Impact of High Capacity Vehicles on EU freight transport

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Motivation

- Freight transport contributes to worldwide CO_2 emission
- New zero emission road-vehicle types and more efficient road transport are necessary
- We analyzed two new long-haul duty vehicle (HDV) configurations and their impact on EU freight transport

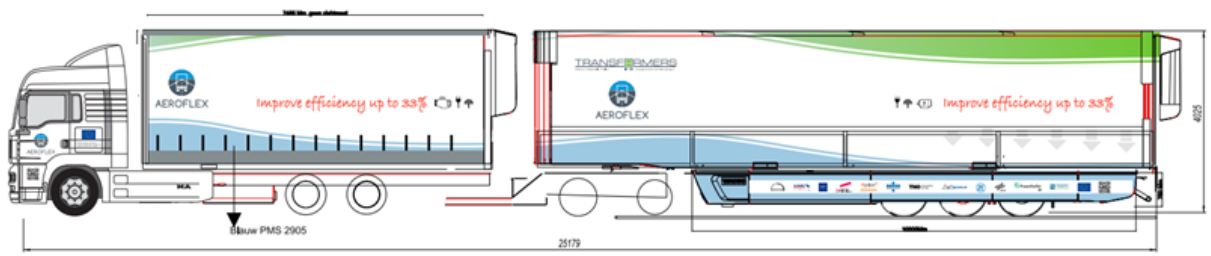
- Using our self-developed macroscopic freight transport model DEMO-GV (‘Deutschlandmodell für den Güterverkehr’)
- Upscaling on European level

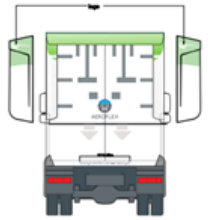
Source (16/03/2021):
https://www.genius-community.com/tag/wlan/
https://www.mantruckandbus.com/de/innovation/meilensteine-des-fortschritts.html

Motivation

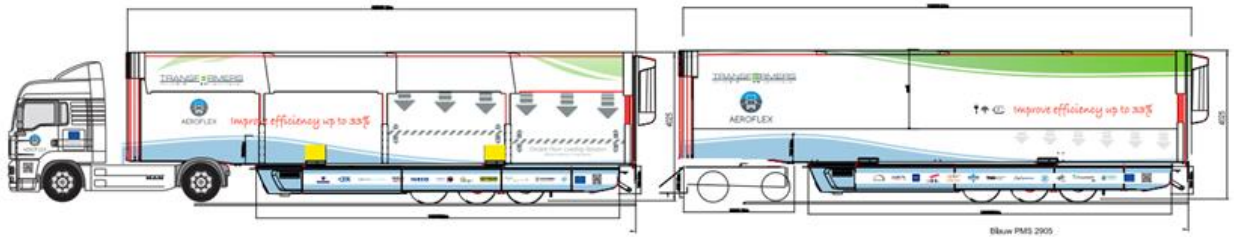
Two new long-haul duty vehicle (HDV) configurations with e-dolly (battery package and an e-axle):

- **EMS1** (European Modular System) – 25.25 m and 60 t GCW





- **EMS2** (European Modular System) – 32 m and 74 t GCW



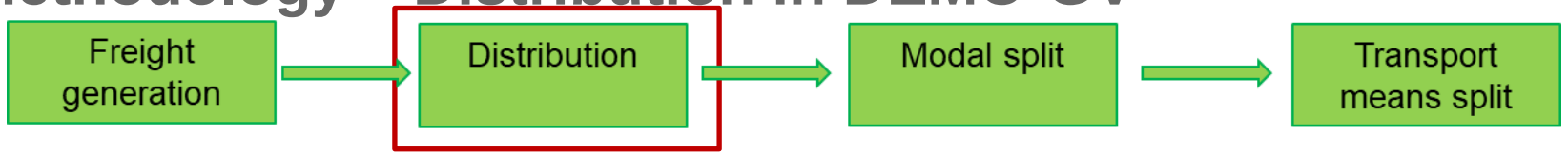
Methodology - German freight transport model DEMO-GV

