnung von modalen Verlagerungen im Güterverkehr für die Ableitung konsistenter Bewertungsansätze für die Bundesverkehrswegeplanung, (2015)
3. Daniel McFadden: Conditional logit analysis of quantitative choice behavior, In: *Frontiers in economics,* p. 105-142, (1974)

4. EUROSTAT:
https://ec.europa.eu/eurostat/de/data/database,
(status: 2020)
5. EUREF:
https://data.europa.eu/euodp/en/data/dataset/energy-modelling, (status: 2020)