Long-Term Climate Impacts of the Introduction of Mega-Trucks

Study for the Community of European Railway and Infrastructure Companies (CER)

Conducted by

The Fraunhofer-Institute for Systems and Innovation Research (ISI) – study co-ordination

The Fraunhofer-Center for Applied Research on Technologies for the Logistics Service Industries (ATL)

The Fraunhofer-Institute for Logistics and Material Flows (IML)

TRT – Trasporti e Territorio

NESTEAR

Karlsruhe, May 12th 2009

Document information:

Title: Long-Term Climate Impacts of the Introduction of Mega-Trucks

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Client : Community of European Railway and Infrastructure Companies (CER), Brussels

Version: ^ 1.0

Date of publication: May 12th 2009

This document should be referenced as:

Doll, C., D. Fiorello, E. Pastori, C. Reynaud, P. Klaus, P. Lückmann, J. Kochsiek, K. Hesse (2008): Long-Term Climate Impacts of the In-troduction of Mega-Trucks Study to the Community of European Railways and Infrastructure Companies (CER), Brussels. Fraunhofer ISI (study co-ordinator, Karlsruhe) TRT (Milan), NESTEAR (Gentilly), Fraunhofer-ATL (Nuremberg), Fraunhofer-IML (Dortmund). Karlsruhe, July 2008.

Project information:

Project name: Long-Term Climate Impacts of the Introduction of Mega-Trucks

Study of the Community of European Railway and Infrastructure Companies (CER)

Contract no:

Duration: May 15th to July 31st 2008

Commissioned by:

Document control information:

Status: Final

Distribution: Electronic distribution

Availability: Public

Coordinator`s review: Claus Doll, 29.3.2009

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Abbreviations

CO_2	carbon dioxide
CT	combined (rail-road) transport
ERTMS	European Rail Traffic Management System
ETML	European Traffic Management Layer
ft.	feet
GIS	geographical information system
GVW	gross vehicle weight
HGV	Heavy goods vehicle
IWW	inland waterways
km	kilometre
LHV	long and heavy vehicle
Mt	mega tons (CO_2)
MT	Mega-Truck
SSS	short sea shipping
t	ton (commonly metric)
TEU	twenty-foot equivalent unit
tkm	ton-kilometre
WL	single wagon load

Executive Summary

The European Commission is currently exploring the pros and cons of extending truck size and weight limits. This study seeks to contribute to the exploration process by pointing to possible long-term threats associated with the introduction of Mega-Trucks, in particular with regard to European climate policy and to the market position of the railways. The main findings of the study are summarised by subject, drawing on the various elements of analysis applied by the multi-national project team.

Experience from German field tests reveal that Mega-Trucks may take 20 % of HGV goods volumes. If allowed on all roads, this share may increase to 30 %. While simulations for the UK arrive at lower values, the application of the LOGIS model finds a total replacement of conventional trucks in high quality logistics markets in long distances above 1000 km concentrating on major corridors. These findings are confirmed by the two European case studies. Moreover, current studies suggest a share between 10 % and 30 % of long distance rail container shipments may be shifted to road in case of a general permission of Mega-Trucks in the EU.

Contribution of Mega-Trucks to climate policy

<u>The study finds strong evidence that the introduction of Mega-Trucks will most likely end up in a negative climate gas balance in the medium term:</u> in most scenarios negative impacts in the medium run are much stronger than initial positive effects. <u>Thus, the authors reject the consideration of longer and heavier road freight vehicles as a suitable element of climate protection policy.</u>

Long-term climate impacts with a time horizon to 2025 are derived with a System Dynamics model created within this study. The model outputs suggest that the impact of Mega-Trucks takes place in three phases:

(1) The road sector accepts Mega-Trucks rather quickly, resulting in a decrease of CO_2-emissions due to efficiency gains on the road. Within a time horizon of 3 to 6 years an annual decline of 0.5 Mt is expected.

(2) If Mega-Trucks are established in road haulage, modal shift tendencies will take place in the rail sector. With a high degree of certainty modal shift effects will counterbalance CO_2 reduction targets. **Within 5 to 20 years an additional emission of 2 Mt CO_2 per annum is expected due to the introduction of 60 t Mega-Trucks.**

(3) If demand for road freight transport keeps on growing faster than rail demand, in the long run efficiency gains in the road sector might partly compensate for the additional

CO_2 emissions due to modal shift. But this option will only happen with 60 t Mega-Trucks and within a time frame of 15 to 30 years.

Reducing the maximum gross weight of Mega-Trucks from 60 t to 50 t will increase their likely adverse climate impacts due to lower efficiency gains in the road sector. However, the modal shift tendencies will only slightly be affected as most goods that have a potential for modal shift are volume critical. These results of the System Dynamics model are very strong.

Potential modal split effects by Mega-Trucks

Analytical studies for Germany and the UK uncover rather high impacts of Mega-Trucks on road – rail modal shares. **The highest affected market segment is container shipments, where losses of rail demand up to 50 % are predicted.** This, however, depends highly on assumptions on operational and service-related responses of the carriers due to declining demand. Across all unitised goods and container markets the study arrives at a risk for rail container shipments to be shifted to road between 10 % and 30 %. Mega-Trucks appear a strong competitor rather than a supplement to combined rail-road transport as their cost saving potential in long-distance unimodal road haulage is much higher than in terminal access.

Actual implementation of Mega-Trucks in Sweden and field tests in the Netherlands and Germany have led so far to lower modal shift effects due to restrictions of Mega-Trucks to motorways in national traffic only and to specific exceptional permissions. Applications of the LOGIS model contrast this by arriving at reductions of rail container traffic by up to 85 % in high value trans European combined transport markets in case of the EU-wide allowance of 60t Mega-Trucks.

Besides container markets Mega-Trucks are also expected to take some share of rail bulk goods markets. Given the specific industry structure in the UK, here a range between 5 % and 10 % is estimated for potential modal shift.

The study has arrived at the following ranges of traffic volumes lost by the railways due to the introduction of 60 t Mega-Trucks:

- Bulk goods including heavy industry and chemical products 3 % to 5 %,
- Food, food products and semi final products 10 % to 15 %,
- Continental container traffic 20 % to 30 % and
- Maritime container traffic 10 % to 20 %.

For HGVs with reduced weight these share are somewhat lower, but not much as a large share of goods is size rather than weight sensitive.

Policy and regulation options

Regulation decisions, e.g. restriction to motorways, and road quality standards are decisive for the profitability of Mega-Trucks relative to standard HGVs, but less important for modal shift. Restrictions may be abolished in the medium to long-term due to pressure by the forwarding industry.

While 60 t vehicles appear unacceptable due to safety and infrastructure reasons, 50 t vehicles prove to be even more harmful for climate goals due to lower efficiency gains in the road sector.

Study structure

The study has been commissioned and financed by the Community of European Railway and Infrastructure Companies (CER), and lasted from May to July 2008. The study team was led by the Fraunhofer-Society for Applied Research (FhG), Germany and conducted in co-operation with TRT Trasporti e Territorio (Italy) and NESTEAR (France).

To provide evidence on the subject of long-term environmental impacts entailed by the introduction of Mega-Trucks the study applies four different assessment steps: literature and market reviews, case studies of European corridors, an extension of the LOGIS geographical European logistics model operated by NESTEAR, and by developing a System Dynamics model developed for this study by TRT and Fraunhofer-ISI.

1 Preliminaries

1.1 Background of the Study

Via Council Directive 1996/53/EC the European Union regulates the maximum size of vehicles in intra-national and inter-national traffic as well as the weight limits in international road freight traffic. Vehicle lengths are restricted to 16.50 m for truck-trailer combinations and 18.75 m for articulated vehicles. The maximum permissible weight of 40 t can only be exceeded when carrying 40-ft. containers from and to combined transport terminals. Exceptions from these rules are subject to special permissions by national governments.

The general allowance of 25.25 m / 60 t road vehicles in Sweden and Finland since the mid 1990s and field trials in the Netherlands and in some German Länder demonstrate that the concept works. But the Transport Committee of the European Parliament and some Member States expressed their opposition to a general extension of the provisions of directive 1996/53/EC towards extra long and possibly extra heavy lorry combinations mainly due to safety and infrastructure availability reasons.

The European Commission now explores the pros and cons of extending truck size and weight limits. For this purpose the Commission has issued a study on the impacts of Mega-Trucks on safety, infrastructures, modal split and the wider economy. This report seeks to contribute to this exploration process by pointing to possible long-term threats associated with the introduction of Mega-Trucks in particular with regard to the market position of the European railways.

The study is commissioned and financed by the Community of European Railway and Infrastructure Companies (CER) lasting from May to July 2008. The study team is led by the Fraunhofer-Society for applied research (FhG), Germany, represented by its institutes for Systems and Innovation Research (ISI), responsible for project co-ordination, the Work Group on Technologies of Logistics Services (ATL and the Institute for Material Flows and Logistics (IML). Further Partners are Trasporti e Territorio (Italy) and NESTEAR (France). This international team shall ensure that all relevant aspects are covered and that the results are neutral and scientifically sound.

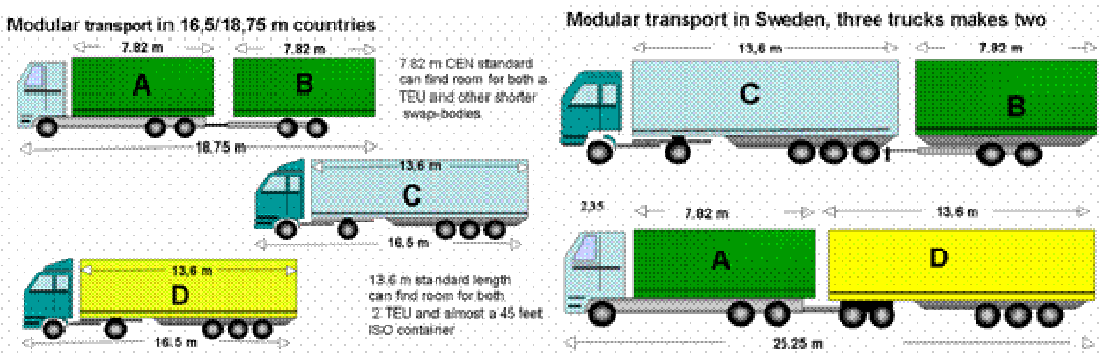
1.2 The concept of Mega-Trucks

There is a variety of synonymous names for extra-long and heavy truck and trailer combinations. LHVs (= long and heavy vehicles), Euro-Combis or “Eco-Combis” are the most common ones. Other expressions are “Giga-Liner”, “Mega-Liner” or “Mega-Trucks”. In this report the latter expression is used.

“Mega-Trucks” are road-freight vehicles which exceed the size limits of current heavy goods vehicles (HGVs) of 16.50 m / 18.75 m prevailing on most European countries. Mega-Trucks may have a maximum length of 25.25 m and can thus carry a 50 % higher volume of goods than traditional HGVs depending on weight limits. Concerning weight limits, different types are tested or in use, ranging form 40 t in the German trials to 60 t gross vehicle weight in Sweden. Against current maximum weights of 40 t / 44 t this would mean a theoretical increase in goods tonnage by more than 50 %. Depending on the type of goods loaded and the logistics process, this can result in cost savings of up to 25 %, 17 % less fuel consumption and 15 % less CO_2 emissions per ton of goods transported.

The technical concept of Mega-Trucks is rather simple. Besides somewhat stronger motors in case of higher permissible gross weight, an additional trailer is added to a standard HGV. Given current truck-trailer combinations several alternatives are possible as shown in Figure 1 at the example of LHVs in Sweden. Accordingly, the use of Mega-Trucks does not cause major investments in vehicle fleets.

Figure 1: Modular concept of Mega-Trucks in Sweden



Source: CEDR (2007)

The obvious advantages of the Mega-Truck concept are accompanied by a number of disadvantages and threats. First, massive demand shifts from rail and waterway transport to road haulage are to be expected due to the higher price efficiency and more attractive loading conditions (weight and volume) provided by Mega-Trucks in comparison to standard HGVs. Further, increased efficiency in transport always attracts new demand. This “induced demand” may absorb a certain share of the benefits by increasing congestion and emissions. Thirdly, declining rail volumes on some tracks will decrease productivity, increase freight rates and thus further push the modal shift from rail to road.

1.3 Objectives and scope of the study

The study investigates the trade-off between increased efficiency and threats of the concept of Mega-Trucks by taking a long-term perspective. It aims at clarifying which effect is dominant for different specifications of Mega-Trucks in Europe. The study acknowledges safety and infrastructure related impacts but concentrates its analyses on the case of modal shifts between rail and road freight transport.

Concerning the effects of increased road transport efficiency, modal shifts and induced demand the study focuses on climate gas emissions. Acknowledging that a sound benefit cost assessment needs to include operating costs, infrastructure maintenance and investments, safety, air pollution, noise, etc. the study seeks to answer the question whether the permission of Mega-Trucks could be a suitable element of European climate change mitigation policy. Thus, all output indicators besides CO_2-emissions are disregarded.

The study considered two concepts of Mega-Trucks:

- 25.25 m, 60 t gross weight
- 25.25 m, 50 t gross weight.

The time horizon of the study is 2025 for the system dynamics model application and 2020 for the LOGIS geographical analysis of European logistics relations. The geographical scope is the EU-25 plus Switzerland. However, due to the general approach taken, national results will not be presented.

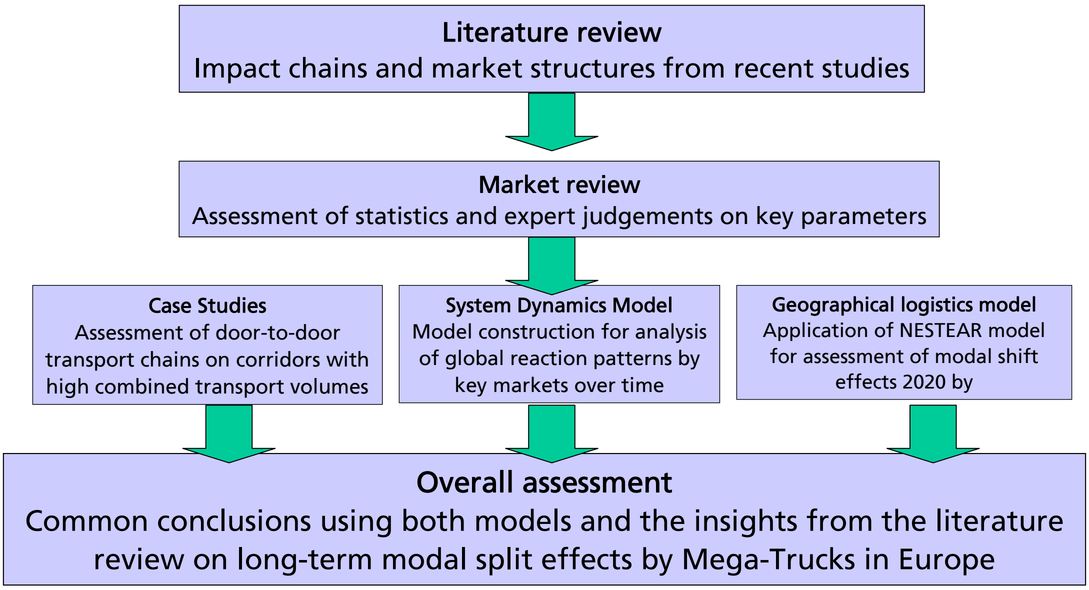
1.4 Structure of the analysis

To answer the objectives formulated above, the study applied a set of different, independent tools. These are:

- Assessment of current studies and field experiences on impacts of Mega-Trucks on railway performance, energy efficiency and greenhouse gas emissions
- Review of relevant statistics and market structures to understand the market sizes and generate model input data
- Adjustment and application of the NESTEAR LOGIS module of the New Opera Model on 2000 European logistics flows on their affinity towards Mega-Trucks
- Establishment of a long-term system dynamics model on European freight transport development and the role of Mega-Trucks on climate gas emissions
- Two case studies on typical European transport relations, investigating the potential for Mega-Trucks on the corridor level
- Final conclusions based on the results of all previous steps

Figure 2 illustrates the structure of the assessment steps.

Figure 2: Structure of the study



2 Review of Current Evidence

2.1 Overview of studies and field tests

There are a number of current studies on the topic of Mega-Trucks, their cost efficiency, safety, environment and modal split impacts available. These are very briefly enumerated below:

1. TML (2009): Effects of adapting the rules on weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC", Study conducted by TML, TNO, LCPC and RWTH Aachen on behalf of the European Commission.
2. TRL (2008): Longer and/or Larger and Heavier Vehicles (LHVs) – A Study of the Likely Effects if Permitted in the UK
3. Ministry for Transport, NL (2008): Experiences with longer and heavier vehicles in the Netherlands
4. Kessel and Partner + SGKV (2007): Effects of innovative concepts of commercial vehicles on national economy – Study for the German Minister for Transport
5. CEDR (2007): Report on 60 t Vehicles
6. German Federal Environmental Agency (2007): Communication on long and heavy lorries
7. TIM-Consult + Kombiverkehr (2006): Competition effects of Gigaliners in combined transport. Study for the International Road-Rail Intermodality Union (UIRR).
8. US FHWA (2004): Comprehensive Truck Size and Weight Study

Further, the presentations and the statements at the Commission consultation meeting at July 31st 2008 have been acknowledged in the course of this study.

2.1.1 The position of the German Environment Agency 2007

The German Federal Environment Agency (UBA 2007) derives unit fuel consumption rates from assumptions on fully Mega-Trucks carrying 52 pallets to a 40 t HGV carrying 34 pallets. The resulting fuel consumption per pallet decreases by up to 25 %. At load rates of Mega-Trucks below 40 pallets, however, cost efficiency would be less than for standard HGVs.

Comparing standard HGVs to freight trains CO_2 emissions are 300 %, NO_X emissions 290 % and dust and particulate matter 200 % as high. The authors conclude, that even with a full load the specific emissions per ton of cargo of the railways look much more favourable than Mega-Trucks. In contrast, the balance of traffic noise emissions strongly depends on the actual load rate of the Mega-Trucks.

As concerns the impacts on other transport modes the study compares the loading capacities of different alternatives as shown in Table 1. Mega-Trucks are thus very similar to single wagon load conditions of the railways. Their higher cost efficiency will thus break the positive trend of rail freight demand. The publication reports cross price elasticities of rail transport of 1.8 and of inland navigation of 0.8 with respect to price changes in road transport and calls on an uncited Dutch study concluding that the general permission of Mega-Trucks would cause 5 % of rail transport shifting to road. Own expectations on how much of German rail traffic would be dispatched are not given.

Table 1: Comparison volume and weights of several cargo transport facilities

Vehicle	Max. volume	Max. payload	Example: Washing machines, refrigerators
Standard railway wagon	120 m³	25 t	160 units
Special railway wagon	140 m³	27 t	253 units
Jumbo HGV	105 m³	26 t	180 units
Mega-Truck	150 m³	40 t	279 units

Source: values from UBA (2007)

As concerns road space occupation the publication reviews the commonly used argument that 2 Mega-Trucks would replace 3 standard HGVs and that – considering the usual safety distance of trucks – space consumption per ton shipped is reduced to 44 %. By calling on modal shifts the authors assume that three Mega-Trucks would simply replace three standard-HGVs. Accordingly, road space and in particular space at rest areas will be more crowded.

Road infrastructure will be stressed at bridges, their life expectancy would decrease and more maintenance would be necessary. Finally, the items of more severe traffic accidents and the insufficiency of some infrastructure elements (small roundabouts) are raised.

2.1.2 TIM Consult 2006: impacts on combined transport

On behalf of the German Kombiverkehr and the International Union for Combined Road-Rail Transport Companies (UIRR) TIM Consult has conducted a study on the impacts of long and heavy vehicles on combined transport. By analysing four door-to-door transport relations across Europe the study concludes on the likely impact of 60 t / 25.25 m Mega-Trucks on combined transport. The cost efficiency gain against conventional HGVs is assumed ranging between 20 % and 25 %. The corridors, market segments and results are presented in Table 2.

Table 2: Results by TIM (2006) for selected market segments

Market segment	Corridor analysed	Impact on combined transport
Maritime container traffic national	Hamburg – Cottbus	-17 %
Maritime container traffic international	Calais – Warsaw	-44 %
Continental container traffic national	Saarbrücken - Budapest Munich – Milan	-27 %
Continental container traffic international		-81 %
TOTAL in selected markets		-55 %

The study concludes that Mega-Trucks are not appropriate for use in combined transport chains, but would replace them partially as the cost advantage of combined transport currently is very limited. Balancing road transport efficiency gains against modal shift effects the study estimates lorry trips in road haulage to increase by 24 %.

The study raises a number of challenges by the introduction of Mega-Trucks, including the re-thinking of the share of road space cars and motor cycles on the one hand and extra long trucks on the other, the design of crossings and – in case of permission of Mega-Trucks on high level roads – the installation of facilities where they can be split.

2.1.3 Kessel and Partner (2007)

The study by Kessel and Partner (2007) on behalf of the German Ministry for Transport, Building and Urban Development (BMVBS) has looked at the transport-related impacts of innovative vehicle designs. It has applied the same segmentation of the transport market as TIM (2006), but with a further differentiation into weight and volume critical goods. The market reactions assumed are based on long-term elasticity observations and result in considerably lower losses for combined transport than found in TIM (2006). The used elasticities are presented in Table 3.

Table 3: Cross-price elasticities of rail transport in relation to road costs

		Elasticity for weight-critical goods	Elasticity for volume-critical goods
Maritime traffic	national	0.9	1.5
	international	0.8	1.0
Continental traffic	national	0.5	1.0
	international	0.4	1.0

As concerns the specific market of combined transport the authors could not find a clear price to volume trend in statistical data; the presented elasticities thus refer to rail freight transport in general. The study was performed in two steps:

- First, only price effects were taken into account
- Second, also the supply side effect of reduced services on combined transport relations was investigated

The study further points to a number of issues limiting the use of Mega-Trucks, which have not been assessed in the model calculations:

- Increased motorway tolls for Mega-Trucks
- Capacity of Mega-Trucks allows either three 20 ft. containers or a 20 ft. plus a 40 ft. container. These combinations are only considered appropriate for 1/3 of maritime traffic.
- The same holds for the access to combined transport terminals, where forwarders usually use one specific container format only

- In door-to-door transport a certain manoeuvrability of the vehicles is required, which is often difficult due to space limitations. Alternatively a division of Mega-Trucks outside the motorways is assumed.
- Further, the more strict verification of social legislation, the restricted engagement of drivers from low wage countries and rising energy costs have not been considered in the study
- Finally, Trans-Alpine traffic has been disregarded as it is assumed that Switzerland and Austria will maintain their rail-friendly policy

The study has investigated four combined transport relations competing with road:

- Bremerhaven to Stuttgart (one transhipment)
- Rotterdam to Ludwigshafen (one transhipment)
- Bremen to Stuttgart (two transhipments)
- Ludwigshafen to Tarragona (two transhipments plus change of train at the Spanish border)

On the basis of these relations the study concludes that Mega-Trucks do not contribute to cost savings in access or final haul within combined transport chains. The cost saving potential in unimodal road transport is much higher. The impact per rail transport market are summarised in Table 4 for the scenario of only cost based market reactions.

Table 4: Reduction of rail volumes due to the introduction of Mega-Trucks

		Weight-critical goods	Volume-critical goods
Maritime Traffic	national	- 3.3%	-12.9%
	international	-1.9%	-10.4%
Continental Traffic	national	-2.1%	-16.1%
	international	-3.5%	-16.1%

Across all market segments, pure cost efficiency effects will cause a reduction in combined transport demand of 14.3 %. However, when considering the deterioration of combined transport service quality due to less frequent departures or omitted direct services, an impact of 32.3 % is forecasted.