- We use our macroscopic freight transport model ‚DEMO-GV' for the 3 transport modes: ‚rail', ‚road' and ‚inland waterways' (iww): 601 traffic cells on European area (431 German, 170 foreign ones)
- All traffic cells are connected via 3 networks (each mode one network)
- Freight demand is differentiated into commodity groups according classification NST 2007 and consider combined transport (CT) as own transport mode
- 'DEMO-GV' is a classic 4-step approach which includes freight generation, distribution, modal split and transport means split

Methodology – Freight generation in DEMO-GV

- Produced and needed freight volume [tons] is calculated for each traffic cell (sources and sinks)
- Calculated freight volumes corresponds to gross value added (GVA) (Müller et al. 2015)
  1. Calculating freight volume which is exported/imported from/into Germany, overseas transport included
  2. Calculating freight volume which is just transported inside Germany
  3. Adding missing foreign overseas freight volume
  4. Calibrating source freight volumes for each commodity group

Methodology – Distribution in DEMO-GV



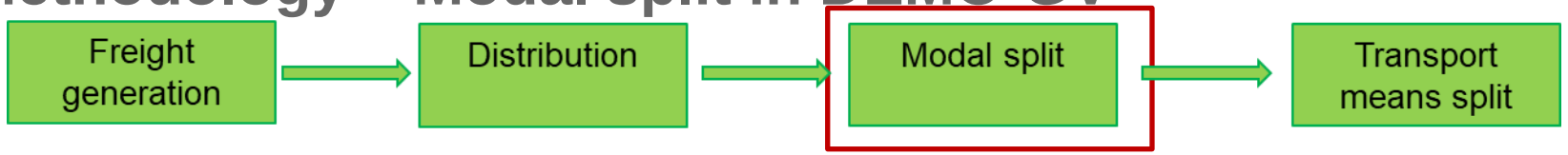
- Distributing freight volumes between source-sink-relations via ‘iterative proportional fitting’
- Gravitation assumption between source i and sink j:

$$\exp\left(\beta_c \cdot EMU_{ij}\right) \cdot m_i^q \cdot m_j^s$$

$$EMU_{ij} = \ln\left(e^{u_{rail}} + e^{u_{road}} + e^{u_{iww}}\right)$$

β_c:	Fading rate of commodity c between source i and sink j [1]
m_i^q:	Total freight of commodity c which is transported from source i [t]
m_j^s:	Total freight of commodity c which is transported to sink j [t]
u_m:	Utility between source i and sink j for each commodity c and mode m [1]
EMU_{ij}:	“Estimated maximum utility” source i and sink j [1]

Methodology – Modal split in DEMO-GV



$$u_{y,i,j,c,s,m} = \beta_s^C \, BC\left(c_{y,i,j,c,s,m}, \lambda_s^C\right) + \beta_s^T \, BC\left(t_{i,j,c,s,m}, \lambda_s^C\right) + \beta_s^P \, p_{y,type,m} + \beta_s^D \, BC\left(d_{y,type,m}, \lambda_s^D\right)$$

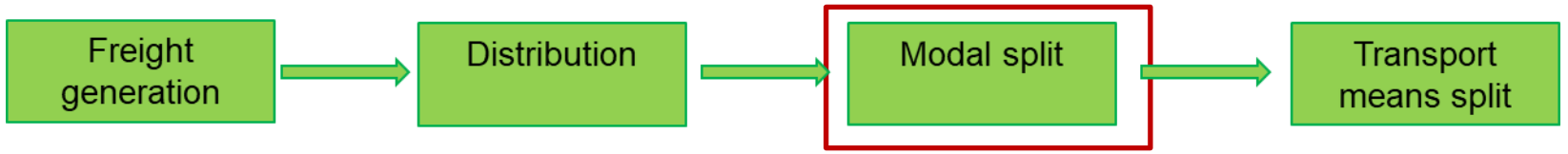
Segment	Description
1	Maritime CT
2	Continental CT
3	Delivery about 100 t or more
4	Agriculture products, groceries
5	Stones and bulk
6	Petroleum products
7	Chemical products, fertiliser
8	Metal and metal products
9	Cars, machines, equipment
10	Other goods