2.1.4 TRL (2008)

The study by the Transport Research Laboratory (TRL and the Heriot-Watt University has been prepared for the Department of Transport in 2008. The study has looked at the impact of longer or longer and heavier vehicles (LHVs) on road safety, environmental issues, infrastructures, operating costs, congestion and other social and policy-related issues. Starting from different vehicle configurations diverging in length and weight, eight scenarios of LHV use in the UK have been developed. Traffic and environment related impacts have been derived by applying a micro simulation freight model. The main findings are:

- Depending on technical vehicle configurations longer vehicles would face a considerable safety risk and the consequences of collisions of heavier vehicles, e.g. bridge structures, are expected considerable.
- Large investments would be required to upgrade parking facilities and the management of road infrastructures (e.g. traffic light phasing) would require costly re-adjustments.
- LHVs would be likely to be used mainly for regular flows of low density products on primary distributions such as pallet-load networks, fast-moving consumer goods, deep sea container movements and forest products.
- At most one third of HGV flows would be suitable for LGVs, while standard estimates considering regulations on LHVs arrive at shares of 5 % to 10 % at tkm.
- Depending on scenarios fuel consumption and CO2 emissions per tkm could be reduced by between 8 % and 28 % when LHVs would be introduced.
- But: 25.25m vehicles would represent a considerable threat to rail operations in the deep sea container market. Including bulk goods markets, estimates arrive at a maximum of 8 % to 18 % of all rail tkm to migrate to 60 t LHVs.

Although the study finally concludes that overall effects of Mega-Trucks are likely to be positive due to the saving in vehicle kilometres, the warning concerning likely investment needs at road infrastructures and the adverse environmental impacts due to modal shift effects are strong. The results are subject to a great deal of uncertainty as similar sudden extensions on vehicle dimensions and possibly weights have not been observed before.

2.2 Practical experiences and field tests

2.2.1 The case of Sweden

Sweden has first introduced a restriction on vehicle lengths to 24 m in 1968 due to road safety reasons. Attempts to adopt maximum vehicle lengths to the European standard of 18 m in 1973 were rejected as studies did not conclude on any significant safety improvement. A minor increase in vehicle length to 25.25 m in 1979 showed no impact on safety or infrastructure requirements as the road network since a long time was designed to accommodate these long vehicle combinations.

Vehicle weights in Sweden have been constantly increased since the 1930s. The latest increase took place in 1993, where the maximum permissible weight was increased from 56t to 60 t. Figure 3 presents the development over time.

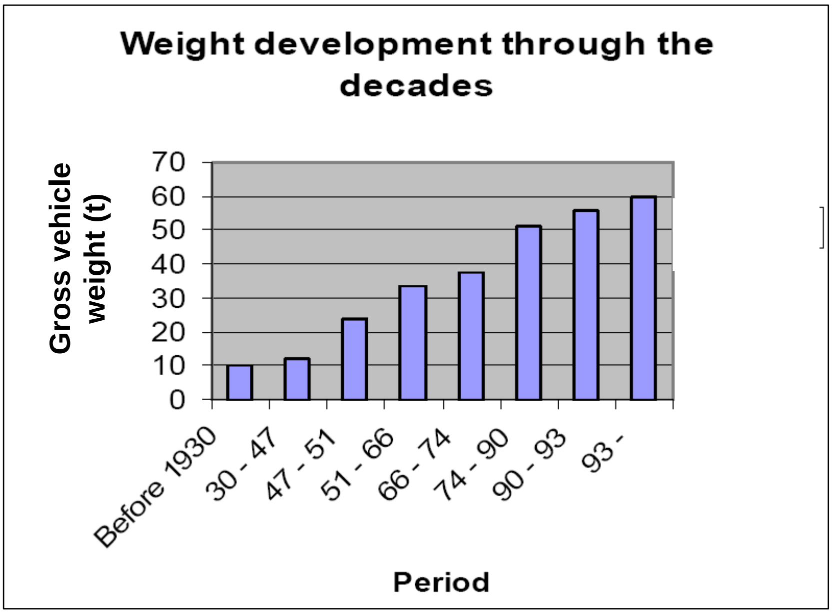


Figure 3: Increase of truck weight limits in Sweden (Data source: CEDR (2007)

CEDR (2007) reports no modal shift effects to be entailed by these weight limit increases. But this has to be considered against the background that the vehicle size remained constant and that in parallel to road weight limits the permissible maximum axle loads of railway wagons was also raised.

2.2.2 The Dutch experiences

In the Netherlands Mega-Trucks are also known as Ecocombi, Eurocombi or LZV (Langere en Zwaardere Vrachtautocombinatie, longer and heavier lorry combination). When in 1999 the first LZV where introduced, they where limited to 50 tonnes and 22 meters. Successively this was lifted to 60 tonnes and 25.25 meters. 155 vehicles in 71 carrier companies participated in the field test. It was planned that these vehicles are operated on in intermodal transportation feeding and discharging intermodal terminals. Preconditions to the usage of MT where

- No MT employment under certain weather conditions (in winter - snow/ice)
- Minimum driver experience and qualification higher than normal truck drivers
- Special security equipment
- No driving in cities
- No overtaking
- No crossing of railway lines

No security impeachment was reported in the Netherlands. Traffic jams were reported to have fallen by 0.7 – 1.4%. CO_2 emissions fell by 11% for heavy duty and 22% for volume critical transports. Saving potential on the carrier side for vehicles above 20 tonnes was reported between 7 and 31 % with an average of 25%. Substantial modal shift was not observed due to the geographical restrictions.

2.2.3 The German field trials

A number of German federal states (Länder) have recently carried out field trials on the use of long and heavy vehicles. Commonly these tests have been designed as special permissions for selected forwarders or hauliers on pre-defined relations. At the time of writing this report (July 2008) only one of them, the state of Lower Saxony, has issued a report on the experiences made. The available evidence of the field trials is summarised case by case in the following paragraphs. Some of these tests are currently running, have recently been finished or are still in planning.

<u>Lower Saxony</u>

The federal state of Lower Saxony (Niedersachsen) is located in the north-west of Germany bordering to Netherlands and to the city-state and port of Hamburg and surrounds the states and seaports of Bremen and Bremerhaven. Lower Saxony is rather sparsely populated with a density of 168 inhabitants per km². The map in Figure 4 depicts the geographical position.

Figure 4: Political map of the German federal States

The Lower-Saxony MT-trial period lasted from 1st of June 2006 to October 2007 (after extension). Exceptional permits where granted to three freight forwarders; Contrans

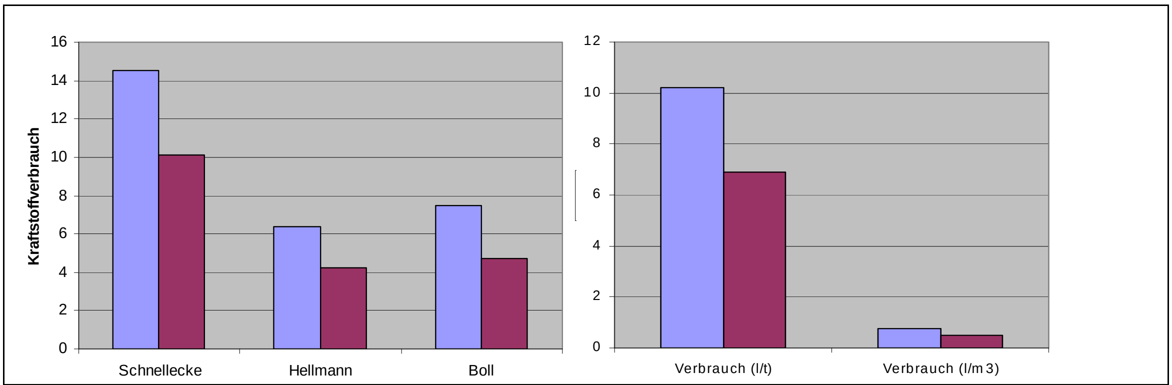
Logistics, Boll Logistik and Hellmann Worldwide Logistics. These companies had to fulfil the following covenants:

- max weight of the vehicle not higher than 40 tonnes
- max length of the vehicles not longer than 25.25 meters
- only selected routs where permitted
- drivers had to have lengthy driving experience and
- undergo a special training before driving the MT
- the routes were planned avoiding tunnels, roundabouts and other traffic hubs
- Mega-Trucks needed to be clearly marked as being extraordinarily long
- Two cameras to record behaviour in traffic and as manoeuvring support

"MTs can make an important contribution to coping with the increasing demand in transportation and to the protection of the environment" said Mr. Hirche the minister of economics of Lower-Saxony after one year of the MT-trial. The published results in the final report are backing this statement.

For the carriers diesel consumption went down by an average of 25%, resulting from a 10 % to 15 % higher fuel consumption per truck-km, but a 40 % to 50 % higher pay-load. Figure 5 shows the results for 40 t Mega-Trucks and HGVs per vehicle kilometre, ton-kilometre and volume-kilometre for each of the three companies having participated at the field trial.

Figure 5: Fuel consumption per vehicle-km (left) and per ton / volume (right) of Mega-Trucks and HGVs by company



Blue: conventional HGV, : 40 purple: 40t Mega-Truck

Source: Data from IVH (2007)

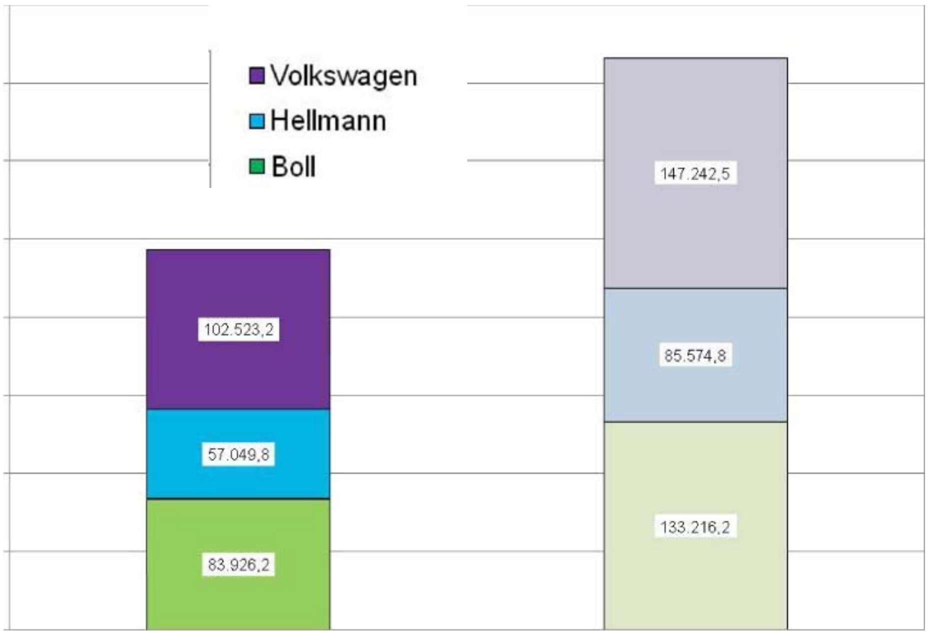
Among the testing companies the savings in driven kilometres are between 30 % and 37 %. This has to be compared to 4.3% higher diesel consumption of Mega-Trucks.

Every third driver can be saved which means a 33% decrease in haulage related costs. Maintenance for 40 t Mega-Trucks is comparable to the maintenance costs for normal trucks. In total the field test concludes with a reduction of specific operating costs per ton kilometre between 18 % and 25 %.

Concerning the market share of Mega-Trucks within road haulage, the field test indicated a possible share at vehicle fleets in Lower Saxony of 10 % to 15 %. Translated into vehicle kilometres and extrapolated to the whole of Germany the final report arrives at an expectation of 21 % of HGV trips might be replaced by Mega-Trucks. Other studies mainly for the automotive industry arrive at a market share of Mega-Trucks of 4 % to 22 %. .

Concerning environmental and climate impact the study expects total CO_2- and NO_X-emissions of road transport: going down by roughly 33 %. Figure 6 shows more detailed results by participating company.

Figure 6: CO_2 efficiency of Mega-Trucks according to the field trial in Lower Saxony



Source: IVH (2007)

<u>Baden-Württemberg</u>

The Baden-Württemberg trial is scheduled to run until September 2008. The trucks are transporting raw materials and semi-finished products between the Daimler premises in Stuttgart and Sindelfingen. Maximum weight is 60 tonnes with a length of 25.25 meters.

<u>North-Rhine Westphalia (NRW)</u>

Until June 2008 several forwarders in NRW were testing MT on different routes within NRW but also to Rotterdam. Maximum length is also 25.25 meters but the max. weight is with 44 tonnes below the test in Baden-Württemberg. The focus is also on volume critical transports like textiles.

<u>Thuringa</u>

The test in Thuringia is announced but did not yet officially start operating. Two companies are granted the permission to use the MTs for volume sensitive transports of mattresses and food products between well defined destinations. Maximum weight is 40 tonnes and max. length 25.25 meters.

<u>Bremen</u>

Bremen gave special permission to a coffee roaster to exceed the normal cap of 40 tonnes maximum weight. The truck does not exceed the length of traditional trucks and should hence not be referred to as MT. According to senior officials of the city of Bremen, this is not a trial period but a permanent special permit.

2.3 Summary of results

Table 5 provides a brief overview of the main findings of the studies and test cases by country. There it is evident that the practical experiences in Sweden, the Netherlands and the German trials show lower market reactions than the desk top studies suggest. There are a number of reasons behind this bias, which have partly been addressed by the studies themselves.

Table 5: Summary of study and field observation results by country

Sweden	Increase of weight limits from 40 t (1966) to 60 t (1993), parallel increase of train lengths and rail wagon axle loads ➔ overall effect on modal split negligible.
Netherlands	Field trials on selected relations on national territory only. Conditions: short distances with generally Small haulage market ➔ only limited effects. road +0.05% - 0.1%, inland waterways -0.2% to -0.3%, rail (total) -1.4% to -2.7%
UK	Model results (TRL08): 8 % to 18 % shift from rail with 60 t payload (bulk 5 %-10 %, deep sea containers 22 %-54 %) and 2.5 % to 5.5 % with 44 t vehicles. Domestic CT only integrated model consideration due to dynamic market
Germany	Model and logistics chain forecasts (TIM07, K+P06): Huge potential for modal shifts in combined transport (up to 55 % reduction). Field tests by the federal states not yet evaluated.

Source: Fraunhofer-ISI

The first and most evident reason for the limited reactions in practice is, that these tests are restricted to national territories. The analytical analyses, however, suggest the much bigger modal shifts to happen in international long-distance transport. Second, the field tests in the Netherlands and in Germany are restricted to a few forwarders and/or haulage companies. The effect of getting rail or combined transport demand on a particular relation below a critical volume, such that supply has to be reduced, is not captured by these low market shares.

It can thus be concluded that the results of the theoretical studies need to be considered with care as they probably over-state the real relevance of Mega-Trucks, but they are in no way completely contradicted by practical experiences.

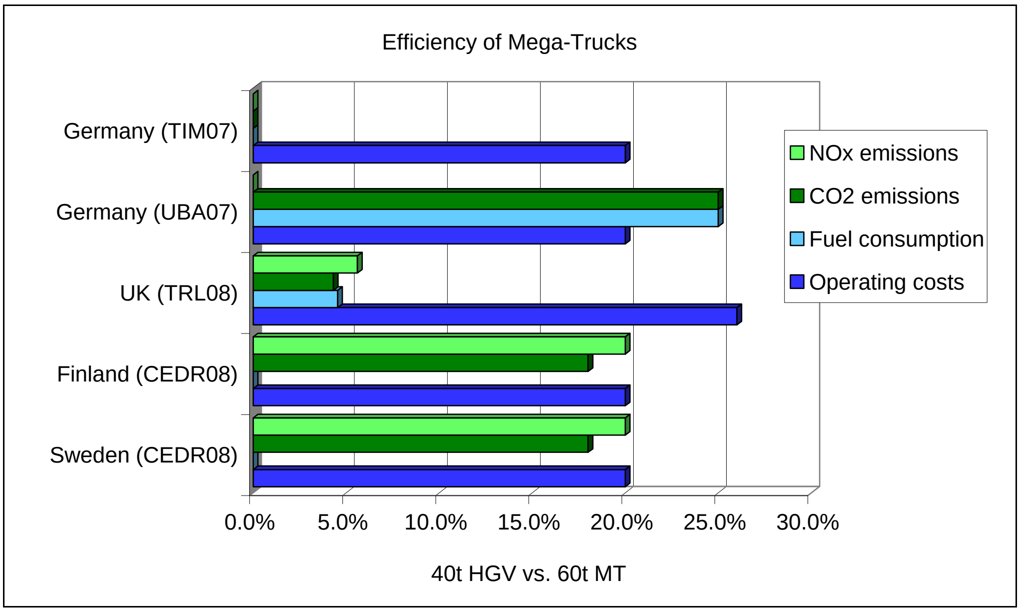
2.3.1 Cost savings by Mega-Trucks

The cost efficiency of Mega-Trucks strongly depends on the assumptions made on vehicle loading and access regulation. In case the load in tons or volume units is not clearly above that of conventional HGVs the additional costs of maintenance, service, educated drivers, detouring inaccessible routes, etc. will offset the theoretical cost advantage. Most studies and field test consider cost efficiencies in average being 18 % to 25 % against conventional HGVs.

Besides TRL (2008) most sources consider fuel and CO_2 efficiency around 20 % to 30 %. According to TRL (2008) fuel consumption, CO_2 emissions and NO_X exhaust of 60 t Mega-Trucks is only 4 % to 5 % below that of HGVs related to ton kilometres. TRL (2008) in general considers environmental impacts less favourable than other sources.

With the exception of UBA07 most sources consider NOx efficiency of Mega-Trucks somewhat lower than conventional HGVs.

Figure 7: Selected efficiency measures reported by different studies



Source: Fraunhofer-ISI based on data from several studies

2.3.2 Price elasticities

Given the rather high cost saving potential of Mega-Trucks between 20 % and 30 %, some market segments may experience a rather drastic drop of unit rates in road haulage. The studies reviewed quite a wide range of direct and cross price elasticities of rail/road transport with respect to price changes in the road haulage market. The existing values are summarised in Table 6. Here in particular the big difference between the

British values reported by TRL (2008) and the German values, in particular by UBA (2007) are striking.

Table 6: Price elasticities reported by different studies

Country + Source	Market / conditions	Rail volume by road prices	IWW volumes by road costs
UK (TRL08)	Rail bulk markets	0.29	
Germany (UBA07)	Long-term market obs., cost change <1 %	1.80	0.80
	Long-term market obs., cost change < 20 %	1.90	0.80
Germany (K+P06)	CT maritime national - weight critical	0.90	
	CT maritime national - volume critical	1.50	
	CT maritime international - weight critical	0.80	
	CT maritime international - volume critical	1.00	
	CT continental national - weight critical	0.50	
	CT continental national - volume critical	1.00	
	CT continental international - weight critical	0.40	
	CT continental international - volume critical	1.00	

Source: Fraunhofer-ISI based on different studies

2.3.3 Potential losses of rail market shares

As emphasised in the above reviews, the potential impact of the introduction of Mega-Trucks on their share in road haulage and on modal split depends on several factors, including cost efficiency and expected cost developments, price elasticities, regulation or specific requirements of particular markets. Taking these impacts into account to a different degree, the studies and field experiences arrive at very different expectations on the impact of Mega-Trucks on the rail modal share. This concerns markets as well as reaction intensities. The values found in the reviewed studies are given in Table 7.

The wide range of the German values on the one hand reflect the assumptions on price elasticities of the studies carried out and on the other hand demonstrate the relevance of supply effects resulting from falling demand (vicious circle). Concerning the entire rail market UBA (2007) and TRL (2008) arrive at the conclusion that it is not only the high value combined transport segment, but also considerable shares of bulk and medium value goods, which are affine to long and heavy road vehicles. This generalisation of reaction patterns is important as bulk and medium value goods markets are some 85 % of total rail ton kilometres in Europe.

Table 7: Price elasticities reported by different studies

Country	Source	Market	60 t MT min.	60 t MT max.	40 t MT min.	40 t MT max.
OBSERVATIONS						
Sweden	CERDR08	Overall	0.0%		0.0%	
Netherlands	CERDR08	Road	0.05%	0.1%		
		Rail total	-1.4%	-2.7%		
		IWW	-0.2%	-0.3%		
MODEL STUDIES						
Netherlands	UBA07	Rail total	-5.0%			
UK	TRL08	Rail total	-8.0%	-18.0%	2.5%	5.5%
		Rail bulk	-5.0%	-10.0%	0.0%	0.0%
		CT maritime nat.	-22.0%	-54.0%	11.0%	27.0%
		CT cont. nat.				
Germany	K+P06, TIM07	CT total	-14.3%	-55.0%		
		CT cont. nat.	-18.2%	-44.0%	-16.1%	
		CT cont. int.	-17,0%	-19,6%		-16.1%
		CT maritime nat.	-16.2%	-27.0%	-12.9%	
		CT maritime int.	-12.3%	-18.0%	-10.4%	

Source: Fraunhofer-ISI based on different studies

2.4 Conclusions on studies and field test reviews

The reviews show the result that the cost saving potential in unimodal road transport due to the introduction of Mega-Trucks is much higher than in combined transport with access and final haul performed by Mega-Trucks. It is even argued that Mega-Trucks will not make combined transport more cost-efficient at all.

Real implementations of Mega-Trucks (Sweden) and field tests (Netherlands, Germany) lead to much lower or even negligible modal shift effects than model- or corridor-based desktop studies. This can be explained by manifold restrictions of Mega-Trucks in practice as required by Directive 1996/53/EC to national territories, particular road classes and specific exceptional permissions on the one hand and by the rather relaxed conditions implicitly assumed by the analytical models.

Current studies omit a number of factors:

- The impact of road charges, and the development of fuel prices and other operating and personal costs
- The real loading capabilities of Mega-Trucks, which can only take certain combinations of containers. This is less attractive in maritime and combined transport

- The very limited road access capacity of many major seaports
- Insufficient infrastructure quality to carry Mega-Trucks particularly in the new Member States
- Door-to-door transport may require splitting of MT outside motorways
- The rail protection policy of Switzerland and Austria, which will most probably be maintained
- The possible weakening of regulatory standards for Mega-Trucks over time to serve the needs of the forwarding industries.
- Restrictions due to complex logistics patterns. Real modal shift will be below technical potential

The real market potential of Mega-Trucks thus will range somewhat below the values found by the theoretical studies.

3 Market Structures

This chapter aims at exploring market sizes and structures relevant for modal shift effects from rail and combined transport to Mega-Trucks as well as the market potential for Mega-Trucks within the road sector. Further, the chapter will discuss a number of key variables for the subsequent definition and application of the system dynamics forecasting model.

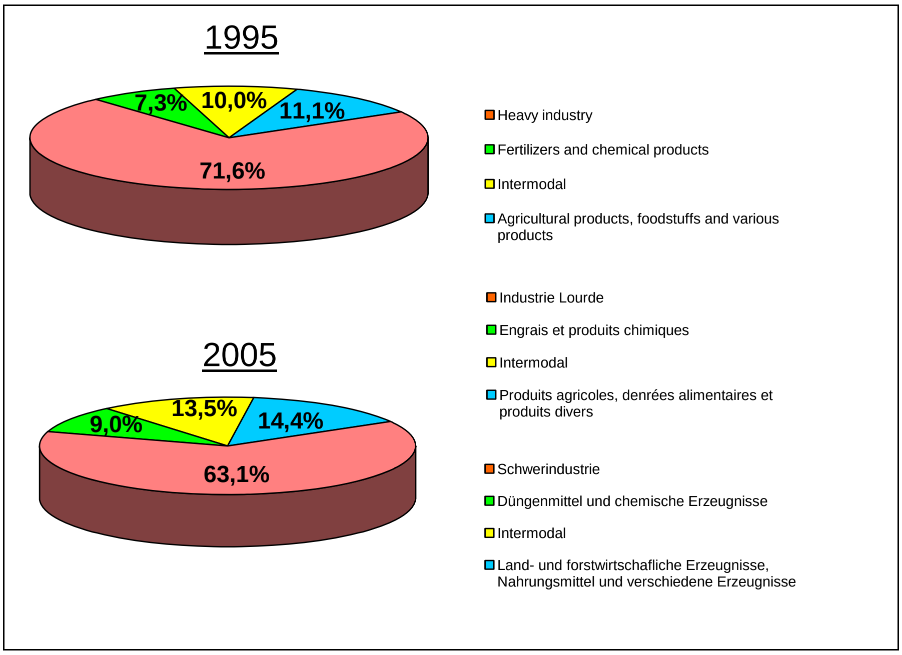
3.1 Market structures in 2005

3.1.1 Total railway market

Base year of the analysis for this study is the year 2005. For this time period UIC railway statistics and Eurostat goods flow records are available to draw conclusions on the structure and size of various market segments.

According to the statistics of the International Union of Railways (UIC 2007) 13.5 % of ton kilometres are performed by “intermodal goods”. This category contains high value goods carried in containers, swap bodies or unitised forms.

Figure 8: Goods flows in Tkm 1995 and 2005 by rail in Europe - broad goods classes



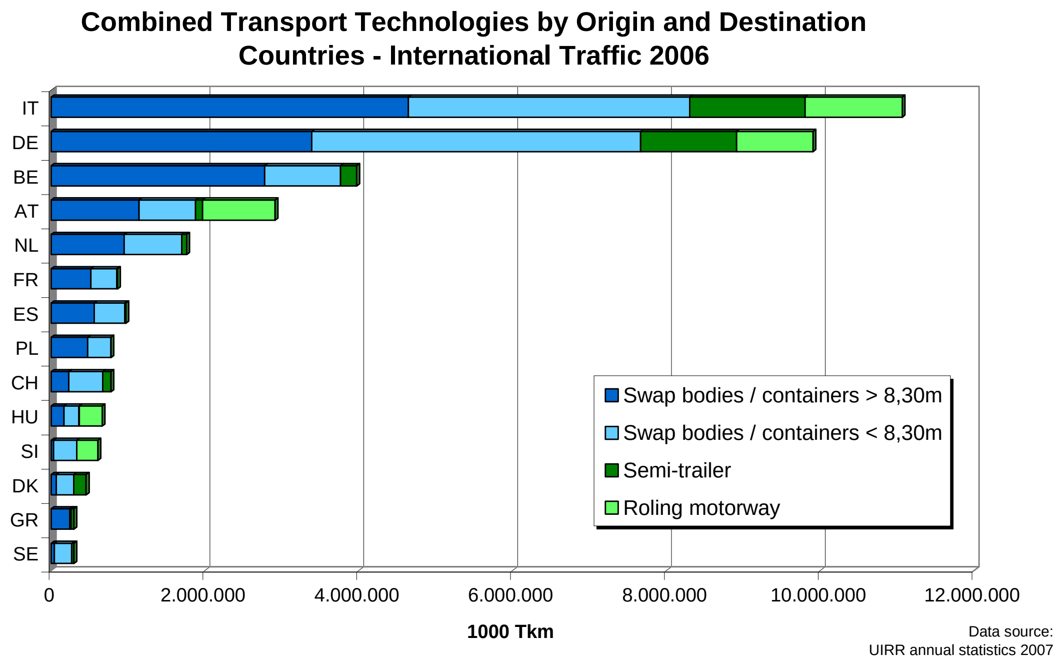
Source: UIC (2007)

The growth of the market share of intermodal goods from 10.0 % in 1995 to today's value and similar developments in the market segments for medium value goods and chemical products indicates the change of the market structure in the past decade. The statistics report a considerable reduction in transport performance of inputs and products of heavy industry, so-called bulk goods. They still form the vast majority of rail business, but their decline is expected to continue as Europe's economies will have to further transform towards high technology development and production to stay competitive in world markets.

3.1.2 Combined transport market

In intermodal or combined transport roughly two third of the market is operated by UIRR members. From UIRR annual statistics 2007 (UIRR 2007) detailed figures on the different technologies or container and vehicle types shipped are available by carrier or by associated country respectively. By depicting this data Figure 9 reveals that Germany and Italy are by far the most important sending and receiving countries of intermodal services, carrying far more than 50 % of total ton kilometres. Second, units above 8.30 m length, i.e. 40 ft. containers, carry 54 % of goods in containers and swap bodies. Accordingly, about 37 % of all containers and swap bodies moved are 40 ft. units.

Figure 9: Combined transport performance by technology and UIRR member country 2005



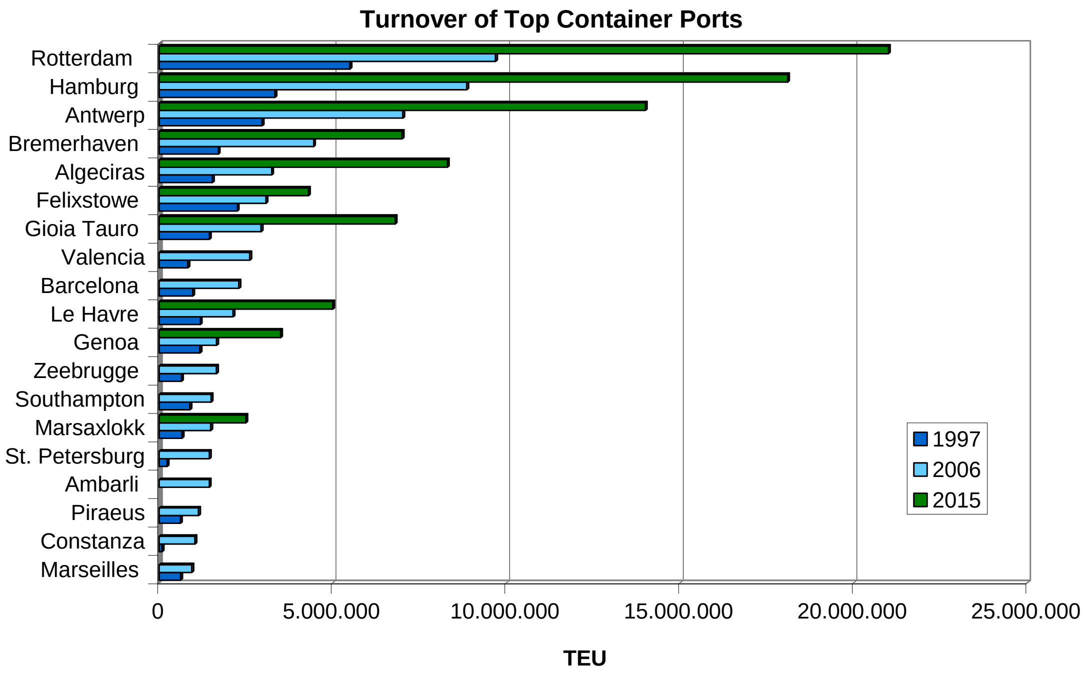
Source: UIRR (2007)

3.1.3 Port hinterland traffic

Maritime traffic is the fastest growing market segment worldwide and in Europe. Therefore, infrastructure provision and capacity management in port hinterland traffic appears of top priority in national and European transport investment and development plans. In the current study the segment of maritime container traffic is therefore considered separately with special attention.

Figure 10 shows the past, current and projected future turnovers in twenty-feet equivalent units (TEU) for the major European ports. More than half of these ports show growth rates of more than 100 %, and even the port with lowest growth rates (Bremerhaven and Felixstowe) are expected to increase their turnover by roughly 40 %.

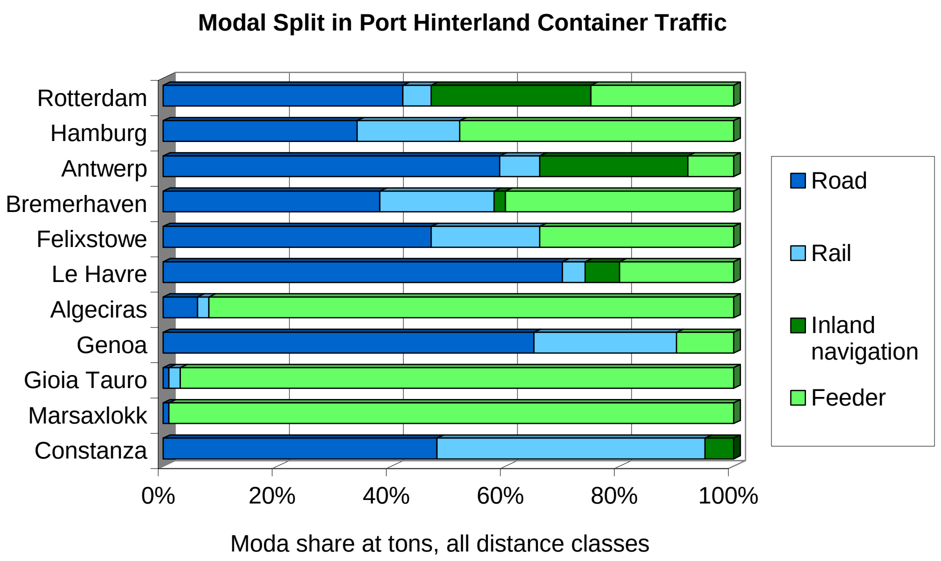
Figure 10: Turnover in major European seaports in TEU



Source: Fraunhofer-ISI based on data from Uniconsult (2007)

Figure 11 shows the modal shares of port hinterland transport at tons for all distance classes. In most cases road has a share of roughly 40 % with the exceptions of Le Havre and Genoa having above 60 % and Algeciras, Gioira Tauro and Marsaxlokk having nearly 100 % of feeder transport. Across all ports the role of short sea shipping as feeders is comparable to road, while rail transport plays a less significant role. Inland waterway constitutes a significant mode for the two major ports of Rotterdam and Antwerp.

Figure 11: Turnover in major European seaports in TEU



Source: Fraunhofer-ISI based on data from Uniconsult (2007)

3.1.4 Selected market segments

Using current Eurostat data on freight transport volumes (in tons) and goods demand or transport performance (in tkm) together with the segmentation elaborated above the market structure for the base year 2005 determines as given in Table 8.

- Within the railway sector 73 % of goods volumes (in t) are bulk, while container goods constitute only 15 % of the market.
- Measured in tons * distances (tkm) the picture looks slightly different: bulk constitutes only 66 % of the market while container goods are at 20 %.
- Road volumes in terms of tons constitute a much higher share of food, agricultural and semi-final products (24 %) than the railways have in this commodity

(11 %). The share of container goods is somewhat lower in road (11 %) than in rail (15 %).

- Looking at ton kilometres road is particularly strong in food and semi final products (40 %), which is like container traffic rather sensitive to modal shifts.
- Across all commodities rail constitutes a market share of 8 % at tons and 18 % at ton-kilometres across all EU countries. The rail market share at tkm is slightly higher for heavy industry goods (26 %) than for chemical products and containers (each roughly 20 %).

The analysis of data reveals that rail is stronger in the bulk market than road – but the difference in market share to all other commodities does not appear striking. The vast majority of bulk goods from heavy and chemical industries is transported by lorries.

Table 8: Market structure 2005

	Rail incl. CT main run		Road incl. CT access		Total rail + road		Rail share
Volume (million t)							
Heavy industry	974,2	66%	9552,6	60%	10526,8	60%	9%
Chemical industry	102,1	7%	793,1	5%	895,2	5%	11%
Food, semi final, etc.	174,7	12%	3928,7	24%	4103,4	23%	4%
Containers (others)	228,4	15%	1772,7	11%	2001,1	11%	11%
TOTAL	1479,4	100%	16047,0	100%	17526,5	100%	8%
Performance (1000 million tkm)							
Heavy industry	221,9	58%	628,1	36%	850,0	40%	26%
Chemical industry	30,2	8%	121,0	7%	151,2	7%	20%
Food, semi final, etc.	54,5	14%	691,1	40%	745,6	35%	7%
Containers (others)	75,9	20%	282,5	16%	358,5	17%	21%
TOTAL	382,5	100%	1722,7	100%	2105,2	100%	18%

Source: Fraunhofer-ISI

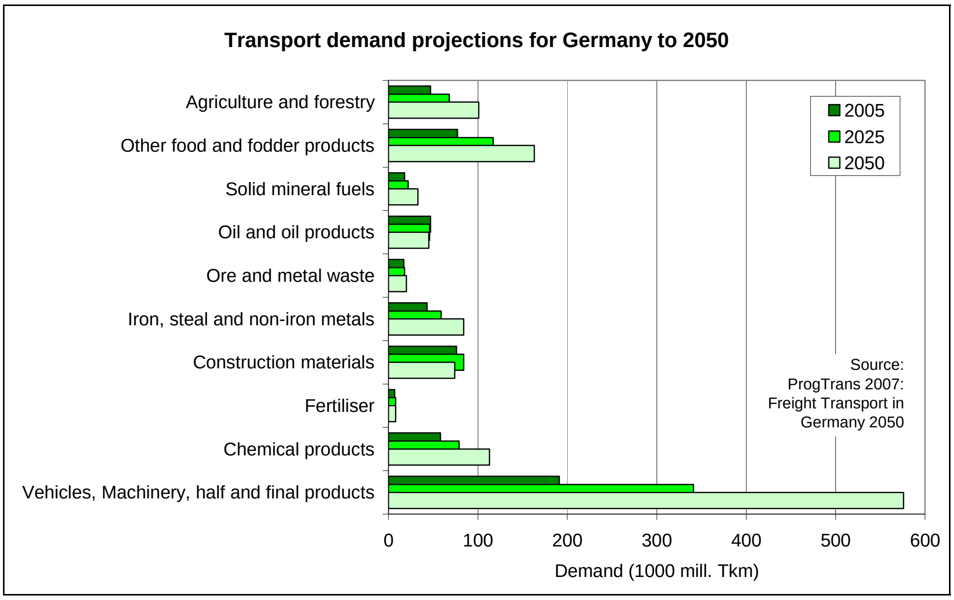
For the modelling work and the consideration of reaction schemes the goods structure is slightly adopted:

- The two bulk goods elements are summarised to a single commodity as it is expected that their affinity towards shifts to road appears equal.
- Container traffic is split into maritime container traffic (to and from seaports) and continental (all remaining) container traffic. On the basis of flow analysis in the UIRR statistics maritime container traffic is considered being 25 % of total container traffic for both modes.

3.2 Demand forecasts

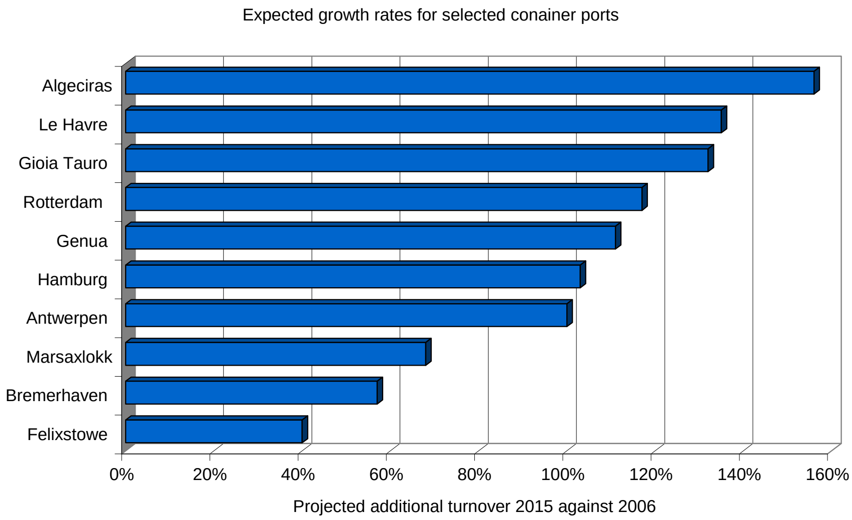
Basis for the forecasts transport volumes is the report on market development in Germany until 2050 by ProgTrans (2007) and a projection of maritime traffic demand of major European ports by Uniconsult (2007). The ProgTrans (2007) assumptions for Germany are considered representative for the whole EU. Figure 12 presents the results by goods structures and Figure 13 gives details for the major European ports.

Figure 12: Long-term forecast of goods transport in Germany by commodities



Source: Data from ProgTrans (2007)

Figure 13: Forecast of maritime traffic in major European ports until 2015



Source: Data from Uniconsult (2007)

Extrapolated to 2025 the following assumptions for the four market segments chosen emerge:

- Bulk goods, including heavy industry and chemical products: + 20 %
- Food & semi final products: +50 %
- Final and unitised goods (all destinations): +80 %
- Seaport traffic +110 %

Total ton kilometres are expected to grow by 45 %. This is in accordance with results of the TRENDS database (Manzos and Capros 2006) for the EU.

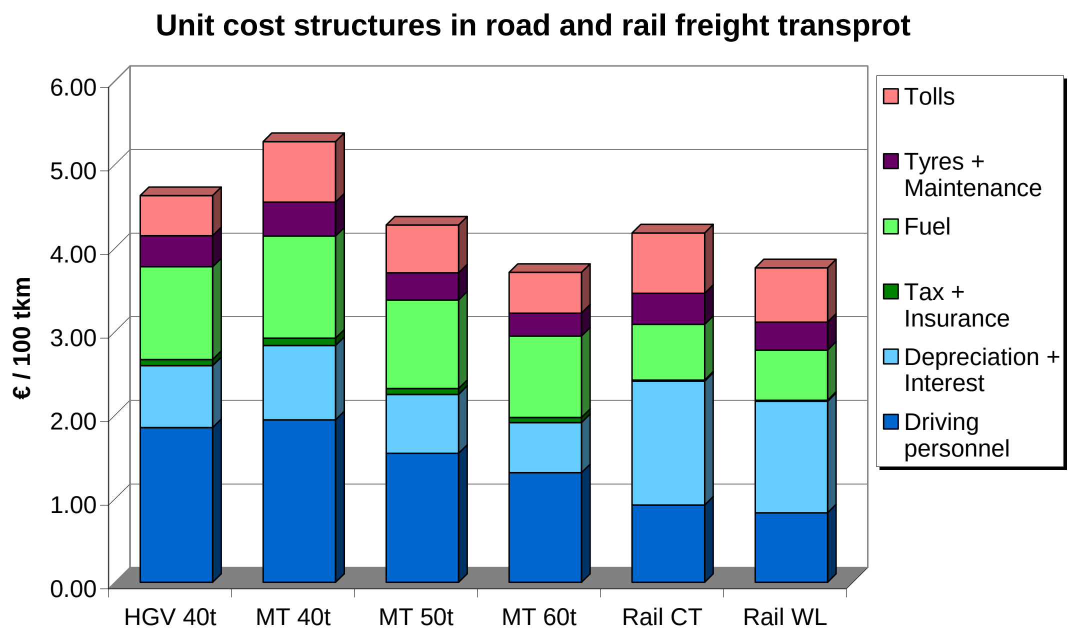
3.3 Cost efficiency of Mega-Trucks

For the application of price elasticities unit costs per vehicle or ton kilometre and their development over time are required. Current unit costs and cost structures in road haulage are taken from statistics of the International Road Union (IRU). The structure of the cost categories (tolls, maintenance, fuel, taxes, depreciation and personnel) in 2005 is depicted by Figure 14.

The bad performance of 40 t Mega-Trucks in comparison to common HGVs is due to the unit chosen (€/t of payload). Having expressed the operating costs in volume categories (€/m³ of load space) would change the picture in favour of 40 t Mega-Trucks.

For the rail sector cost structures have been estimated on the basis of annual reports of Deutsche Bahn AG. For total cost levels it is assumed that combined transport is only marginally more cost efficient than a standard HGV and that wagon load transport performs slightly better than the two.

Figure 14: Unit costs in road and rail transport by vehicle type 2005



For the future development of operating costs it is assumed that fuel costs rise much faster (+100 % 2025 compared to 2005) than other components (+25 % until 2025). This will cause a slight cost advantage for the railways given their currently lower share of energy costs.

3.4 Diffusion rates

Based on expert judgements and statistical data on fleet-renewal-rates Fraunhofer ATL elaborated the following conclusions:

- Statistical data indicates an eight year replacement cycle for heavy trucks and tractors (>7.5 tonnes). Since MT will be operated on intensive long distance transportation it is assumed that a more accurate figure would be six years.
- The first effects on the market will be to the conventional trucks and tractors on road transportation. Modal shift from rail to road will set in later and will be slower since the operational systems in intermodal operations will need more time to accommodate MTs.
- It is most likely that large logistics network operators like DHL, TNT, UPS, Schenker, Dachser, etc…, will be the first users of MTs for unitized loads such as containers and swop bodies. These carriers will be able to implement MT operations within two to three years after legalization.
- For other users with the regular replacement cycle the six to eight years period of market penetration may be applied.

Eventually it can be summarized that modal shift from rail to road caused by MT will occur after the network traffic of large logistics providers have implemented the MT in their fleets. Market penetration into the regular carrier fleets is assumed to follow the 6-8 years replacement cycle measured as industry average.

In the analytical work it is assumed that Mega-Trucks will be legalised on all networks across Europe in 2008.

3.5 Potential for modal shift

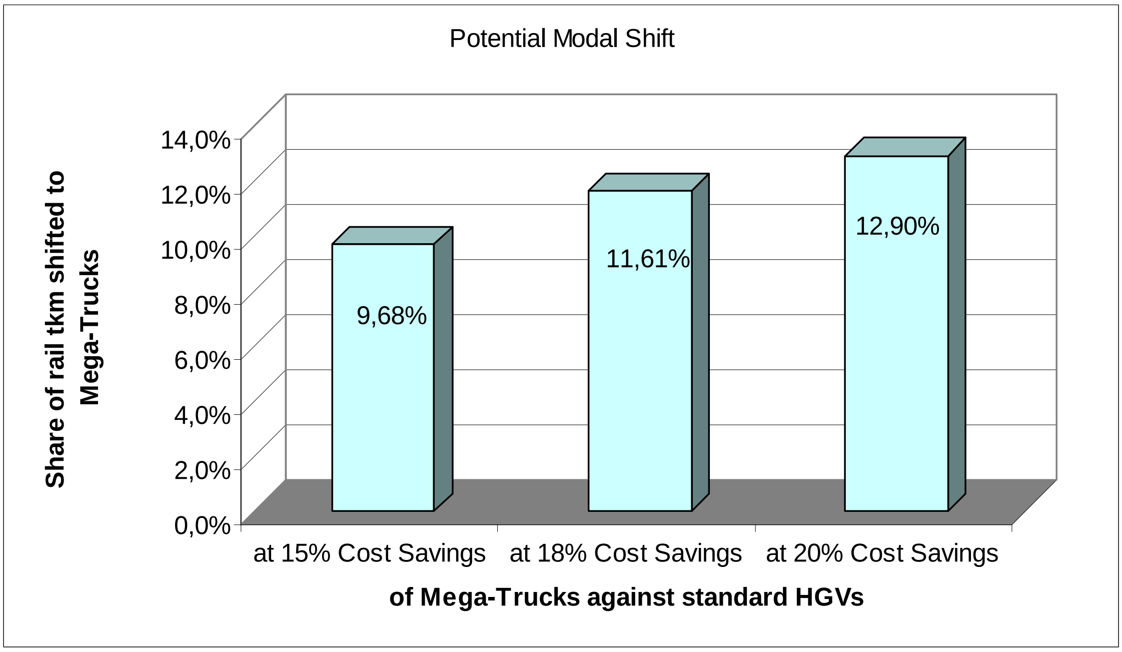
There are two major forces limiting the penetration of MT into the carrier fleets in Europe. The first is that it can be assumed that alpine countries like Switzerland and Austria will not allow MT on the north-south corridor. The second is that under current circumstances the operational scope of MT will only include highways.