$\beta_s^C, \beta_s^T, \beta_s^P, \beta_s^D$ and $\lambda_s^C, \lambda_s^T, \lambda_s^D$ calibrated for each segment (BVU et al. 2012)

Calibrating $u_{y,i,j,c,s,m}$ according to freight demand in 2010 (distribution matrix, PTV Group, TCI Röhling, Mann 2016):

$$u_{y,i,j,c,s,m}^{calibrated} = u_{y,i,j,c,s,m} + \alpha_{i,j,c,s,m}$$

Methodology – Modal split in DEMO-GV



Calibrating $u_{y,i,j,c,s,m}$ according to freight demand in 2010 (distribution matrix, PTV Group, TCI Röhling, Mann 2016):

$$u_{y,i,j,c,s,m}^{calibrated} = u_{y,i,j,c,s,m} + \alpha_{i,j,c,s,m}$$

$$p_{i,j,c,s,m} = \frac{\exp\left(u_{i,j,c,s,m}^{calibrated}\right)}{\sum_{mode} \exp\left(u_{i,j,c,s,mode}^{calibrated}\right)}$$

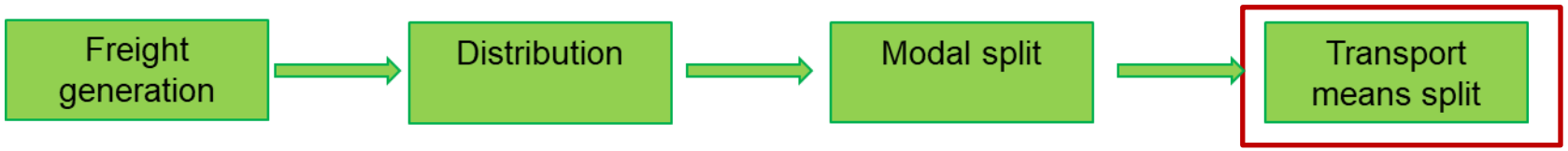
$$m_{i,j,c,s,m} = p_{i,j,c,s,m} \cdot m_{i,j,c,s}$$

$m_{i,j,c,s,m}$: Freight of commodity c or (maritime/continental) CT, between source i and sink j, mode m [t] Modal split

$p_{i,j,c,s,m}$: Probability of transporting freight of commodity c or (maritime/continental) CT, between i and j, mode m

$m_{i,j,c,s}$: Total freight of commodity c or (maritime/continen -tal) CT, between in and j [t]

Methodology – Transport means split in DEMO-GV



Means Split on road, depending on gross combination weight (GCW)

- Truck 3.5 ≤ 7.5 t GCW
- Truck 7.5 ≤ 12 t GCW
- Truck 12 ≤ 18 t GCW
- Truck 18 ≤ 26 t GCW
- Truck 26 ≤ 40 t GCW
- Truck 40 ≤ 60 t GCW **(EMS1)**
- Truck 60 ≤ 74 t GCW **(EMS2)**

Mean Split depends on **cost per ton and regional (≤150 km) or long-distance (>150 km) traffic**!

All α/γ's are calibrated on observed freight transports on road (Eurostat 2011): **Maximum likelihood estimation**

$$u_{i,j,c,s,m=road,tm} = \left(\alpha_{regional,cl} \cdot c^{ton}_{i,j,c,s,tm} + \gamma_{regional,cl,tm}\right) \cdot \delta^{regional}_{ij} + \\ + \left(\alpha_{longDistance,cl} \cdot \ln\left(c^{ton}_{i,j,c,s,tm}\right) + \gamma_{longDistance,cl,tm}\right) \cdot \delta^{longDistance}_{ij}$$

Methodology - Upscaling on European level

- After all, results have to be extended on European level (EU-28)
- We assume (EUREF 2016 projection):

$$\frac{tp_{German,c,i}}{total\ tp_{German}} = \frac{tp_{EU-28,c,i}}{total\ tp_{EU-28}}$$

$tp_{German,c,i}$: Freight transport performance at German level for commodity c with mode i [tkm]