As mentioned above, it can be expected that elasticities will be the highest in scheduled network operations of large logistics service providers. Seaport hinterland logistics is also assumed to be less affine to road transportation. This is because terminal capacities are already scarce and the feeding/discharging traffic of many MT in comparison to fewer trains makes cross-docking with trains much more attractive.

High value and special goods are rather Mega-Truck affine whereas bulk-loads are less elastic.

A preliminary assessment of the maximum shift potential from rail to MT showed the following results depending on the realized savings on road carrier side (see figure 15). The analysis was built on 2005 data from EUROSTAT with current market shares in the 24 commodity groups detailed in EUROSTAT reports based on thousand tonne kilometres. The elasticity was validated with current market shares in terrestrial transportation and scoring model affinities. Since the German field tests showed an average saving of 18% on carrier side, the range of potential savings was elected to be 15%, 18% and 20% carrier savings through the employment of MT.

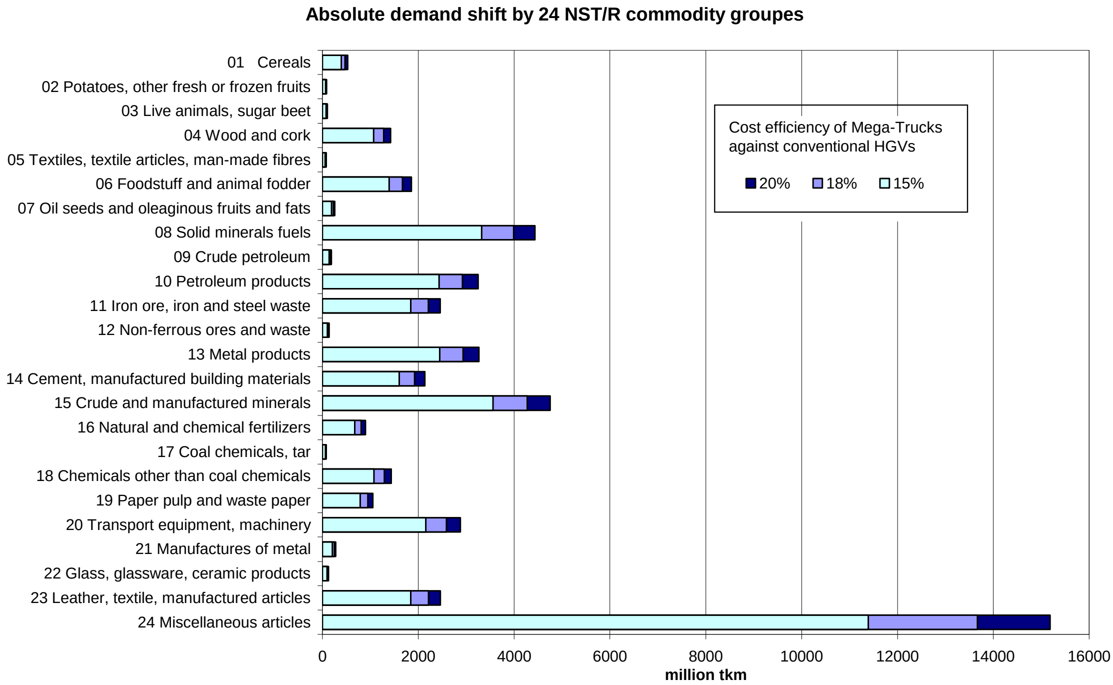
Figure 15: Maximum potential saving based on commodity group elasticities



Source: Fraunhofer-ATL based on Eurostat data

The maximum total shift at 20% average carrier savings would here be around 13%. This corresponds to a total of 44.418 million tkm. Figure 16 illustrated details of modal shifts by the 24 commodity types of Eurostat. In the subsequent section a detailed discussion on the four coarse market segments will be lead.

Figure 16: Total potential demand shifts from rail and CT to road by Mega-Truck cost efficiency



Source: Fraunhofer based on Eurostat data

Given the wide deviation of estimates and study results for the possible market share of Mega-Trucks, the following values used for the subsequent modelling process are expressed in plausible ranges instead of selecting single values.

3.5.1 Specific aspects concerning single wagon transport

In Germany and other parts of Europe single wagon transport and siding transport still plays an important role. Round about 40 % of transport performance is single wagon transport realising about 50 % of turnover. The European Commission estimates even that 50 % of EU rail movements are individual wagons. Thus, even the bulk good market segments of heavy industry and chemical products must operate a considerable share of single wagon shipments.

Railion, the freight carrier of DB AG realised in 2001 on average losses of more than 80 € per wagon. (Bendt, 2001). This difficult situation of single wagon load markets will worsen further in case road transport becomes cheaper due to longer or heavier trucks, price competition will increase.

The advantage of wagons concerning loading capacity in comparison to truck will most likely fade by the introduction of Mega-Trucks. The study of UBA (2007) underlines this by showing that the average loading capacity of railway wagons are only 1.5 times the loading capacity of standard HGVs.

More price competition and fading capacity advantages can shrink the capability and willingness to subsidise single wagon transport, Competition in the block train market among train operating companies has already set single wagon load services under pressure in the liberalised railway markets.

In the northern European countries like Norway or Sweden, single wagon transport has already been abandoned. Sweden is one of the countries where mega trucks are already operating for a long time.

3.5.2 The bulk goods market

The bulk goods market as presented in the subsequent model applications consists of the two partial markets

- heavy industry (58 % of total tkm in rail transport, 40 % tkm in road transport, share of rail at tkm: 26 %) and
- chemical industry and fertilizers (8 % of rail tkm, 7 % of road tkm, 20 % railway market share)

Both markets are characterised by high quantities of goods or big lot sizes between origin and destination of a shipment. Heavy industry goods contain steel and metal waste, ores, building materials, oil and oil products and solid fuels. These are commonly weight sensitive and not very time critical. The potential for modal shifts to railways is thus considered limited.

Products of the chemical industry are likely more time critical, but some of these goods are at the same time safety relevant. This is not only the security of the product itself and the driver, but also for inhabitants and the environment in case of an accident. Chemical products must thus only be hauled with experienced and well-skilled drivers. For such dangerous sensitive goods the industry thus prefers to take the railways in case direct track access is available.

The studies reviewed report extremely diverging market share of Mega-Trucks in the bulk sector. Applying 60 t Mega-Trucks TRL comes to a 5 % to 10 % market share, while Dutch evidence only considers 1.4 % to 2.7 % for the entire rail market. With 40 t Mega-Trucks TRL (2008) calculates 2.5 % to 5.5 %, which is 30 % of the market share with 60 t vehicles in the bulk market. On this basis the following ranges of values are selected:

Table 9: Potential rail market shares for Mega-Trucks in bulk goods

Market segment	Evidence	min.	max.
National MT60 t	TRL values / 2 wrt. NL evidence	2.5 %	5 %
Internat. MT60 t	MT60 t: TIM07 ratios / 2: 70 %-100 % of national	2 %	3.5 %
National / internat. MT40 t	TRL08	0%	0%
National / internat. MT50 t	less attractive for bulk, 30 % of shift due to MT60 t	0.6 %	1.5 %

3.5.3 The food, agricultural and medium value goods market

According to the UIC definition the segment consists of food and food products, semi-final- and consumer goods. In 2005 it has constituted 14 % of rail market in tkm and 12 % in tons. Accordingly, the average transport distance of this market segment is somewhat below the average rail distance of 260 km. The shares of food-related and semi-final products in road transport are 40 % at km and 24 % at tons.

The segment is largely road-affine. In rail transport it is assumed that high quantities of food, food stuff and semi-final products are transported via single wagon load. According to expectations from practice, this segment is of some difficulty and low productivity for the railways and shows a high tendency for modal shift towards the more flexible road sector.

Evidence from literature on rail market volumes shifting to Mega-Trucks in this market segment is not directly available. Conclusions from findings for bulk and container markets and for total rail sector reactions allow only rather general statements on the modal shift tendency of food and semi final products to road. A sound empirical basis is not available.

General statements meet the expectation, that the relative modal shift potential of this market segment ranges somewhere between bulk goods and combined transport. Given the high share and the sensitivity of single wagon load traffic we tend to conclude that the elasticity of food and semi-final products is closer to the elasticity found for container traffic than for bulk goods, in case Mega-Trucks with a maximum permissible weight of 60 t are introduced.

This goods segment consists rather of size than of weight critical goods. The modal shift potential of lighter Mega-Trucks (40 t) is thus considered not much lower than for 60 t vehicles.

On the basis of these considerations the final ranges of modal split potentials have been selected as shown in Table 10.

Table 10: Potential rail market shares for Mega-Trucks in food and semi final goods

Market segment	Evidence	min.	max.
National MT60 t	values for bulk goods +100 % = average rail shift by TRL08	5 %	10 %
Internat. MT60 t	as national 60 t Mega-Trucks	10 %	15 %
National / internat. MT40 t	40 % (TRL08) 60 %(K+P06) of MT60 t	1.6 %	6 %
National / internat. MT50 t	Average MT40 t and MT60	2.8 %	8 %

3.5.4 The continental combined transport market

The segment is defined by consignments of goods in containers or swap bodies from and to locations other than seaports. In the scope of this study this is equal to the segment of non-port related combined rail-road transport. Container traffic including maritime and non-maritime takes a share of 20 % of rail market in tkm and 15 % in tons. Concerning road the share is 16 % in tkm and 11 % in tons. Hereof, UIRR statistics suggest that 75 % are not related to seaport access.

There is a variety of studies from Germany and the UK investigating this market segment in detail. German evidence suggests a range of 18 % (Kessel and Partner 2007) to 44 % (TIM 2006) possibly shifted to Mega-Trucks with a gross weight of 60 t. TRL (2008) confirms these estimates for the UK. Kessel and Partner (2006) extend the upper range of potential modal shifts to over 30 % in case declining demand in combined transport leads to reductions in service supply, e.g. less lifts per week or more transhipments due to fewer available direct connections between terminals.

The range of estimates is considerably higher than for national connections. TIM (2006) and Kessel and Partner (2007) suggest lower ranges of 17 % to 20 %. Container goods are mainly size critical. Thus, according to the approach for food and semi-final goods, the potential for mode shift for 40 t Mega-Trucks is considered only slightly below the values fond for 60 t units. The rations to the shift potential of 60 t trucks is given in literature between 50 % (TRL 2008) and 85 % (Kessel and Partner 2006)

Based on these findings Table 11 presents values finally selected.

Table 11: Potential rail market shares for Mega-Trucks in continental container transport

Market segment	Evidence	min.	max.
National MT60 t	K+P06 values (low / 2 wrt. field tests)	20 %	30 %
Internat. MT60 t	reduced lower bound of K´+P06	17 %	20 %
National / internat. MT40 t	60 %-75 % of MT60 t (TRL08, K+P06)	6 %	15 %
National / internat. MT50 t	Average MT60 t – MT40 t	8 %	25 %

3.5.5 The maritime combined transport market

The segment is defined as consignments of goods in containers (20 ft. or 40 ft.) from or to seaports. According to the elaborations for continental container goods the maritime container segment constitutes 25 % of total container market in ton-kilometres. This is 3 % of the total rail market in ton-kilometres.

As for continental container markets a variety of studies of potential shifts from rail to road after the introduction of Mega-Trucks is available. Due to infrastructure capacities in the access to seaports, due to the commonly big lot sizes and due to restrictions of Mega-Trucks in carrying particular container combinations, the potential of maritime container markets shifting to roads is considered more limited than for continental markets. However, there are factors in favour of such shifts, e.g. the limited availability of rail access facilities in ports.

The ranges for modal shifts given in current studies is 16 % (Kessel and Partner 2007) to 27 % (TIM 2006) and 54 % (TRL 2008). As discussed above, the upper ranges include the impacts of closing or reducing combined transport connections due to decreasing demand.

The ranges given for international consignments are somewhat lower than in the national case as it can be expected that these anyway rail-affine markets will be sufficiently stable to withstand the price pressure form Mega-Trucks. Values given in literature range between 12 % (TIM 2007) and 18% (Kessel and Partner 2006)

Table 12 presents the values finally selected.

Table 12: Potential rail market shares for Mega-Trucks in maritime container transport

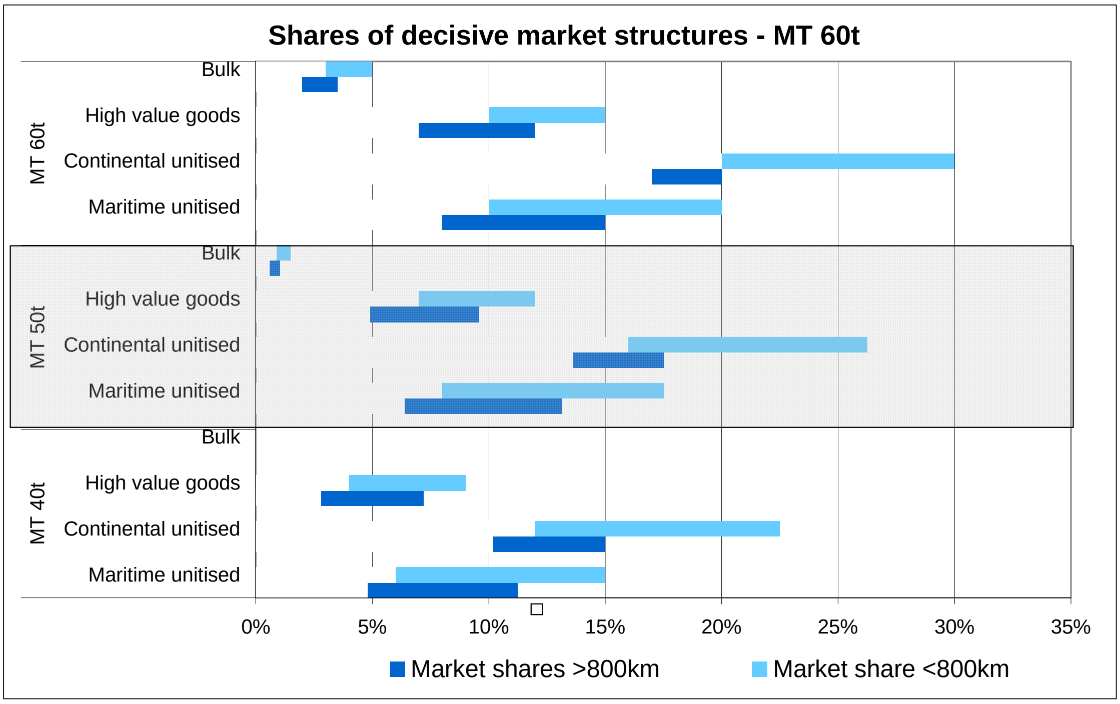
Market segment	Evidence	min.	max.
National MT60 t	K+P06 values (low / 2 wrt. field tests	10 %	20 %
Internat. MT60 t	reduced lower bound of K+P06	8 %	15 %
National / internat. MT40 t	60 %-75 % of MT60 t (TRL08, K+P06)	5 %	15 %
National / internat. MT50 t	Average MT60 t – MT40 t	6 %	18 %

3.5.6 Summary of selected market shares

The ranges of potential market share selected above are summarised in graphically in Figure 17. Across all markets the highest risk for modal shares appears for continental combined traffic. In contrast to maritime traffic here no general restrictions of terminal access capacities are assumed, and thus the direct unimodal shipment by truck instead of transhipments to and from rail are considered preferable for the shippers. But in container markets uncertainties about the effect of Mega-Trucks are much higher than in bulk or medium- to high value goods as the supply side impact of reduced services entailed by declining demand might be considerable.

In absolute terms the bulk market, consisting of heavy industry and chemical products, is expected to create as many ton kilometres of cargo shifted from rail to road as the container market when permitting 60 t Mega-Trucks across Europe. For lower weight limits there might be some potential, but this is expected to be minor.

Figure 17: Summary of potential rail market shares shifting to Mega-Trucks



Factors restricting the modal shift potential (or risk) of Mega-Truck are considered as follows:

- Road Regulation: Likely restriction of Mega-Trucks to motorways or similar roads without level crossings and with lane separation due to safety reasons. This measure would partly remove the flexibility advantage of Mega-Trucks against the railways. The costs of splitting long vehicles at motorway exits will be very cost relevant for short and medium distances. However, in the long run it can be suspected that this kind of restriction will be weakened due to pressure by the industry.

- Road infrastructure quality: Besides the exception of Sweden road infrastructures in most EU countries have not been designed for the accommodation of Mega-Trucks. In some countries, particularly in the new member states, the road network is furthermore of very poor quality, such that the accommodation of Mega-Trucks is practically not possible.

- Port access capacity: In many western European ports the access by road is either congested or transhipment capacities are not available. A shift of high quantities of goods from road to rail can thus only be considered for smaller ports with spare capacity.
- Rail supply: Improved supply quality of the railways. Through the introduction of ETRMS Level 2 and 3 in combination with the European Traffic Management Layer (ETML) the capacity availability and the flexibility of track allocation on railway networks are expected to grow considerably. Productivity, flexibility and attractiveness of rail services are expected to grow accordingly.

A more analytical elaboration of modal shift effects across the EU, by distance bands and over time is subject of the model applications in Chapters 5 and 6.

3.6 Potential for Mega-Trucks in road haulage

For the subsequent analyses the size of Mega-Truck markets in road haulage are required for estimating road congestion and the related cost and environmental impacts and for determining the final energy and CO2 balance of the Mega-Truck scenarios against the base case without Mega-Trucks.

From literature, only little information on potential market shares of Mega-Trucks is available. In any case this will be highly dependent on regulatory conditions.

TRL (2008) reveals with a detailed logistics model that, without any restrictions, 54 % of all HGV trips (above 32t) are possible candidates for the application of Mega-Trucks. In case Mega-Trucks are restricted to the motorways only, the share of candidate trips reduces to 33 %. In case commodity types are restricted a share below 10 % is found for the UK.

German evidence by IVH (2007) reveals a replacement of trips in Lower Saxony is 10 % to 15 %. Extrapolated to Germany a share of 21 % is found. The report further cites studies from the automotive industry saying that Mega-Trucks may replace 4 % to 22 % of HGV trips.

In the subsequent scenarios we assume that Mega-Trucks are restricted to the motorway network for safety and acceptability reasons. Leaving the motorways means to costly cut Mega-Trucks into two individual vehicles by adding another engine and driver. For the system dynamics approach (Chapter 6) we apply an average across all commodities of 20 % of ton kilometres potentially going to Mega-Trucks with 60 t gross weight.

It is generally expected that HGV market shares on long distances are considerably higher than on short to medium distance relations. Further we assume that the relative potential of a commodity to shift from rail to road also expresses the sensitivity of this commodity shift to Mega-Trucks within the road sector.

With regard to the results of TRL (2008) and the somewhat lower expectations of IVH (2007) the following very crude assumptions as input for the System Dynamics model are taken:

- trips below 800 km 50 % of respective market share of railways shifted to road
- trips above 800 km: 50 % above respective rail market shares.

A much more detailed assessment will be carried out by the geographical logistics model approach described in Chapter 5.

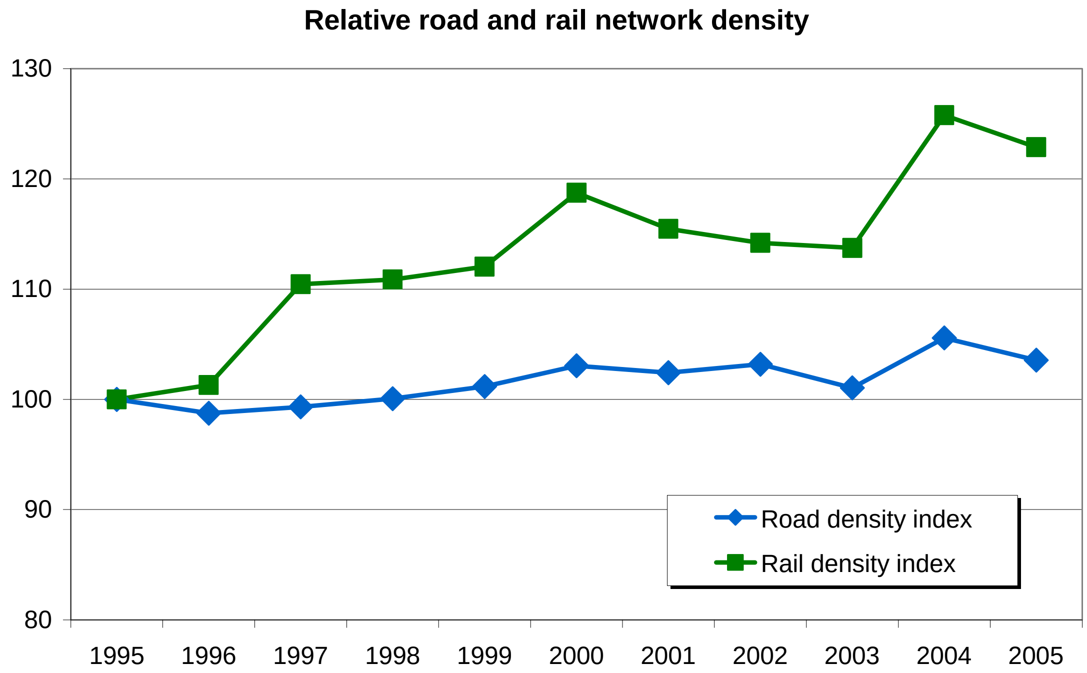
3.7 Infrastructure supply

Congestion may counter-balance the cost efficiency gained by Mega-Trucks on the road and decreasing rail demand may cause rail freight rates to become less attractive due to the high share of fixed costs in the railway sector. However, reliable figures on the development of congestion across all modes and countries in Europe are not available. We consider the increase of network densities a proxy to judge the past development. Figures for the EU-15 from 1995 to 2004 are available from Eurostat. This leads to the following conclusions:

- Rail: 18 % demand increase with 4 % reduction of network length. The largest reductions took place in Germany (-18 %) and France (-6 %), while the UK showed an increase in network length of 17 %. For the model forecasts a network growth at 0.5 % p.a. is assumed
- Road: 31% demand increase in ton kilometres (+27 % national traffic and +44 % international traffic) on all road types with a 23 % extension of the motorway network from 1995 to 2005 in EU15. While nearly all countries show growth figures above 10 %, the largest extension programs took place in Ireland (+253 %) and in Portugal (+241 %). For the system dynamics model a network growth at 2.0 % p.a. for motorways is assumed.

The trend of faster growing network density on rail compared to road implies a strategic advantage for the road haulage sector, continuously improving its competitive situation.