$total\ tp_{German}$: Total freight transport performance at German level [tkm]

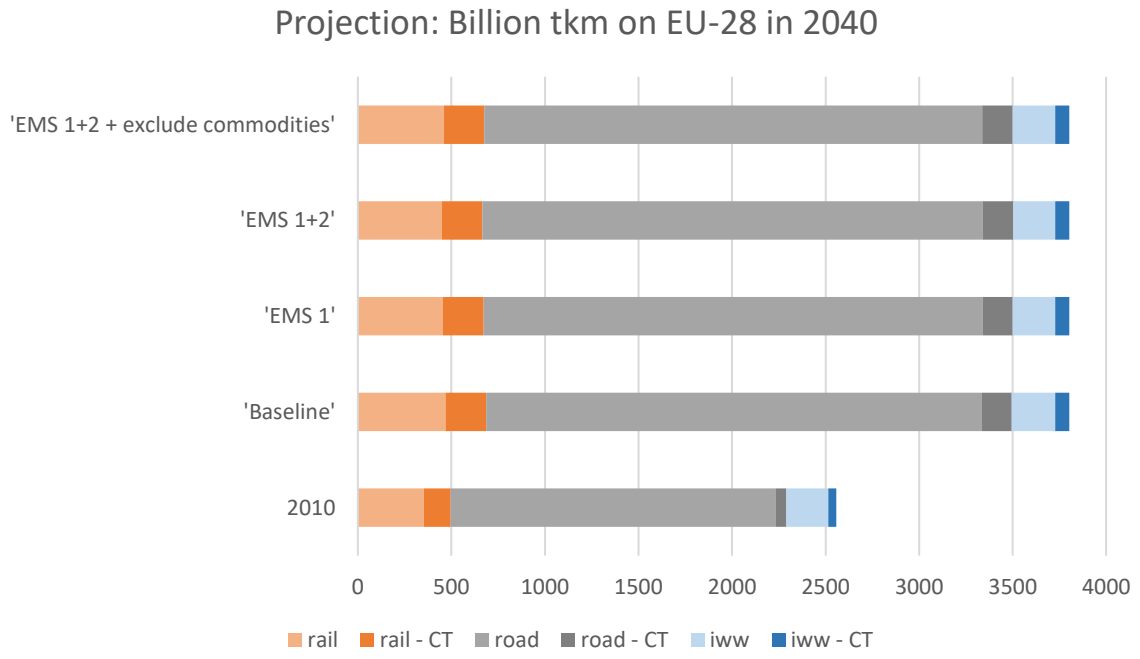
$tp_{EU-28,c,i}$: Freight transport performance at European level for commodity c with mode i [tkm]

$total\ tp_{EU-28}$: Total freight transport performance at European level [tkm]

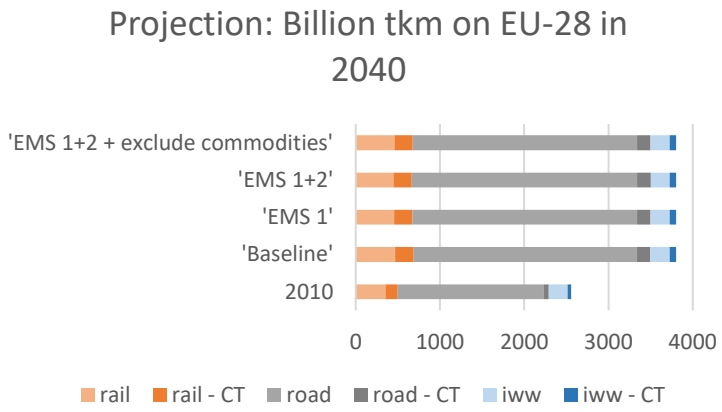
Results – Scenarios to indicate impacts compared to a basline