Figure 18: Network density on motorways and railways 1995 - 2004, EU-15



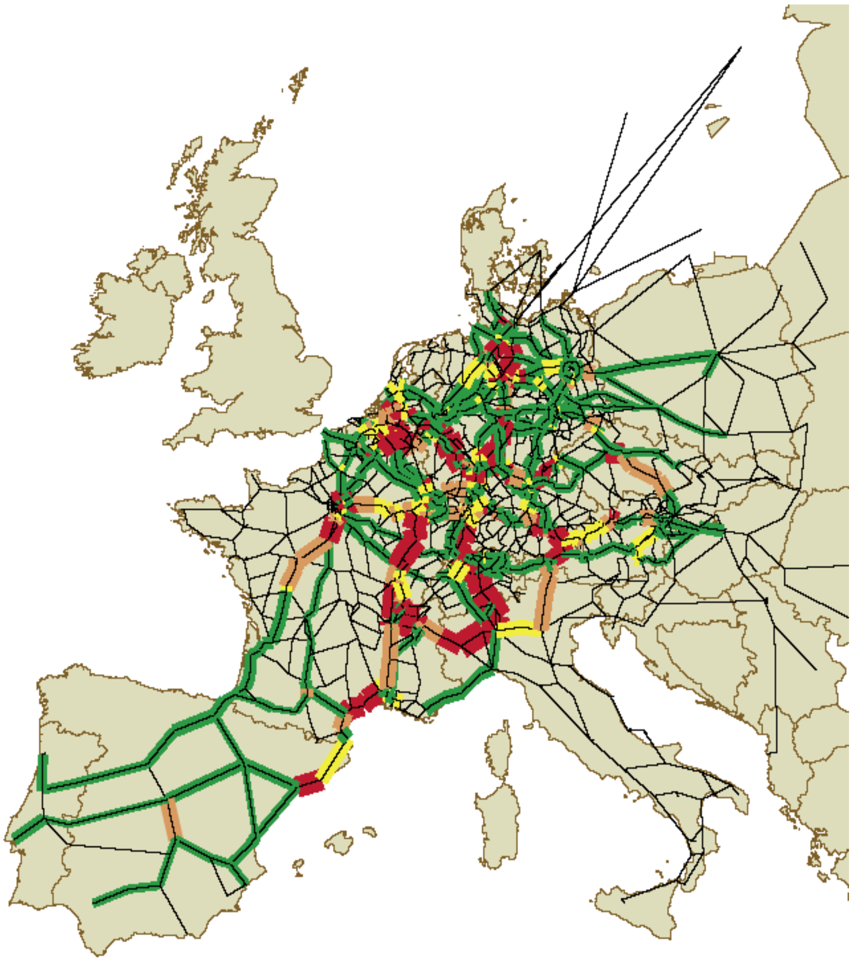
Source: Fraunhofer-ISI with data from EC (2008)

3.7.1 Railway capacity supply

The problematic capacity situation and the expectations for the coming years are documented by the strategic investment needs in major international railway corridors (Figure 19 and CER 2005).

Considering the implementation of the European Rail Traffic Management System (ERTMS) level 2 and 3 and the installation of ETCS in combination with planned investments a stable capacity situation until 2020 is expected. However, on the regional level it is acknowledged that capacity gains might be large enough to over-compensate demand growth, but this strongly depends on local conditions and demand structures.

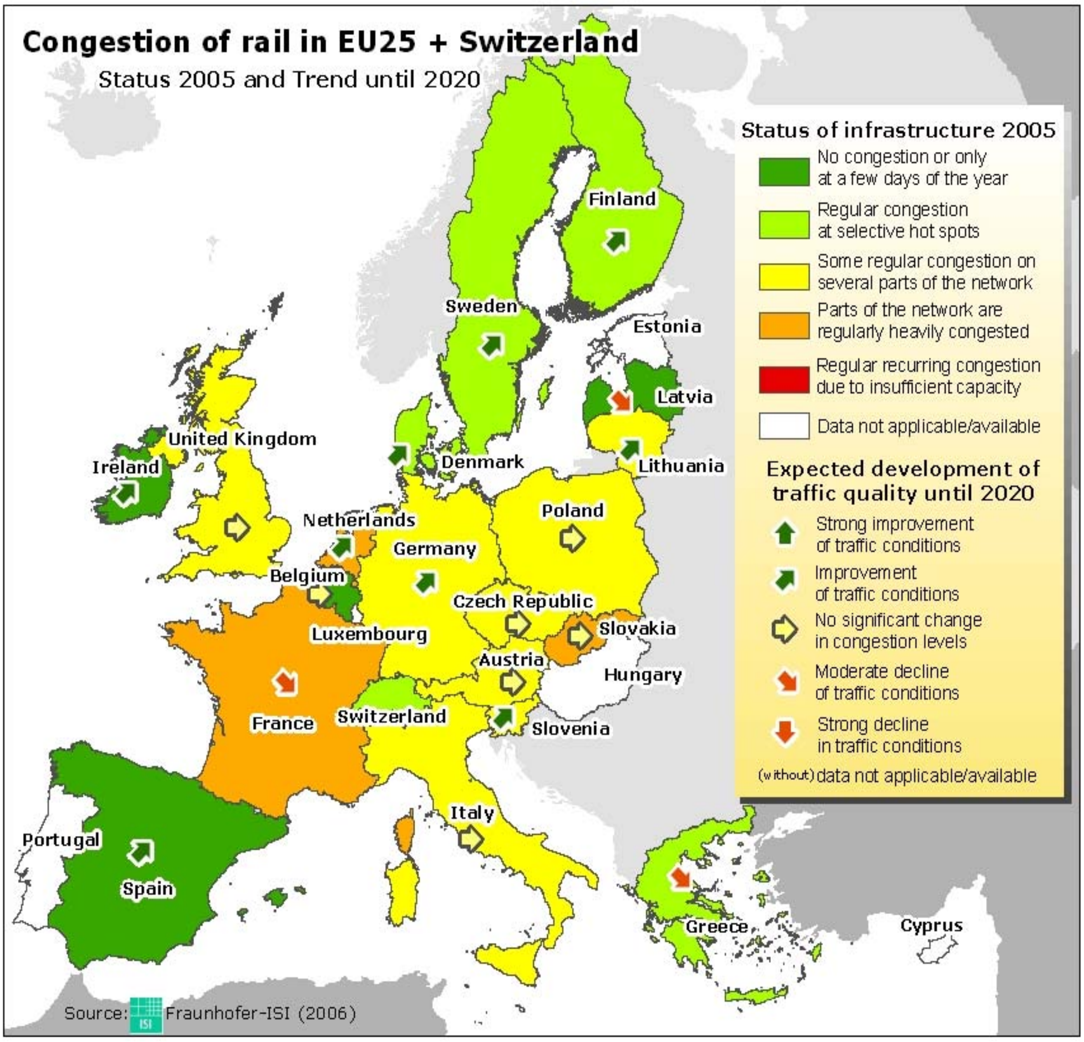
Figure 19: Bottlenecks on international railway corridors



Source: CER (2005)

Based on a series of interviews with decision makers in the transport sector in 27 European countries and the US the COMPETE project (ISI et al. 2006) has sketched a map of the current status and expected developments until 2020 of the major transportation infrastructures. For the railways the current situation is still considered average to slightly dense in most countries. But there is no consistent trend of future infrastructure quality expectations of national bodies (Figure 20).

Figure 20: Current status and expectations on rail network quality development until 2020



Source: Fraunhofer-ISI, data from ISI et al. (2006)

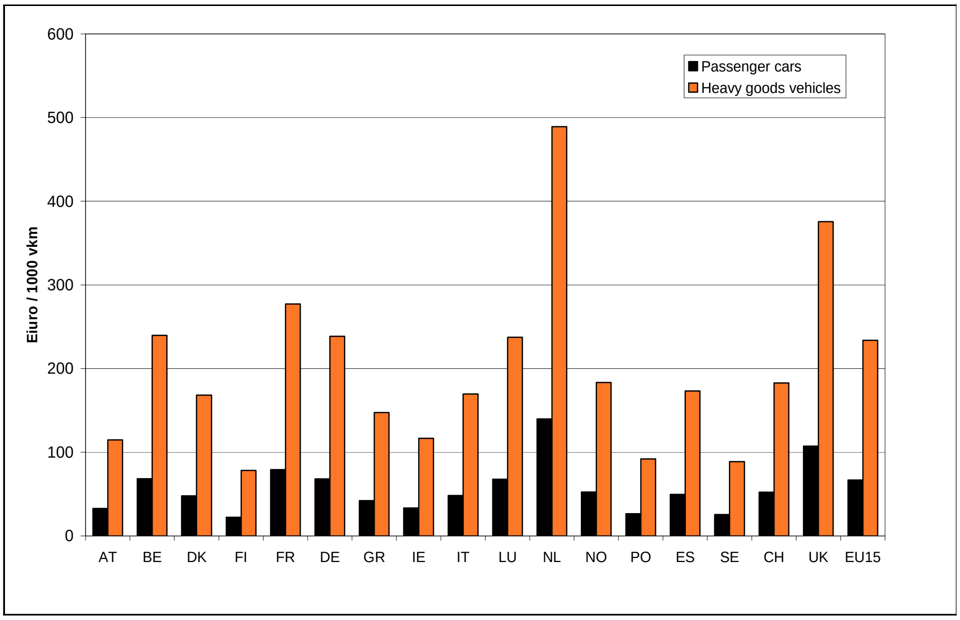
The overall expectation transformed into capacity availability of the System Dynamics model (Chapter 6) is a slightly increasing capacity shortage until 2020. I.e. capacity availability is assumed to grow somewhat slower than demand for rail freight services.

3.7.2 Railway capacity supply

According to Infras/IWW (2004) there is a concentration of road congestion along the "blue banana" from southern England via the Benelux countries, northern France, western Germany to northern Italy. Figure 21 depicts some quantitative measures for 2000 comparing road congestion on the national networks to each other.

In response to increasing congestion levels the European Commission plans to introduce flexible road pricing (smart charging) in combination with improved traffic control systems and investments. The combination of these measures is expected to decrease the growth of congestion in most parts of Europe significantly. Demographic trend and stagnations in passenger traffic demand will in the medium run support the goal of calming congestion, at least outside Europe's big agglomerations.

Figure 21: Average and marginal congestion costs per traffic unit in Europe 2000

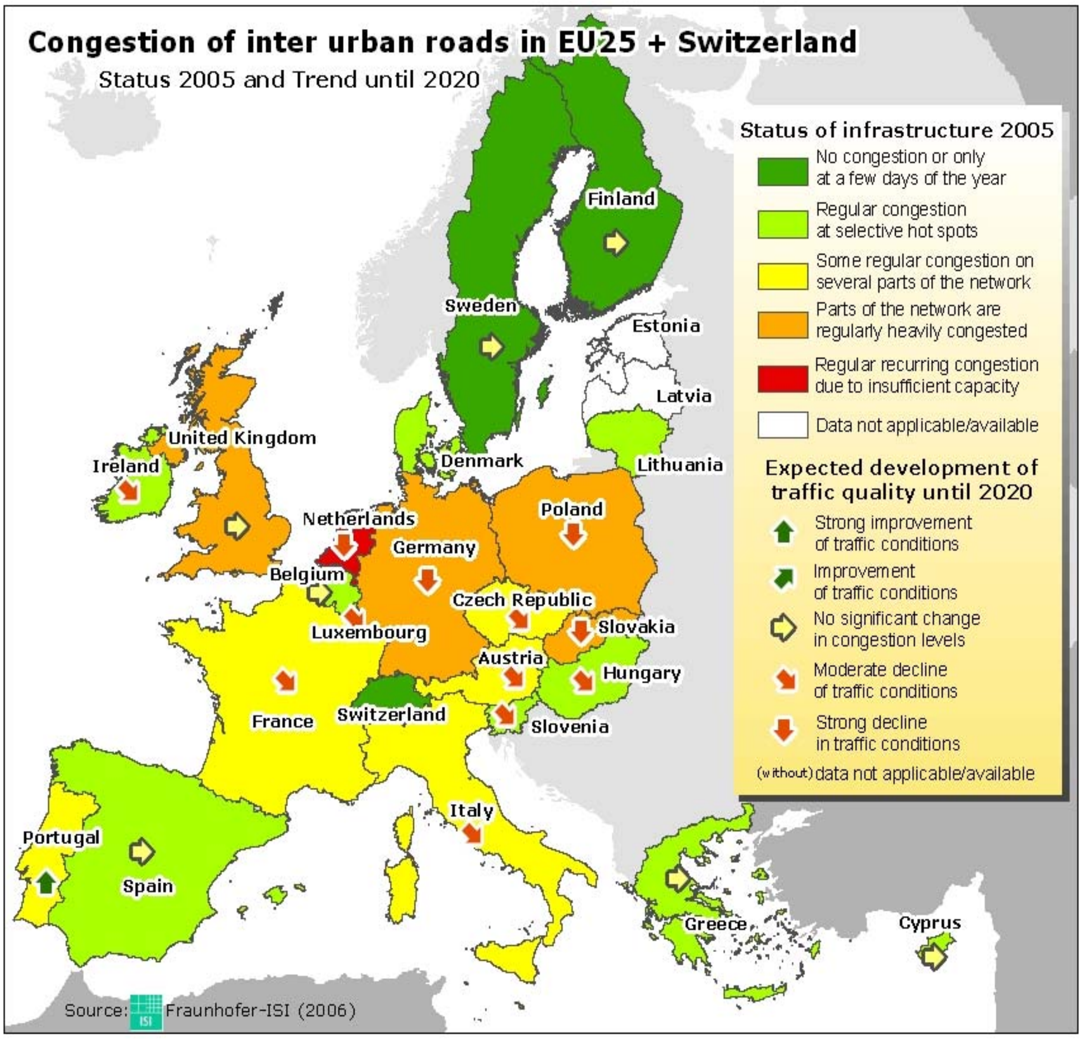


Source: Infras / IWW (2004)

Some EU Member States, amongst others the north-western continental countries and some of the new Member States, expect a drastic deterioration of road congestion condition. National forecasts and the interviews conducted for the COMPETE project (ISI et al. 2006) reveal this situation (Figure 22). Nevertheless, most expectations and national forecasts do not consider the options of traffic management and demographic trends sufficiently.

Besides pure congestion or traffic density considerations, the value of road infrastructure in particular for the use of Mega-Trucks depends on the physical conditions and the dimensioning of pavements. COMPETE analyses have found that these indicators are particularly problematic in central and eastern European countries, where traffic partly detours to secondary roads as the conditions on motorways have become unacceptable in the past decade.

Figure 22 Current status and expectations on rail network quality development until 2020



Source: Fraunhofer-ISI, data from ISI et al. (2006)

To conclude: investments, charging, traffic management and demographic trends will balance out the growth in road freight transport, such that congestion levels until 2020 / 2025 broadly remain at 2005 levels across the EU.

4 Corridor Analyses

4.1 Objectives and structure

The first objective of the case studies is to present practical issues in long-range freight transport. On the basis of concrete examples the pros, cons, potentials and limitations of switching from rail to Mega-Trucks shall be elaborated. This should then lead to a better understanding of cost structures and cost drivers in logistics chains. Finally, the case studies were asked to discuss the role of politics in maintaining rail shares.

To provide evidence for these questions the following two European corridors have been investigated:

- Trans-Alpine traffic from northern Europe to and from Italy
- Seaport hinterland, long east west connection from the Netherlands to Poland

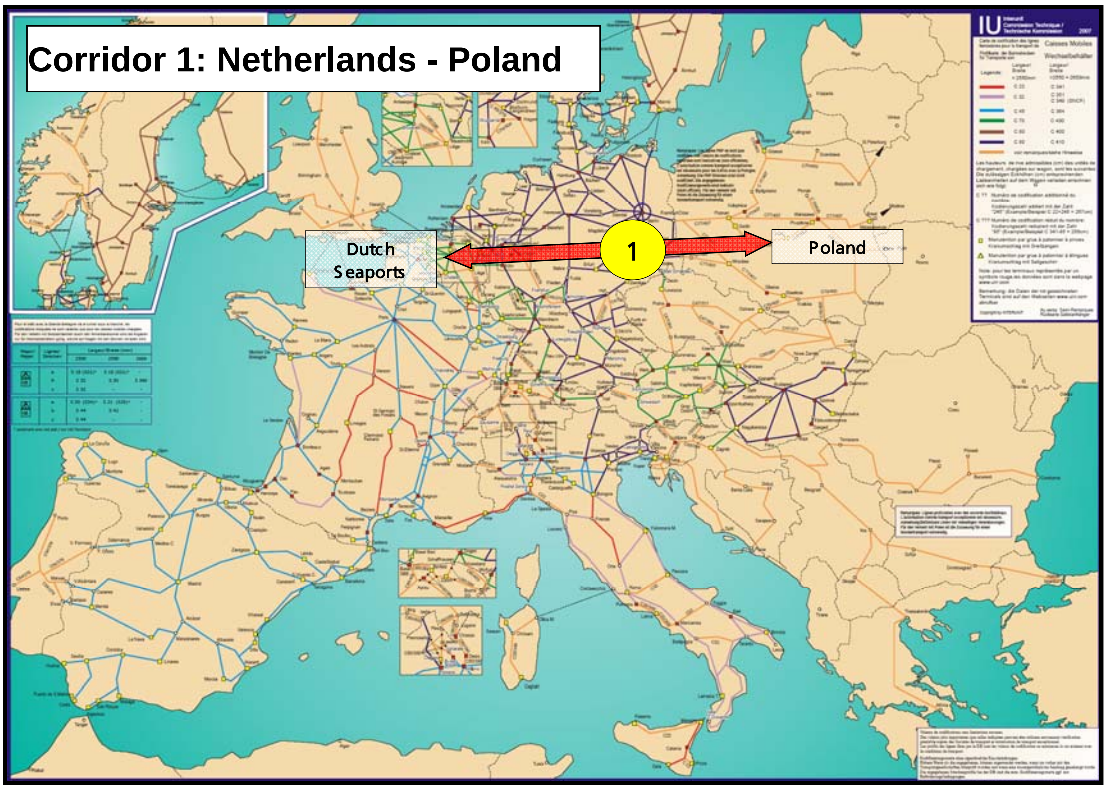
For the analyses of the corridors the following data sources have been applied:

- Previous studies
- Industry contacts
- Experience of the authors

4.2 Corridor 1: Dutch seaports to Poland

The highest risk of Mega-Trucks for the railway and for combined transport in particular is constituted for long distance trans-European relations. One of these is certainly the route from the Dutch and Belgium seaports to the still fast growing economies in the new Member States of central and eastern Europe. To demonstrate the demand situation and their relation to the structure of forwarder and haulage companies the corridor Netherlands – Poland was selected.

Figure 23: Geographic location corridor 1: Netherlands - Poland



Date extracted for the purpose of this case study ranges from the EUROSTAT data-base on international transportation (2004/2005) to expert judgements of Fraunhofer staff and industry partners.

As evident in Table 13 the trade balance between Poland and the Netherlands is highly uneven to the disadvantage of Poland. The lines in the tables depict the data provided by either Dutch or Polish companies.

Table 13: Transport volumes road and rail on the corridor Netherlands – Poland by reporting country 2004 and 2005

Year	**2004**			**2005**		
Reporting country	Rail 1000 t	Road 1000 t	Rail share	Rail 1000 t	Road 1000 t	Rail share
	From Poland to the Netherlands					
Poland	106	54	66.3 %	102	80	56.0 %
Netherlands	106	1054	9.1 %	94	912	9.3 %
Poland + Netherlands	212	1106	16.1 %	196	992	16.5 %
TOTAL	1320			1188		
	From Poland to the Netherlands					
Poland	212	109	66.0 %	217	108	66.8 %
Netherlands	118	1216	8.9 %	113	1250	8.3 %
Poland + Netherlands	330	1325	20.0 %	330	1358	19.6 %
???	1655			1685		

Data source: Eurostat

This allows the conclusion that much of the terrestrial transportation is operated on the road and predominantly by Polish forwarders. An explanation for this may be that many of the companies that attend this relation will have moved towards Poland in order to benefit from cheaper input factor costs.

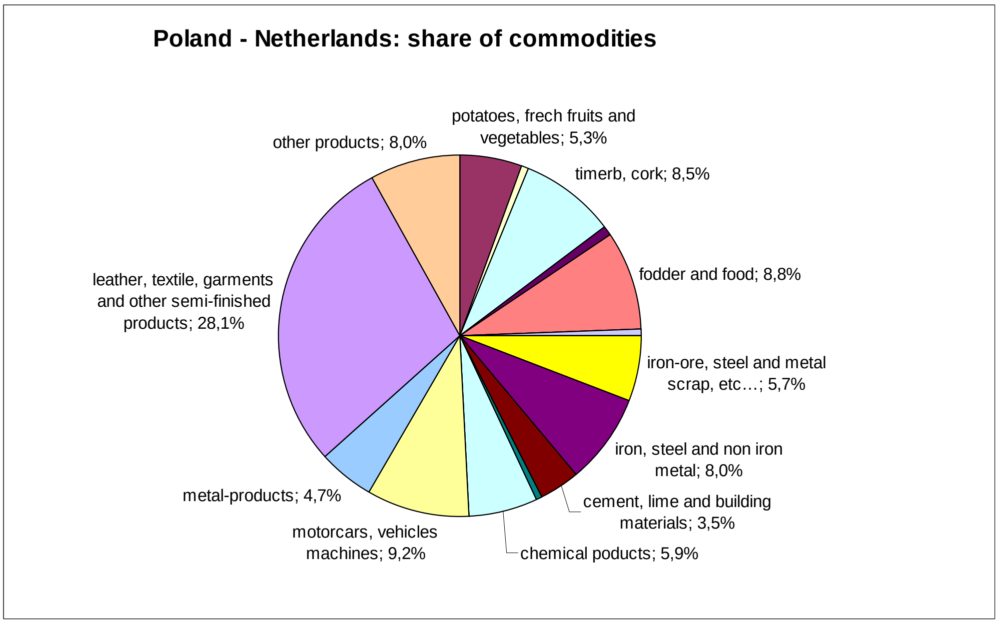
The majority of Dutch transport is operated intermodally using the railways. In 2004 and 2005 the rail share among Dutch companies in both directions was well above 50% whereas the total rail share on terrestrial transportation was either at 16% direction PL-NL or at 19% from NL to PL.

The assumption is that much of the seaport hinterland transportation is shifted to short sea shipping (SSS). Seaport hinterland transportation, which tends to be more affine to rail transportation, is not included in the rail traffic. This would mean that the remaining goods on rail are on average more affine to modal shift. From interviews it is known however, that the railways remain highly competitive due to the poor road infrastructure in Poland.

The composition of goods transported on this route is not especially road or rail affine. There is a tendency to transport garments and leather products from Poland to the Netherlands. This may explain the higher road transportation share in this direction.

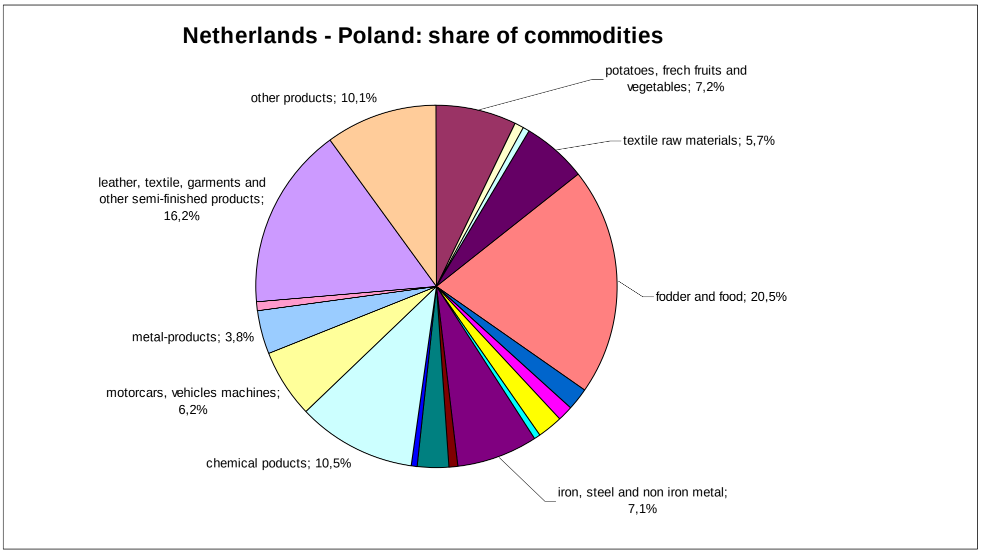
The overall picture is however hazy at best. There is no clear tendency towards either road or rail affine goods. The following figures present the share of commodities per direction.

Figure 24: Structure of goods on the corridor Poland - Netherlands 2004



Source: Fraunhofer-ATL with Eurostat data

Figure 25: Structure of goods on the corridor Netherlands - Poland 2004



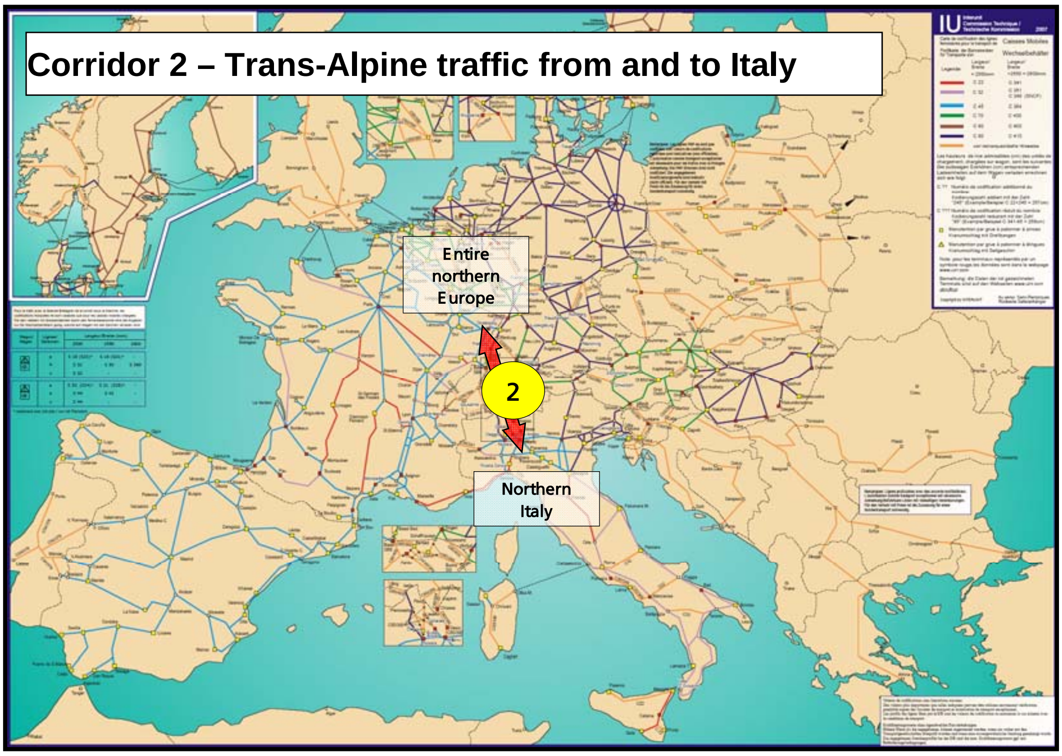
Source: Fraunhofer-ATL with Eurostat data

The bad situation on Polish roads, paired with rail fees expected to fall further and the liberalization of the Polish railway market will make the railway an even more interesting alternative. This may be especially true taking into account the convergence in cost levels between Poland and the Western European countries. For these reasons Fraunhofer ATL predicts low modal shift potential on the Corridor Poland – Netherlands.

4.3 Corridor 2: Trans-Alpine traffic

UIRR statistics (UIRR 2007) impressively show that the vast majority of combined transport volumes and performance takes part across the Alps. Apart from this statistical importance the corridor is of analytical value as the market reactions on the increase of the HGV ton limit from 28t prior to 2001 to the European standard can give valuable hints on the likely market reactions on the permission of Mega-Trucks in the EU.

Figure 26: Geographic location corridor 2: Trans-Alpine traffic from and to Italy



4.3.1 The current demand

There are three main Trans-alpine corridors that can be defined, and they correspond roughly to the transit through or towards the three alpine countries France, Switzerland and Austria.

The market analysis of the transport of goods along these corridors is influenced by different factors, but the main drivers can be found in the type and size of the shipment of goods and in the regulatory issues, which strongly determine the path choice.

The available traffic counts at different Alpine crossings are the most important data source, which can be used to quantify the market size.

The following tables illustrate the market size according to the type of traffic (overall data 2006).

Table 14: Goods traffic through Alps, by road and rail (2006, million tons)

Direction	Alpine crossing	Road	Rail				Total Road and Rail
			WL	CNA	CA	Total	
France	Ventimiglia	18.9	0.5	0	0	0.5	19.4
	Montgenèvre	0.7	-	-	-	-	0.7
	Moncenis	-	3.1	2.7	0.3	6.1	6.1
	Fréjus	12.5	-	-	-	-	12.5
	Mont Blanc	9.1	-	-	-	-	9.1
Switzerland	Gran San Bernardo	0.6	-	-	-	-	0.6
	Simplon	0.8	3.1	4.3	1.6	9.0	9.8
	Gotthard	10.0	5.3	10.6	0.4	16.3	26.3
	San Bernardino	1.5	-	-	-	-	1.5
Austria	Reschen	1.8	-	-	-	-	1.8
	Brenner	34.3	3.6	5.6	2.3	11.5	45.8
	Tarvisio	19.9	5.5	0.6	0.4	6.5	26.4
TOTAL		**110.1**	**21.1**	**23.8**	**5.0**	**49.9**	**160.0**

Source: TRT based on Alpinfo

WL = Wagon Load
CNA = Combined, not accompanied
CA = Combined, accompanied

The most important corridor, in terms of total traffic and in terms of market share of rail services, is the so called Corridor 24 or Genoa – Rotterdam Corridor. It crosses the Alps through Switzerland and includes two major rail lines (Simplon and Gotthard), both subject of ongoing infrastructure development.

An analysis based on the commodity groups transported is possible with respect to each single Alpine crossing.

The following table reports the split of the traffic type with respect to the 2004 traffic at the Gotthard counting place. The analysis is highly influenced by the relevance of category NST/R 9 to which the entire rail unaccompanied combined traffic is attributed.

Table 15: Goods traffic at Gotthard, by road and rail (2004, million tons)

Commodity (NST/R group)	**Road**	**Rail WL**	**Rail CA**	**Rail CNA**	**Total**
0	0.780	0.753	0.038		1.570
1	1.282	0.229	0.028		1.539
2	0.012	0.055	0.001		0.068
3	0.006	0.156	0.001		0.164
4	0.135	0.415	0.028		0.578
5	0.762	1.439	0.119		2.321
6	0.735	0.378	0.022		1.135
7	0.003	0.006	0.001		0.010
8	0.914	0.471	0.091		1.476
9	5.256	2.071	0.149	9.662	17.139
Total	**9.884**	**5.974**	**0.479**	**9.662**	**25.999**

Source: elaboration on CAFT

With respect to the length of the trips, it is possible to classify the traffic according to the origin and destination of the shipments. In particular it is important to quantify the whole traffic excluding the internal traffic: it can be considered as short distance traffic.

The table below shows interesting data:

- the transit traffic constitutes the most relevant share of traffic;
- the overall traffic is unbalanced but data is different for rail and road. While road shows substantially balanced flows in the two directions, the unbalanced share is all attributable to rail traffic, which is a weakness of rail traffic;
- the internal traffic is not negligible, also in terms of modal share: the Swiss policy and perhaps well operated rail traffic brings very good results also on short distance relations.

Table 16: Goods traffic at Gotthard, by road and rail, classified according to the direction of flow and the type of relation served (2004, million tons)

Flow - Direction		**Road**	**Rail WL**	**Rail CA**	**Rail CNA**	**Total**
North – South	Import	0,116	0,249	0,005	0,006	0,377
	Export	0,731	0,392	0,004	0,240	1,366
	Transit	2,854	3,447	0,234	5,486	12,020
	Internal	0,874	0,610	0,000	0,093	1,577
Total North - South		**4,575**	**4,699**	**0,242**	**5,824**	**15,341**
South – North	Import	1,369	0,220	0,005	0,209	1,804
	Export	0,116	0,015	0,001	0,000	0,132
	Transit	3,312	0,642	0,226	3,447	7,627
	Internal	0,512	0,398	0,004	0,182	1,095
Total South - North		**5,310**	**1,275**	**0,236**	**3,838**	**10,659**
Total		**9,884**	**5,974**	**0,479**	**9,662**	**25,999**

Source: elaboration on CAFT

The overall Genoa-Rotterdam corridor includes also important relations on the northern part of the corridor, and therefore the traffic considered does not represent the traffic along the whole corridor.

4.3.2 Policy and regulatory issues

The analysis of the potential market on selected corridors must, beside the flow volumes, take into account the regulatory problems. According to the most recent studies the main directions in the field are towards an increase of tolls according to the forthcoming new Eurovignette Directive (proposal published on 8 July 2008).

The Alpine case is subject of lots of studies, and for the corridor it is relevant to highlight the current conditions in Switzerland.

The Heavy Vehicle Fee (HVF) was introduced in Switzerland in January 2001, as the final step of a long political debate that had started in 1978. The HVF is levied on the whole Swiss road network and the reasons for it are to internalise external costs of transport, finance new railway infrastructures and obtain structural changes in transport industry and in fleet composition in order to limit heavy goods vehicles traffic growth.

All domestic and foreign heavy vehicles and trailers for goods transport with a gross total weight of more than 3.5 tonnes are subject to the distance-related heavy vehicle fee. The HVF calculation depends on the kilometres driven within the borders of Switzerland (on any road), the permissible Gross Total Weight (GTW) according to the registration documents of the vehicle and the emission standard of the vehicle.

The HVF rate increased over time in co-ordination with the increase of the permissible gross total weight of heavy vehicles using the Swiss road network (from 28 to 34 tonnes in 2001 and to 40 tonnes in 2005).

The dynamics in the HVF rate was designed to take into account the development in the emission abatement technologies of diesel engines. The distance-dependent fee, with its differentiation between more or less polluting trucks, meets in that way the principle of internalisation (polluter-pays principle) stated in the Swiss constitution. This principle inspired a charge that includes in its calculation the external costs, such as health costs and damages to buildings caused by air pollution and costs of noise and accidents, nevertheless excluding the congestion cost.

Three reasons are considered decisive for the political implementation of the charge system:

- the HGV charge system was introduced simultaneously with a raise in the weight limit of trucks, as a consequence of which the competitiveness of road transport remains stable;
- the HGV charge system was linked to the polluter pays principle;
- the revenues of the system were reinvested in the improvement of road transport, the extension of the railway network and in the strengthening of public transport.

The HVF is considered an important instrument to encourage transport of goods to shift from road to rail but the choice of transport mode – especially in international transport – depends on various factors, with elements such as reliability and ease of transportation being regarded at least as important as the price. Not surprisingly, the first positive reports of a modal shift in overland traffic have been observed in domestic transport.

Other factors affect the modal competition:

- the productivity of both modes of transport (and road would benefit of higher weight limits);
- the capacity of rail lines, which should boost once the new trans-Alpine rail tunnels will be opened, between 2007 and 2020;
- the trend of other cost factors, notably the fuel price.

Plans

Amongst the current plans, besides the Eurovignette Directive, which should allow to levy higher tolls in specific zones such as the transalpine crossings, it is important to be aware that several initiatives have been undertaken in order to co-ordinate the policy of the different countries and to implement a common plan.

Since the “Declaration of Zurich” concerning the improvement of road safety, in particular in tunnels in the Alpine zone”, signed in 2001, the Ministers of Transport of Germany, Austria, France, Italy, Switzerland and more recently Slovenia, have broadened the objectives of their cooperation. Indeed, “the implementation of the declaration has now proceeded to the stage of identifying measures to be coordinated between the signatory Alpine countries for regulating road traffic and encouraging a shift to an alternative mode of transport with four main areas of work, one of them being the management and regulation of transalpine road freight transport”.

The mandate of the Lyon Conference on 20 October 2006 was inter-alia to commission a study on “…the preconditions for the implementation of new systems for the regulation of Transalpine road freight transport…”, making explicit reference to reservation system mechanisms or “tradable transit permits” which have been developed in sectors like environment or energy.

The study is part of the process that leads to the identification of appropriate traffic management systems for transalpine road freight transport and will have to provide the relevant information to enable the Ministers’ decision in autumn 2008 and, consequently, to give input for an in-depth study aimed at the operational implementation of the models selected by Ministers.

The coordination of the study has been assigned to the Advisory Board under the chairmanship of Austria, which has been entrusted with the Presidency of the Alpine countries Steering Committee for the period 2007/2008.

Another proposal on the political agenda is the Alpine Crossing Exchange (ACE). It uses market mechanisms to ration the number of alpine-crossing trips or the scarce road capacity at the Alpine crossing points and it is considered one of the most interesting schemes.

The Alpine Crossing Exchange

Two basic approaches for an ACE can be distinguished:

- “Cap-and-Trade”

- “Slot-scheme with dynamic price”

In “Cap-and-Trade” system, all heavy goods vehicles with a maximum laden weight of more than 3.5 tonnes have to produce an Alpine Crossing Permit (ACP) for their journey through the Alps, which is subject to the Alpine Crossing Exchange. The ACP is assigned to a specific vehicle and entitles that vehicle to a one-way journey through an Alpine crossing within a specific period of time.

A defined amount of Alpine Crossing Units (ACU) qualifies for an ACP. The required amount of ACU may be dependent on the vehicle type (e.g. emission category). Local and short distance transport may be treated differently concerning the required amount of ACU.

ACU are auctioned at regular intervals. The auction is considered the best means of assignment: it is easy to implement, ensures an efficient result and sets the right incentives. The auction is open for the hauliers as well as to financial institutes and intermediaries. The auction shall take place once per year, and during the auction, the ACU of the present year and those of the future years shall be auctioned. This principle allows all participants to develop long-term strategies and to evaluate the market price of the future ACU.

ACU are traded off-market, i.e. there is no central platform on which the ACU transaction can be carried out. Hauliers, financial institutes and intermediates may trade ACU directly with each other. Short and local transalpine journeys will profit from a possible privileged handling, i.e. an adjustment of the conversion rate, equal to a reduction of the tariff.

The “Slot-scheme with dynamic pricing” is an enhancement of the planned reservation system, with charge that is made for reservation. A maximum transit capacity is set due to safety reasons. The hauliers who want to have a guaranteed passage at certain day and time, must book and purchase in advance a slot, otherwise they will have to wait for a free slot.

The reservation of the slot can be done on an internet-platform; the price of the slot will vary according to traffic forecast and length of the slot period. Both types of the alpine transit exchange require an On-Board Unit for heavy goods vehicles, charging and enforcement stations, ACE back-office system.

The expected costs amount to CHF 50-60 million (€30-36 million), and the minimum level of operational costs is estimated at CHF 15 million (€9 million). Both forms of the Alpine Crossing Exchange are technically and operationally feasible, but the “Cap-and-trade” model can achieve the goal of relocating traffic from road to rail in an efficient and no-discriminatory way. The aim would be to introduce this system together with neighbouring Alpine countries.

4.3.3 The expected development of the corridor

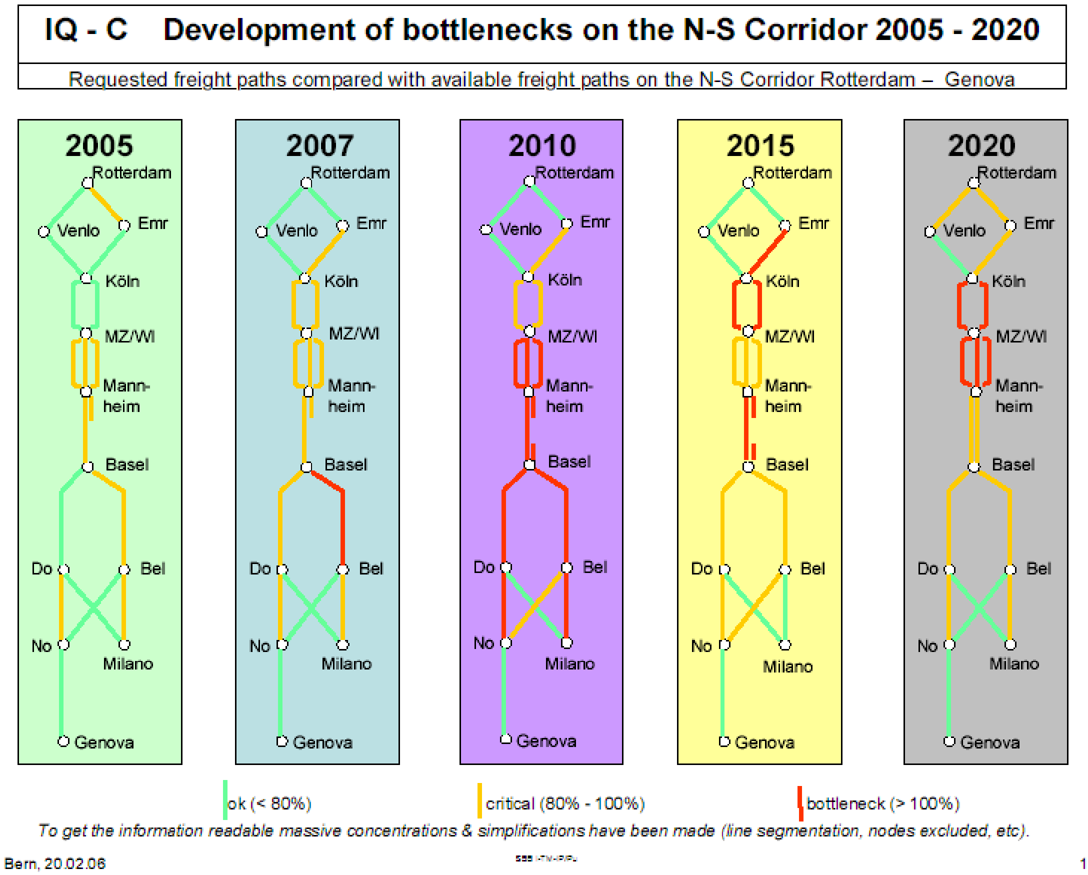
The corridor presents complex problems and issues that are being studied, solved and improved in order to have a consistent programme of development. It is beyond the scope of this study to discuss technical matters such as interoperability, terminals, traction systems etc. but it is important to remark the problem of capacity, which could in fact induce different demand patterns.

On the road side, the congestion problems are local and often of minor relevance, and they do not preclude an general satisfying level of service. On the rail side the corridor suffers from a general lack of capacity (mainly due to the high demand, strongly driven by the Swiss Transport policy).

The various studies conducted on the corridor (see for example the graph below), illustrate that the shortage of rail capacity is mainly located in the transalpine stretch.

The projects that will be completed, such as the new Gotthard base tunnel, and the infrastructure improvements on the feeder lines shall smooth this impact but they will not be ready in the short term.

Figure 27: Development on the Trans-Alpine rail links 2000 to 2020



4.3.4 The potential for Mega-Trucks

In a context where policy and regulation seem to advocate a modal shift in favour of rail transport, the proposed introduction of Mega-Trucks sounds contradictory. On the political side, it is therefore quite uncertain how the introduction of Mega-Trucks can be implemented with respect to transalpine crossings, as this measure would cause a traffic shift back to road. In any case it does not seem a solution that could be proposed and accepted in the short term.

On the other hand, the introduction of Mega-Trucks, could be seen as an increase of the weight limit for road transport. This could have as a consequence a positive impact in terms of vehicles circulating, with a parallel reduction of the congestion effect.

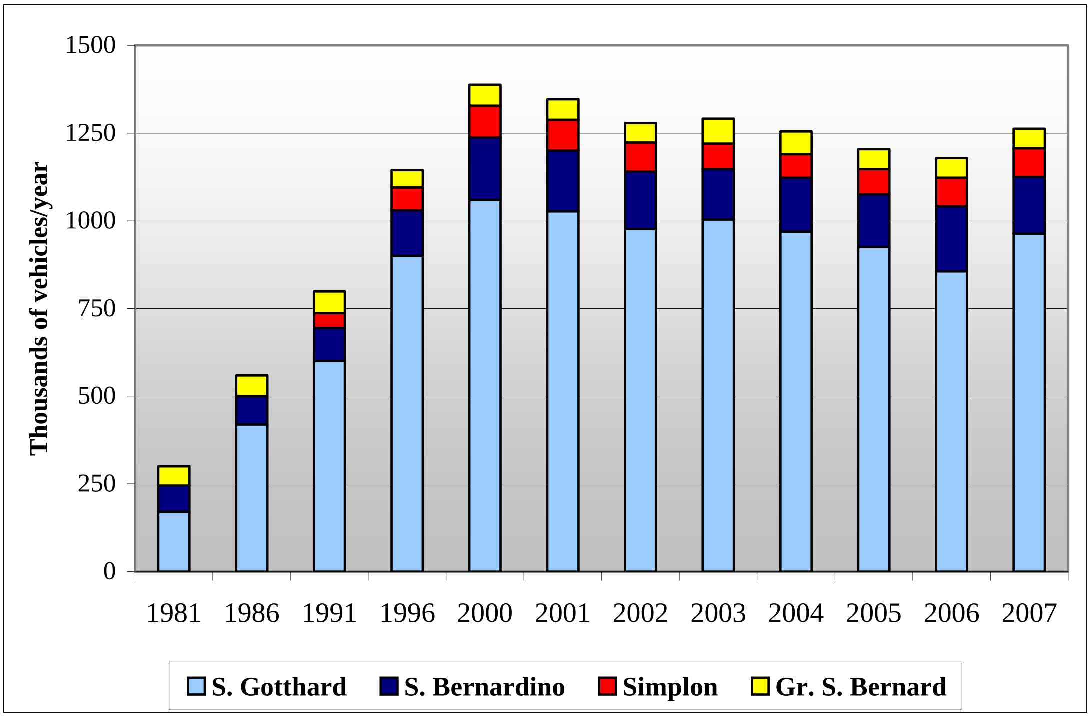
In any case, it is arguable that the introduction would be accompanied by other measures such as speed limitation, number of driving licences, tolls etc. according to the common regulations and may find some more restricting rules for alpine crossings.

Some numbers about the development of the overall road traffic in terms of vehicle-km in the Swiss case can be helpful.

The reduction of vehicle kilometres

The ever increasing transit traffic through Switzerland had been the main driving force to introduce a Heavy Vehicle Fee. Given that together with the launch of the fee in the beginning of 2001 also the weight limit for trucks was increased from 28 to 34 tonnes, it is quite complex to define the absolute impact on vehicle kilometres caused by the heavy goods fee.

Figure 28: Transalpine transport before and after the 2001 introduction of HVF



Source: Federal Office of Transport, 2007

By far the biggest impact of the new traffic regime with the HVF and higher weight limits was certainly on the development of road performance. After a steady increase in vehicle kilometres for over 30 years (5–6 % per year before the introduction of the fee), this trend has clearly been broken since the introduction of the heavy vehicle fee.

Indeed, in the first two years of the toll system, a reduction in vehicle kilometres was observed (by 4% and 3% respectively. This reduction was caused by the combination of the charge and the increase in the maximum allowed weight of HGVs (from 28 to 34 tonnes in 2001). However, in 2003 the yearly vehicle kilometres increased somewhat compared to 2002, with a further increase in 2004 by 4%. After the increase of weight limit from 34 to 40 tonnes in 2005, a new reverse trend happened: by the end of 2005, the total number of kilometres travelled reached a level that was 6.5% lower than in 2000.

For the alpine transit through Switzerland, the increased weight limit led to an increased use of semi-trailers. At the same time a reduction of the number of lorries with lower weight limits could be observed, which kept the total number of transit lorry trips more or less constant in 2001. In 2002 the number of transit transports was reduced by 9%, which partly was an effect of restrictions caused by the accident in the Gotthard tunnel.

The overall trend is that after a constant increase of freight traffic from 1981 to 2000, the Swiss Alps crossings show a fall of 10% in the number of vehicles from 2000 to 2007. However, looking at the recent trend, in the year 2007 the annual traffic of large goods vehicles increased by +7%: 1,263 million large goods vehicles traversed the Alps, 82,000 more than in 2006 (Federal Office of Transport, 2007).