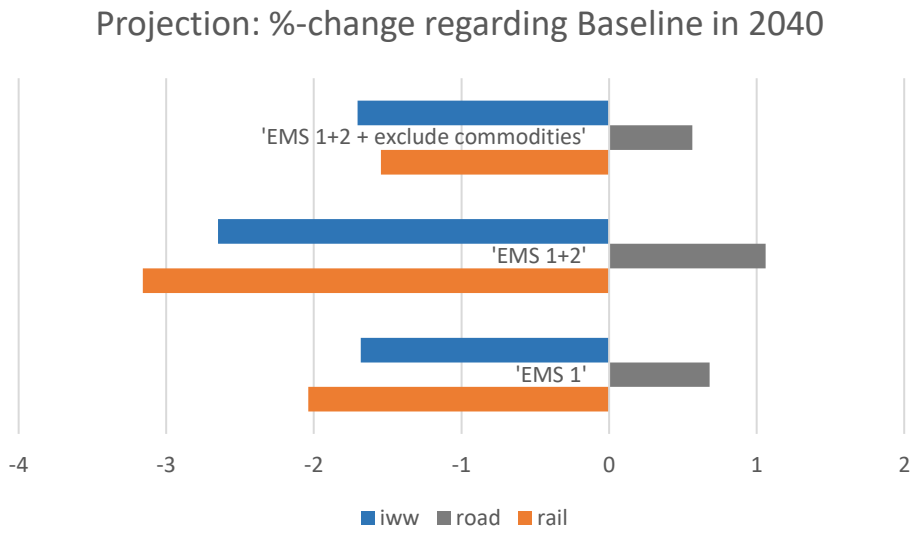
We define 4 scenarios of **EMS 1 and EMS 2 in 2040**:

a) baseline scenario 2040 (without EMS 1 and EMS 2) [‘Baseline’]
b) implementation of EMS 1 (up to 60 t GCW) without any restrictions 2040 [‘EMS 1’]
c) implementation of EMS 1 and EMS 2 (up to 74 t GCW) without any restrictions 2040 [‘EMS 1+2’]
d) no EMS 1 and EMS 2 for ‘heavy commodities’: avoiding heavy cargo (e.g. bulk) will be shifted from rail to road [‘EMS 1+2 + exclude commodities’]



Results – Scenarios: impact on modal split



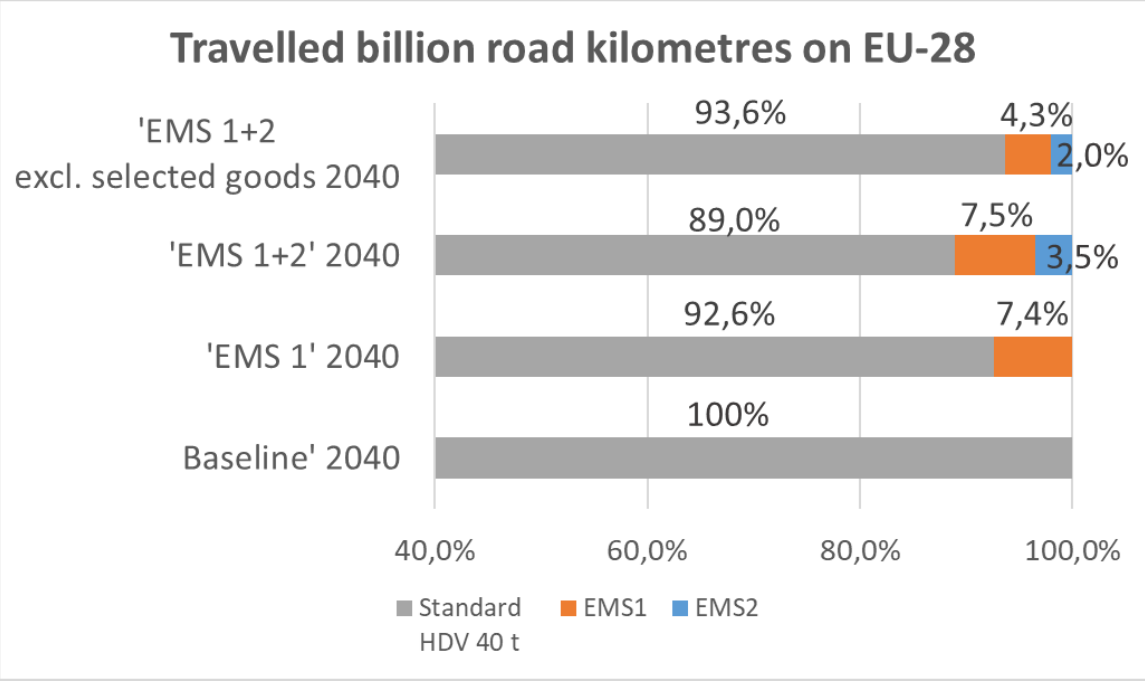


Changes in tkm:

- in scenario ‘EMS 1’: There is an increase of 0.7 % in road, and reductions of 2 % in rail (including CT), and 1.7 % in IWW (including CT)
- in scenario ‘EMS 1+2’: There is an increase of 1.1 % in road, and reductions of 3.2 % in rail (including CT) and 2.6 % in IWW (including CT)
- in scenario ‘EMS 1+2 + exclude commodities’: There is an increase of 0.6 % in road, and reductions of 1.5 % in rail (including CT) and 1.7 % in IWW (including CT)

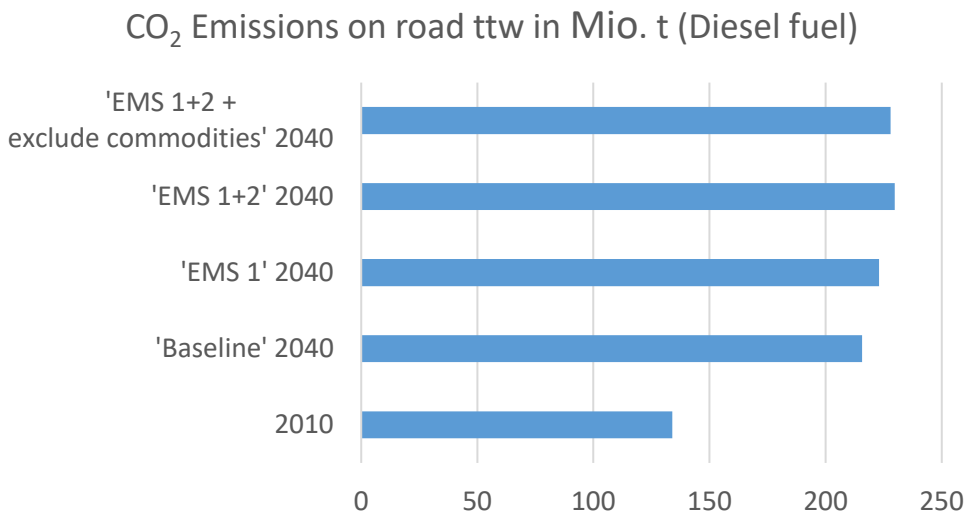
Results – Scenarios: impact on mileage

Travelled kilometres for HDV (up to 40 tonnes GCW), EMS1 (up to 60 t) and EMS2 (up to 74 t) are analysed:



Results – Scenarios: impact on CO_2 emission

Travelled kilometers is used for calculating CO_2 emission on road:



Change of CO_2 emission on road:

- in ‘EMS 1’: increase of 3.4 %
- in ‘EMS 1+2’: increase of 6.5 %
- in ‘EMS 1+2 + exclude commodities’: increase of 5.7 %

Premises for sustainable use of EMS:

- Addresses segments **with high transport performance**
- Addresses **growing cargo groups**
- **Limitation a reverse modal shift** from rail/IWW to road transport by **accompanying measures**
- Embedded in **CO2 reduction strategies** of manufacturing and logistics firms

Summary

- ***Tonne-kilometres*** in scenarios: increase of **road transport and slight reduction for railway and IWW** – due to higher efficiency on road transport

- ***Road mileage***:
  - Baseline: increase of road mileage between 2010 and 2040 of HDV (40 t GCW) by 61 %
  - **EMS 1** realizes up to 7.5 % of mileage of HDV (40 t GCW)
  - **EMS 2** realizes up to 3.5 % of mileage of HDV (40 t GCW)

Thank you

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