To conclude, the introduction of Mega-Trucks along the Transalpine corridor, could have an impact on the road sector where a reduction of the number of vehicles is expected. Nevertheless this impact could be seen as temporary since it could turn out as a short term effect, showing most likely a return to a positive growth rate in road traffic.

As previously said the potential for Mega-Trucks depends on regulations and market segments.

A relevant share of the unaccompanied combined traffic, the most important market segment, is represented by maritime container carried to/from Northern Italy to Northern range ports, a type of traffic which cannot be attacked by Mega-Trucks.

The market segments that are more easily attracted by MT are those of Combined traffic and, but less probably, part of the wagon load traffic. In a scenario where rail traffic is quite strong and benefits of political will and big investments in new infrastructures, the market potential for Mega-Trucks seems more strongly linked to the road freight sector.

5 GIS Logistics Model Application

5.1 Introduction and objectives

The analysis of European logistics flows using data from geographical information systems (GIS) is the first of two analytical steps towards understanding the drivers and the consequences of introducing long and/or heavy vehicles (Mega-Trucks) all over Europe. The GIS analysis is carried out with the LOGIS model developed and operated by NESTEAR. LOGIS represents some 2,000 door-to-door logistics relations in Europe, including road, rail and short sea shipping, and is thus considered particular suitable to answer the question on potential market shares of Mega-Trucks on a European scale. The model was developed to represent high quality logistics chains with special emphasis on combined transport options and with particular focus on shipments from and to the New Member States

The LOGIS model had to be adapted to the current issue of investigation. It considers 60 t Mega-Trucks in competition to conventional 40 t HGVs by reduced ton-specific operating costs (-20 % to -30 %). Regulatory conditions are introduced by allowing Mega-Trucks to perform on motorways and ferry links only; for entering and exiting other roads transhipment- or splitting costs (75 € - 100 €) are due. Only interregional non-bulk traffic is considered using a 16-products classification.

The following sections describe the model setting, hypothesis taken and a summary of the key model results. More elaborate results by hypotheses, modes and distance bands are given in the annex to this report.

In particular the results shall either confirm or update the findings on the potential market share of Mega-Trucks in high-quality logistics markets found in literature. Accordingly, the model outputs will be contrasted to the findings of Chapter 3.

5.2 LOGIS Model of NESTEAR (Freight)

LOGIS stands for “Localisation of transport generation and distribution of flows, and Intermodal Simulation – A new LOGIC with extensive use of GIS database”. The objectives, methodological options and the model structure are briefly addressed in the following paragraphs.

5.2.1 Objectives

The LOGIS model was designed to keep track of the driving factors behind shippers' and hauliers' behaviour in European intermodal transport chains. In a more and more complex and competitive transport environment the model supports decision makers by providing quantitative analyses of investment strategies, service-related measures, pricing or regulation initiatives. In particular the model follows the objectives:

- Adding to the scientific methodological competence of modelling complex inter-modal transport chains with multiple decision options and constraints
- Recording and multilevel modelling of a large sample of European door-to-door transport relations from origin to destination and from local to international networks.
- Evaluation of the contributions of all modes to the achievement of societal and policy objective and thus to help formulating appropriate transport solutions.
- Evaluation of transport projects and politics and environmental impact assessment, both local and global.

5.2.2 Methodological options

Transport flow generation and distribution of the model is based on the definition of a gravity model describing goods flows in tons, from zone to zone (regions). The model has developed a GIS data base of digitised transport networks, including links, nodes, and services, respecting national and socio economic environment.

The core of the model is the identification of point-to-point transport chains. On their basis an intermodal European transport Graph (GERT) was defined, with transport attributes (time, cost, quality, etc.) for measuring transport performance.

The assignment of transport demand to the intermodal network is carried out by the application of a minimal path algorithm for the choice of intermodal solutions (ACHEMINE).

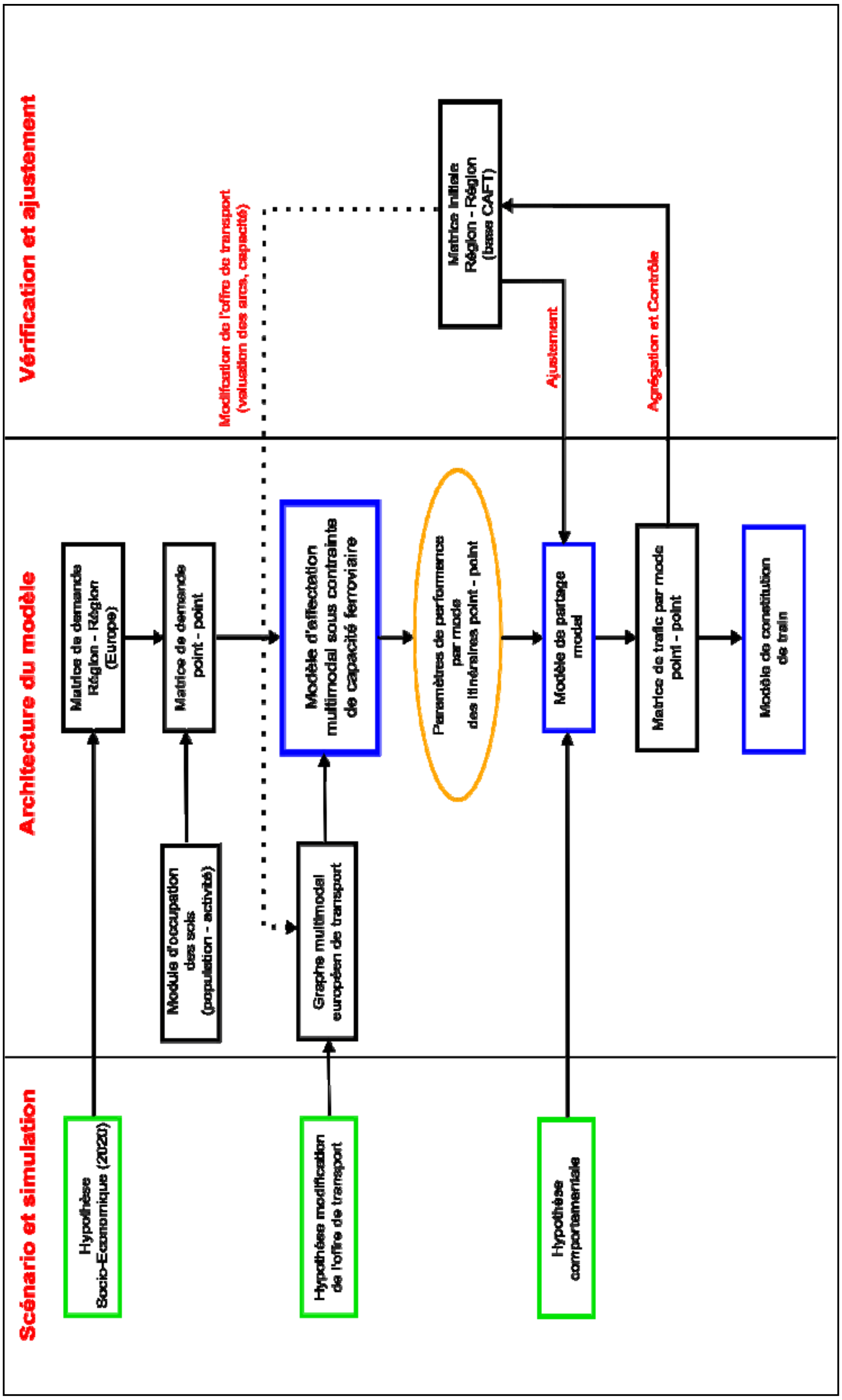
5.2.3 The model structure: "2 steps modelling"

The modelling process takes place in two steps:

- LOGIN generation on distribution with point-to-point localisation of origins and destination.
- SOLTIS: application of minimal path algorithm (to predefined objective function) for identification of intermodal transport solution.

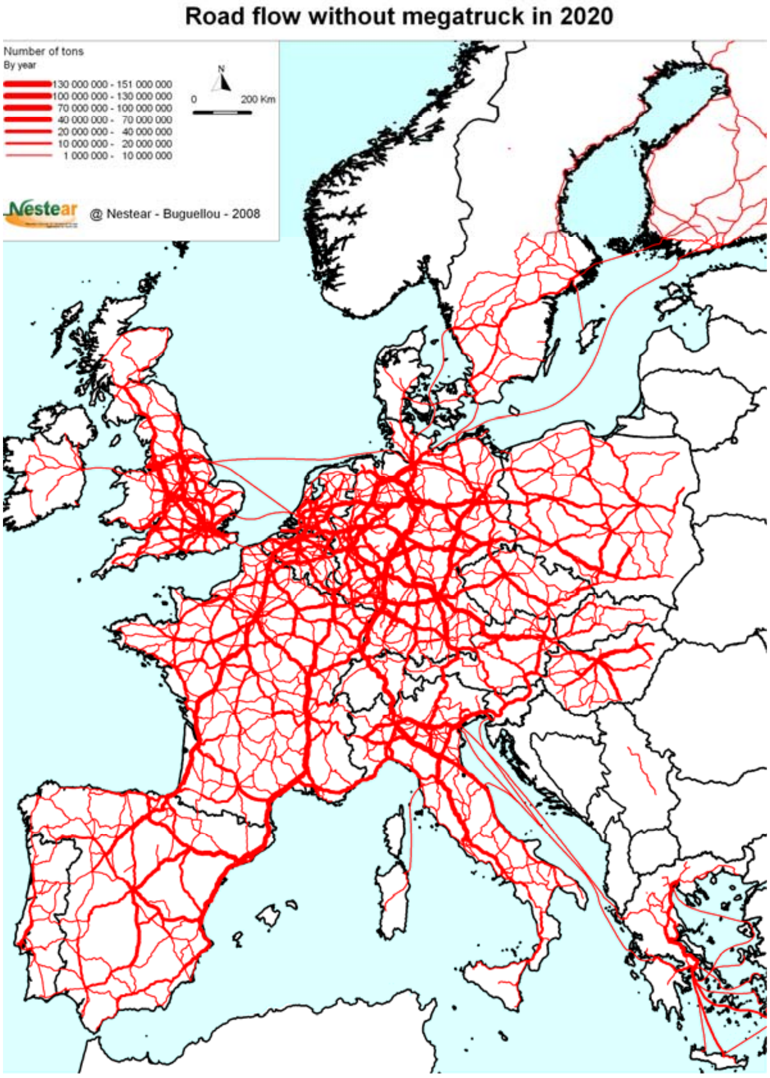
Figure 29 shows the architecture and the data flow in the LOGIS model.

Figure 29: Architecture of the geographical logistics model



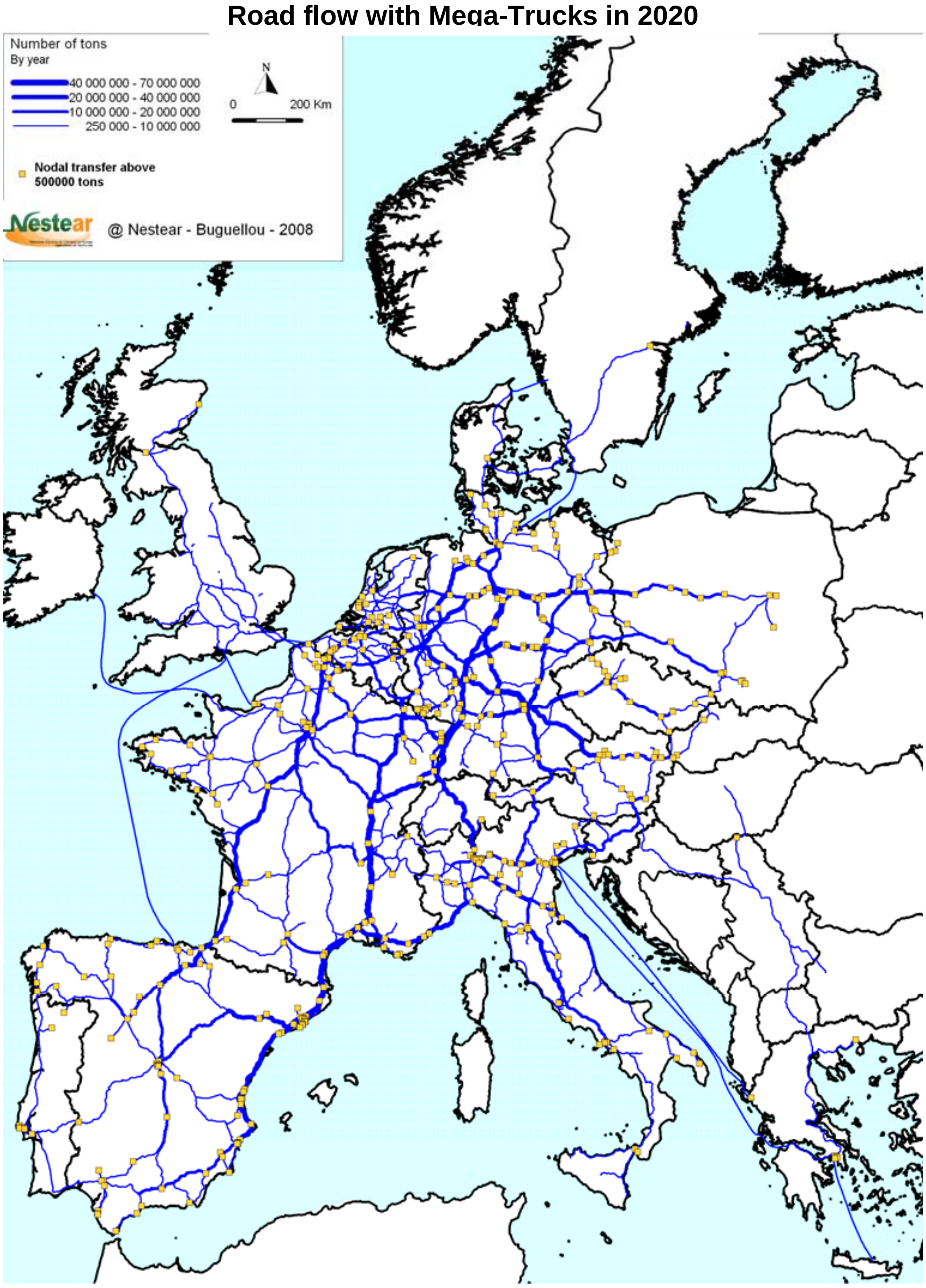
Source: NESTEAR

Figure 30: LOGIS road network 2020 – HGV flows in the base case



Source: NESTEAR

Figure 31: LOGIS road network 2020 – Mega-Truck scenario



Source: NESTEAR

5.3 Methodology

For the network simulation of Mega truck the hypotheses are the following:

- Mega-Trucks can only operate on motorways. For each entry and exit to or from the motorways there is a fixed cost for splitting Mega-Trucks into two units meeting current weight and size limits. Outside the motorways conventional trucks are used.
- Only "interregional" non-bulk products are considered. Regional traffic is completely omitted. This fact is decisive for interpreting the partly very high results for Mega-Truck market shares.
- The operating costs of Mega-Truck are lower than operating cost of conventional trucks.

The analysis of driving factors for the market success of Mega-Trucks is approached by taking different hypotheses for:

- The cost per ton-kilometre of Mega-Trucks as compared to conventional trucks: -20%, -25 % and -30 %.
- The fixed cost of entry/exit: 75 € and 100 €.
- The development of intermodal services: grid network versus the extension of direct connections.

Simulations have been made for horizon 2020 (LOGIS model of NESTEAR for generation in the transport network) with a hypothesis of + 20 % for conventional truck operating costs per ton kilometre.

Tests have been made for Mega-Trucks

- versus conventional trucks and
- versus combined transport (with the hypothesis about rail productivity + 15% and opening of intermodal services)

Results have been generated per distance band. National international traffic relations were included.

The following Section 5.4 shows the main findings for the competition of Mega-Trucks within the road market, e.g. without consideration of modal split effects. Section 5.5 shows the model outputs for the competition of Mega-Trucks with combined transport.

Section 5.6 finally summarises the main findings and discusses open points for further analyses.

5.4 Findings for competition within road haulage

5.4.1 Hypotheses and assumptions

The various combinations for the costs of Mega-Trucks versus standard HGVs and splitting costs to exit or enter motorways from lower level roads result in six scenarios or hypotheses. These scenarios are presented in Table 17.

Table 17: LOGIS hypotheses for competition of Mega-Trucks to HGVs

	Operating costs HGV 2020 against 2007	Operating costs of Mega-Truck vs. HGV	Splitting costs from/to motorways (€)
Hypothesis 1	+ 20 %	-30 %	75 €
Hypothesis 2	+ 20 %	-20 %	75 €
Hypothesis 3	+ 20 %	-20 %	100 €
Hypothesis 4	+ 20 %	-30 %	100 €
Hypothesis 5	+ 20 %	-25 %	100 €
Hypothesis 6	+ 20 %	-25 %	75 €

Source: NESTEAR

For the cost structure of common HGVs in 2007, we assume as follows:

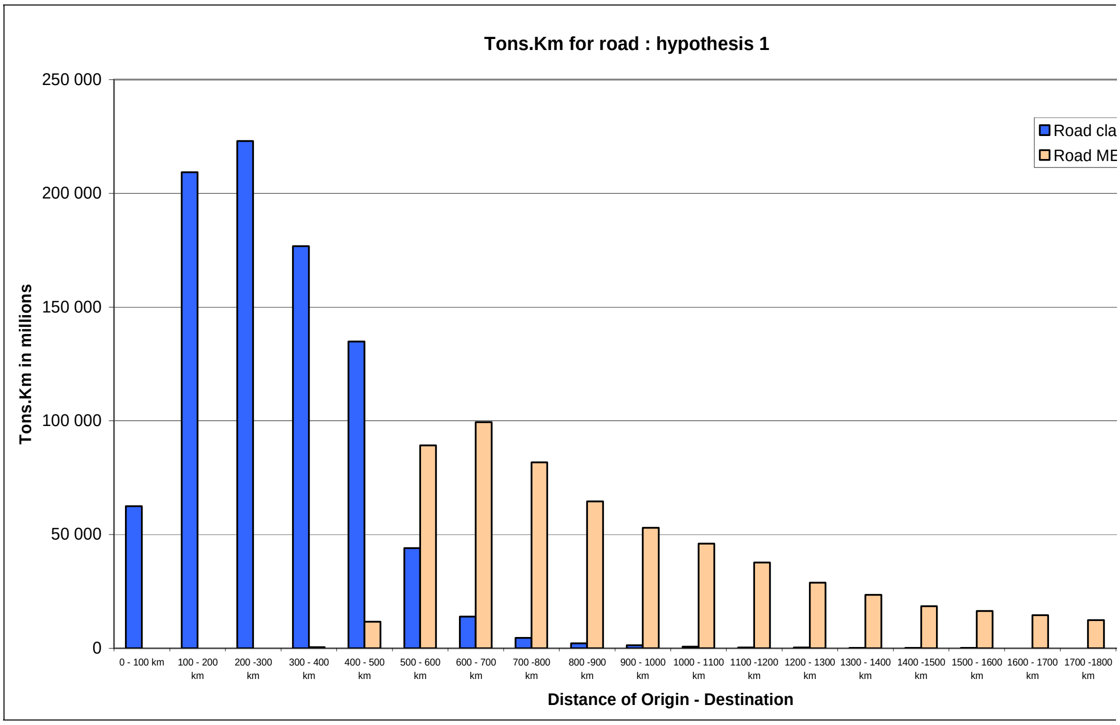
- HGV operating costs: 0.53 € per kilometre
- Cost of driver : 20.80 € per hour
- Cost of exploitation: 152.62 € per day

The road network permissible for Mega-Trucks contains all motorways, ferry lines and their extension to eastern Europe (see maps in Figure 31). Transhipment between modes or lorry types are feasible on each node of the Mega-Truck network.

5.4.2 Results for Hypothesis 1

Figure 32 shows the model outputs for hypothesis 1 (30 % higher cost efficiency of Mega-Trucks against standard HGVs, 75 € splitting costs of Mega-Trucks when entering or exiting motorways). Under the given assumptions, i.e. for high value goods on international routes with origins and destinations located close to motorway exits, the LOGIS model predicts a 100 % market share of Mega-Trucks above transport distances of 1000 km. Below 300 km, on the other hand, no replacement of 40 t HGVs is predicted. The distance bands for road-road competition are thus restricted to transport distances between 300 km and 1000 km.

Figure 32: LOGIS model results for road-road competition, hypothesis 1 by distance bands



Source: NESTEAR

In terms of tons, classic HGVs still carry roughly 80 % of total national and international volumes. In terms of ton-kilometres, however, the share is nearly balanced due to the affinity of Mega-Trucks to long distances. Thus, in international transport 80 % of tkm are expected to be shipped by Mega-Trucks, while the ratio is reversed in national traffic. The summary results are shown by Table 18.

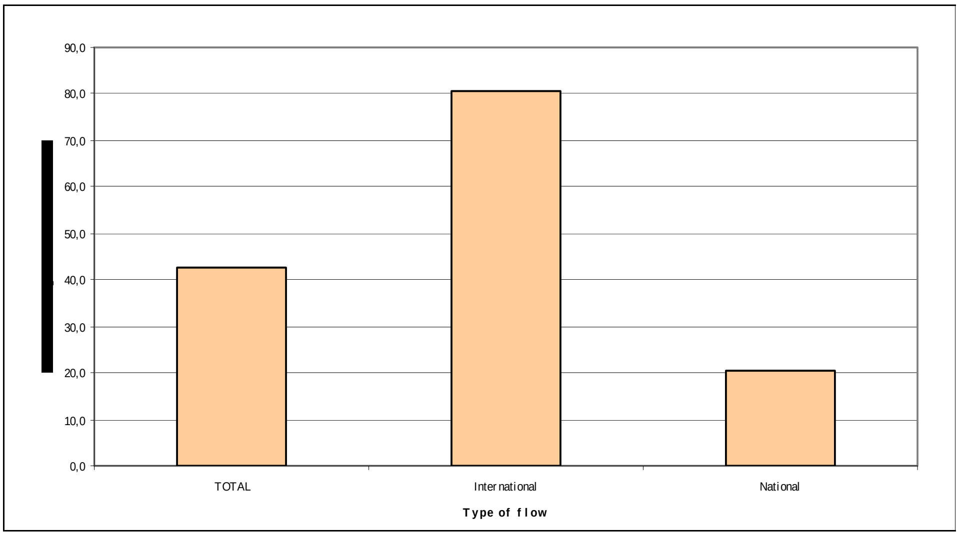
Table 18: Summary results LOGIS model, road-road competition, hypothesis 1

	Results in tkm			**Results in t**
	TOTAL	**International**	**National**	**TOTAL**
Road classic truck	873 932	110 759	763 173	3 993 204
Road Mega-Truck	654 969	459 177	195 792	744 705
TOTAL	1 528 901	569 936	958 965	4 737 909
Proportion MEGATRUCK	**42.8**	**80.6**	**20.4**	**16**

Source: NESTEAR

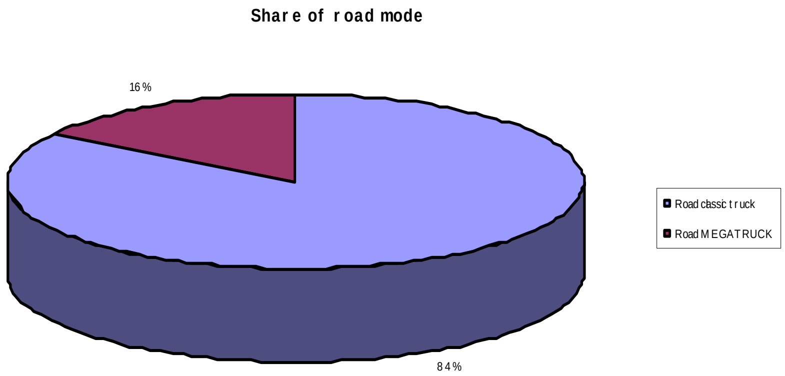
Figure 33 presents the results for national and international traffic in tkm and Figure 34 show the ton results as shares between HGVs and Mega-Trucks.

Figure 33: Summary results LOGIS model, road-road competition, hypothesis 1, tkm



Source: NESTEAR

Figure 34: Summary results LOGIS model, road-road competition, hypothesis 1, tons



Source: NESTEAR

5.4.3 Synthesis for all hypotheses

Table 19 provides an overview of the outputs of the six hypotheses and the reference case (simulation without Mega-Trucks) in the road-road competition test. According to expectations, the highest share of Mega-Trucks appears when the difference in ton-specific operating costs to standard HGVs and the switching costs for entering and exiting the motorway network are highest. In this case (hypothesis 1) 43 % of total ton kilometres are shifted from HGVs to Mega-Trucks. Given the detours necessary to access the motorway network, total ton-kilometres – which is not necessarily vehicle kilometres – are increased by 33 %.

As soon as cost efficiency of Mega-Trucks and switching costs decline, the share of Mega-Trucks goes down by 2/3 to 15 % of total road haulage market (in tkm). In case of the corresponding hypothesis 3 still 14 % of additional tkm compared to the reference case are computed by the model. This detouring-effect needs to be taken into consideration in the final estimation of environmental and climate impacts due to Mega-Trucks.

Table 19: Synthesis LOGIS model outputs for all hypotheses in tkm

Hypothesis	Road classic	Road Mega-Truck	TOTAL	Share of Mega-Trucks	Increase of tkm hypothesis against reference in milliards
	1000 mill. tkm				1000 mill. tkm
Hypothesis 1	874	655	1 529	43	33
Hypothesis 6	984	538	1 522	35	26
Hypothesis 4	1 046	477	1 523	31	27
Hypothesis 2	1 134	380	1 514	25	18
Hypothesis 5	1 161	356	1 517	23	21
Hypothesis 3	1 280	231	1 510	15	14
Road reference	1 496	0	1 496	0	0

Source: NESTEAR

The growth of the share of Mega-Trucks causes a prolongation of distance travelled. The increase is not negligible in absolute terms and must be taken into account in the environmental and energy balance sheet.

More detailed results by hypotheses, modes and distance bands are given in Annex 1 to this report.

5.5 Findings for competition to combined transport

For analysing the competition between standard HGVs, Mega-Trucks and combined transport two scenarios are considered:

- A more conservative scenario where combined transport networks are developed as grid networks with the need for marshalling and re-ordering trains in the absence of occasional direct connections.
- An advanced scenario where direct freight train relations are installed between all major points or demand origin and destination.

For these two scenarios the underlying hypotheses and the summary results are presented in turn.

5.5.1 Conservative scenario: grid network of rail services

The hypotheses tested in both scenarios (conservative and advanced) in the competition between road classical HGV, road Mega-Trucks and combined transport are equal to the hypotheses tested for the road-road competition (Table 23).

Table 20: Summary results LOGIS model, road-road competition, hypothesis 1

	Road Costs:	Mega-Truck Road Costs:	Trans-shipment
Hypothesis 1	cost 2007 + 20 %	- 30 %	75 €
Hypothesis 2	cost 2007 + 20 %	- 20 %	75 €
Hypothesis 3	cost 2007 + 20 %	- 20 %	100 €
Hypothesis 4	cost 2007 + 20 %	- 30 %	100 €
Hypothesis 5	cost 2007 + 20 %	- 25 %	100 €
Hypothesis 6	cost 2007 + 20 %	- 25 %	75 €

Source: NESTEAR

Assumptions on cost structures in the road sector also remain unchanged against the analysis of road-road competition:

- HGV operating costs: 0.53 € per kilometre
- Cost of driver : 20.80 € per hour
- Cost of exploitation: 152.62 € per day

Also in the road-combined transport competition case, the Mega-Trucks network is made of all motorways, ferry lines and extensions to eastern Europe. Transhipment is considered feasible on each node of the Mega-Trucks network.

In the conservative scenario the additional assumptions concerning combined transport services are as follows:

- Costs per train-km on the basic railway network : 17,5 €
- Costs per train-km on the main railway network : - 15 % (14.9€) with assumptions on performance improvement
- 60 € per transhipment between road and rail networks. Transhipment is feasible only on the intermodal nodes.
- installation of a grid of service between intermodal terminals plus a improvement of the frequency compared to the reference case 2005

Figure 35 presents the railway network for simulating combined transport movements 2020.

Figure 35: LOGIS model rail simulation network 2020

Source: NESTEAR

The results for the grid network or conservative scenario are presented in Table 21. The following observations emerge:

- The share of combined transport in the reference case is 10 % of the entire long-distance high quality goods market.
- The smallest cut of combined transport market shares in case of less cost efficiency of Mega-Trucks and high switching costs outside motorways is 51 % (hypothesis 3).
- In case of market conditions promoting of Mega-Trucks (hypothesis 1), the resulting decrease of combined transport market shares is even more dramatic as it drops by 84 % to a resulting market share of 1.6 % (in tkm 2020).

Table 21: Summary results LOGIS model, road-CT competition, conservative scenario

Cases considered	Absolute demand (1000 million tkm)				Market share at tkm		
	Classic HGV	**Mega-Truck**	**Rail in combined transport**	**TOTAL**	**Classic HGV**	**Mega-Truck**	**Rail in combined transport**
Without Mega-truck	1 369	0	144	1 513	90	0	10
Hypothesis 3	1 247	187	75	1 509	83	12,4	4,9
Hypothesis 2	1 121	330	61	1 512	74	21,8	4,0
Hypothesis 5	1 146	313	56	1 514	76	20,6	3,7
Hypothesis 6	978	500	41	1 518	64	32,9	2,7
Hypothesis 4	1 038	442	39	1 519	68	29,1	2,6
Hypothesis 1	871	628	25	1 524	57	41,2	1,6

Source: NESTEAR

More detailed results by hypotheses, modes and distance bands are given in Annex 1 to this report.

5.5.2 Advanced scenario: extension of direct rail connections

The hypotheses tested and the basic assumptions concerning freight transport costs of the advanced scenario with extended direct-rail connections are equal to the assumptions and hypotheses of the more conservative case. The main difference of the two cases is the level of combined transport and rail-service supply.

The core assumption is that at least one direct connection is available between all intermodal terminals. Availability constraints associated with combined transport services in this case are thus considered as very limited.

The results of the advanced case with direct connections between all intermodal terminals are presented in Table 22. The main conclusions to be drawn out of the model results are as follows:

- Advanced rail service quality is expected to double the market share of combined transport serviced (20 %) in high quality European logistics markets.
- The impact of introducing Mega-Trucks in this case still appears drastic but the percentage reduction in rail market shares is slightly less expressed than in the case of grid service networks (conservative scenario).
- Under more relaxed market conditions for Mega-Trucks (hypothesis 1) the market share of combined transport drops from 20 % to 5 % in 2020 (-75 % related to reference rail volumes).
- In the most restricted case (hypothesis 3) rail can maintain a market share of 13 %. This is a drop of roughly 35 % related to reference rail demand.

Table 22: Summary results LOGIS model, road-CT competition, advanced scenario

Cases considered	**Absolute demand (1000 million tkm)**				**Market share at tkm**		
	Classic HGV	**Mega-Truck**	**Rail in combined transport**	**TOTAL**	**Classic HGV**	**Mega-Truck**	**Rail in combined transport**
Without Mega-Truck	1 231	0	307	1 538	80	0	20
Hypothesis 3	1 199	118	203	1 519	79	7,8	13,3
Hypothesis 2	1 098	248	174	1 520	72	16,3	11,5
Hypothesis 5	1 119	237	165	1 521	74	15,6	10,8
Hypothesis 6	967	430	126	1 523	63	28,2	8,3
Hypothesis 4	1 023	381	119	1 524	67	25,0	7,8
Hypothesis 1	864	584	80	1 527	57	38,2	5,2

Source: NESTEAR

More detailed results by hypotheses, modes and distance bands are given in Annex 1 to this report.

5.6 Chapter conclusions

5.6.1 Key model findings

Results show

- A significant share taken of Mega-Trucks versus conventional road. The market share of Mega-Trucks increases significantly with distance.
- Mega-Trucks traffic concentrates along major European corridors
- The share of Mega-Trucks becomes particularly important for international traffic as it increases with distances and concentrates on major corridors
- But Mega-Truck markets are also a privileged market for combined transport: longer distances of international transport taking place along major European corridors

Therefore Mega-Trucks will take a significant share of the expected combined transport market in 2020: this has consequences in terms of environmental impact.

The development of Mega-Trucks might prevent opening of intermodal services and therefore endanger the development of intermodal transport (unable to reach a critical size for EU coverage and increase in productivity of rolling stock): even with a voluntary intermodal policy the intermodal transport would not develop significantly.

It is clear that such tests would need deepening:

- Concerning authorisation of circulation of Mega-Trucks: location of parking places close to motorways or industrial areas (presently there are 1000 points for entry and exit of motorway system; such hypothesis can be analysed more in depth
- Concerning the impact on environment: can be measured very precisely (global and local impact) with the simulation tool used.

5.6.2 Comparison to literature

According to Section 3.6 TRL reports a potential market share of Mega-Trucks across all commodities but with restriction to the motorway network of 33 %. The extrapolated result of the German field trial in Lower Saxony arrives at a market share of 15 % to 21 %. These findings are confirmed by the outputs of the LOGIS model for road-road competition. According to Table 19 the range between the more restricted and relaxed competitiveness of Mega-Trucks against standard HGVs is 15 % (hypothesis 3) to 43 % (hypothesis 1).

Given that the LOGIS model is focussing on high quality goods markets and long-distance relations, the upper values (hypothesis 1) are considered rather high. An average share of tons by Mega-Trucks in total road market around 20 % is expected to be more realistic.

Concerning the competition between Mega-Trucks and combined rail-road transport Figure 17 reports a range of 20 % to 30 % reduction of rail demand in continental container traffic and between 10 % to 20 % in maritime container services above 800 km. In contrast, the LOGIS model assumes a reduction of up to 85 % of container traffic on long-distance continental relations due to the introduction of 60 t Mega-Trucks. The underlying scenario assumes a decisive extension of the intermodal network, although no additional direct freight rail connections are assumed to be installed. With the latter the maximum decline of rail services still is expected to be roughly 50 %.

This discrepancy can be explained by the close location of forwarders at intermodal terminals and at motorway exits. Thus, the restriction of Mega-Trucks to motorways is not really cost relevant on many transport relations. In practice it is thus considered that the real market share will be somewhat lower. The conclusions on possible ranges of market reaction in Figure 17 are thus maintained.

6 System Dynamics Model Application

6.1 Introduction

This report presents the System-Dynamics model for the impact analysis of the introduction of Mega-Trucks in the European freight-transport market. The model was realised as part of the overall project “Long-Run Modal Shift and Climate Effects of Mega-Trucks”.

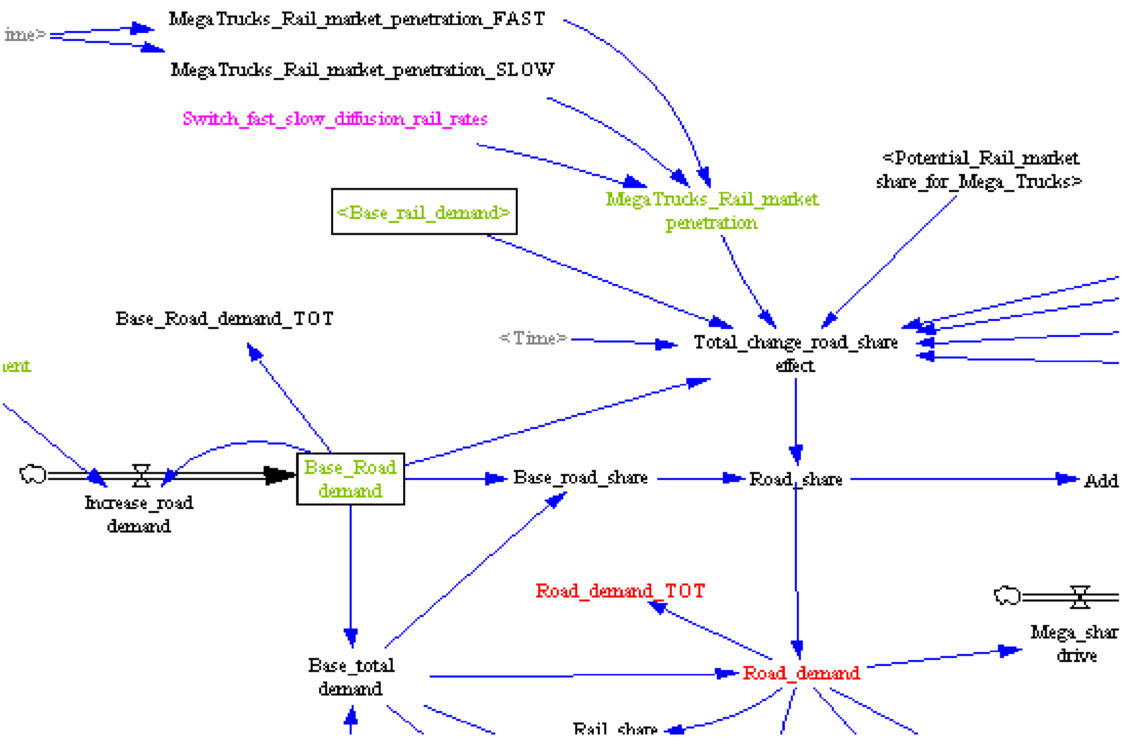
6.2 Model Structure

The modelling technique used for the analysis is System Dynamics. The System Dynamics approach was developed based on early studies of Jay Forrester analysing inter-dependencies and feedback loops over time taking place between ‘objects’ interacting with each other. The model is built in VENSIM®, a dedicated software tool that allows designing System Dynamics models using a simple graphical interface (see for instance Figure 36 below).[1]

In the model, the main variables influencing the system are represented and their relationships are simulated by means of specific parameters (e.g. elasticities). The model's objective is to simulate the impact of the introduction of Mega-Trucks on market shares and then on CO_2 emissions over time at the strategic level. The model also allows users to analyse how results can change under different assumptions as on the parameters or alternative future market trends.

1 For an introduction to System Dynamics see the website: http://sysdyn.clexchange.org/home.html

Figure 36: Sample screenshot from the System Dynamics model



Source: TRT

6.2.1 Impacts considered in the model

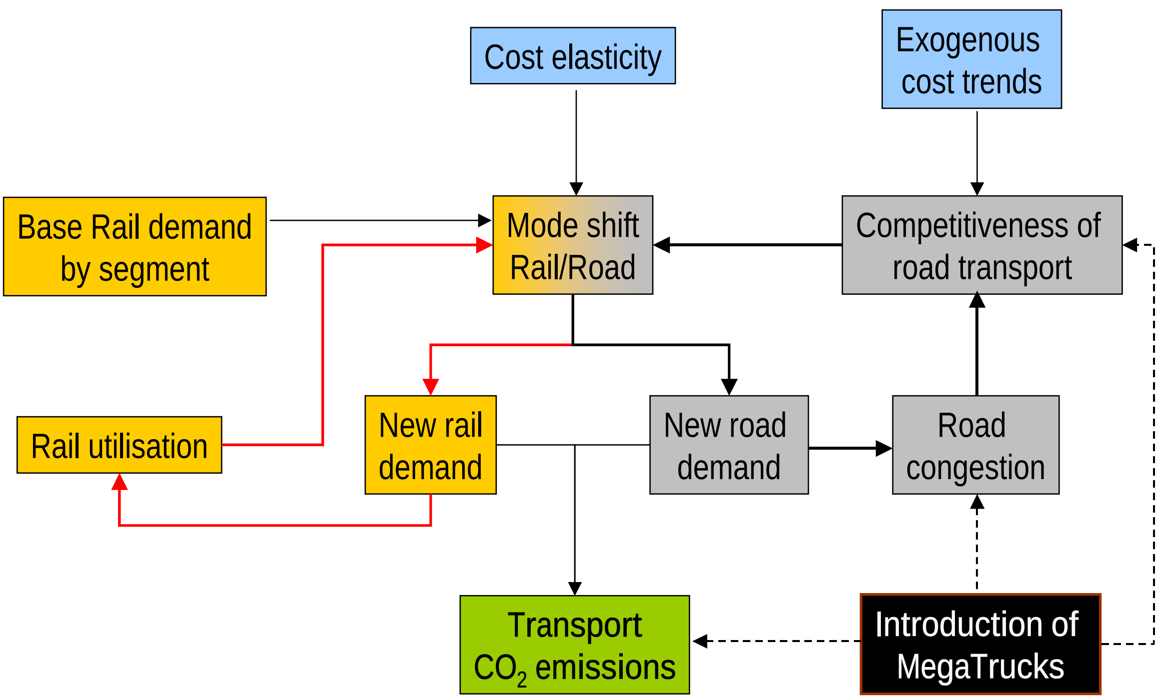
Figure 37 provides a blueprint of the model structure. Basically, the model starts from a demand baseline for rail in four different market segments. The introduction of the MT changes the cost competitiveness of the road market. Therefore a mode shift from rail to road can happen according to a set of demand elasticities. At the same time, when MT enter the road market, they have an impact on road congestion affecting road competitiveness. Instead, the different rail utilisation has a feed-back on rail demand again due to lower congestion or diseconomies of scale. MT also impact on unitary (per Tkm) road transport emissions.

The model also takes into account exogenous influences, their potential impact is significant. In particular, the evolution of road costs – with special reference to fuel costs and tolls – is considered. Also, since congestion has a role on the mode shift, exogenous assumptions as to the future infrastructure supply (in aggregate terms) are included in the model.

The 'sum' of these impacts brings about a change in the development of rail and road demand. In turn, this change, together with the specific technical features of MT (e.g. lower emissions per ton-km transported), causes different total CO_2 emissions.

In the figure, the bold arrows identify the main feedback loops simulated. One loop (bold black arrows in the figure) links road demand to road congestion to competitiveness of road transport to mode shift back to road demand. The other loop (bold red arrows in the figure) starts from rail demand to rail utilisation to mode shift back to rail demand.

Figure 37: Blueprint of the System Dynamics model



Source: TRT

Earlier in this study relevant market segments have been identified (Section 3.5). The System Dynamics model considers these segments: the impacts described above are simulated separately for each segment, i.e.:

- Bulk goods;
- High value goods;
- Unitised goods – continental;
- Unitised goods – maritime.

As far as congestion is concerned, however, total traffic (sum of the four segments) is considered, because the infrastructures used are largely the same and all segments contribute to congestion.

A further segmentation concerns the features of Mega-Trucks. In order to analyse alternative scenarios, MT are modelled in three versions: 60 tons, 50 tons or 40 tons. A separate set of parameters is coded for each version; the user can choose which type of MT is activated for the simulation.

6.2.2 Main parameters

Throughout the model, several parameters are used to simulate the reaction of demand to changing the conditions. All parameters represent either exogenous changes in the system conditions (e.g. demand growth rates) or relationships between elements of the systems (e.g. cost elasticities). For most parameters a minimum and a maximum value are defined in the model and the user can choose between them for the simulations. This choice is important due to the uncertainty that is associated to the quantification of the parameters, for a twofold reason. First, the model works at a strategic level whereas in the real world the kind of relationships described take place at a 'micro' level and are affected by specific conditions. Second, the links between the elements of the systems are complex and make partially reference to new conditions (the introduction of a new alternative).

In the following tables the main parameters are summarised. For discussions on the selection of parameters and model variables see Chapter 3. Here only the architecture of the model is described.

Table 23: Demand baseline assumptions

Market segment	*2005 Demand (Mio Tkm)*		*2005-2025 Average Growth rate*			
	Rail	*Road*	*Rail (min/max)*		*Road (min/max)*	
Bulk	1,119,997	10,263,566	1.1%	1.6%	0.9%	1.3%
High value goods	226,937	4,867,253	1.7%	2.3%	1.9%	2.6%
Continental unitised	163,884	1,409,286	2.3%	3.3%	2.1%	3.0%
Maritime unitised	54,628	469,762	3.5%	5.1%	2.1%	3.0%
All commodities	1,565,447	17,009,867	1.4%	2.0%	1.3%	1.9%

Table 24: Mega-Trucks potential road market shares

Market segment	*Road demand shifted to Mega-Trucks*					
	MT 60t		*MT 50t*		*MT 40t*	
	min.	*max.*	*min.*	*max.*	*min.*	*max.*
Bulk	1.4%	2.7%	0.6%	1.0%	0.0%	0.0%
High value goods	4.1%	7.6%	2.9%	6.0%	1.7%	4.5%
Continental unitised	9.1%	16.6%	7.5%	13.1%	5.5%	12.6%
Maritime unitised	6.6%	12.6%	5.3%	11.1%	4.0%	9.5%
All comodities	3.0%	5.5%	1.9%	3.7%	1.0%	2.6%

Table 25: Mega-Trucks potential rail market shares

Market segment	*Rail demand shifted to Mega-Trucks*					
	MT 60t		*MT 50t*		*MT 40t*	
	min.	*max.*	*min.*	*max.*	*min.*	*max.*
Bulk	2.7%	4.6%	0.8%	1.4%	0.0%	0.0%
High value goods	8.6%	13.6%	6.0%	10.9%	3.4%	8.2%
Continental unitised	18.4%	24.7%	14.7%	21.6%	11.0%	18.5%
Maritime unitised	8.9%	17.4%	7.2%	15.2%	5.4%	13.0%
All comodities	5.9%	9.2%	3.6%	6.2%	2.0%	4.2%

Table 26: Market entry and diffusion rate of Mega-Trucks in rail and road

Market segment	*Year of market*		*Speed of diffusion of MT*			
			Rail		*Road*	
	Rail	*Road*	*fast*	*slow*	*fast*	*slow*
Bulk	2012	2010	8	12	7	10
High value goods	2012	2010	8	12	6	9
Continental unitised	2012	2010	6	9	5	8
Maritime unitised	2012	2010	6	9	4	7
All comodities	2012	2010	7	10	5	8

Table 27: Elasticities

Market segment	Elasticity of rail market share				Direct price elasticity of road demand	
	wrt. rail utilisation		wrt. road utilisation			
	min.	max.	min.	max.	min.	max.
Bulk	-0.1	-0.5	0.4	0.8	0.0	-0.04
High value goods	-0.3	-1.0	0.4	0.8	0.0	-0.07
Continental unitised	-0.1	-0.4	0.6	1.0	0.0	-0.07
Maritime unitised	0.0	-0.2	0.6	1.0	0.0	-0.07
All comodities	-0.2	-0.6	0.4	0.8	0.0	-0.05

*incl. relative share of MT and network utilisation

Table 28: Road-cost structure

	Unit	Base year cost structure 2005			
		HGV 40t	MT 40t	MT 50t	MT 60t
Driving personnel	€/vkm	0.50	0.53	0.53	0.53
Depreciation + Interest	€/vkm	0.20	0.24	0.24	0.24
Tax + Insurance	€/vkm	0.02	0.02	0.02	0.02
Fuel	€/vkm	0.30	0.33	0.36	0.39
Tyres + Maintenance	€/vkm	0.10	0.11	0.11	0.11
Tolls	€/vkm	0.13	0.20	0.20	0.20
TOTAL	€/vkm	1.25	1.42	1.45	1.48
rel. to HGV 40t			1.14	1.16	1.19
Load factor	t/vkm	27	27	34	40
Specific costs	€/100 tkm	4.63	5.27	4.28	3.71
rel. to HGV 40t			1.14	0.92	0.80

Table 29: Road cost development over time

	Growth 2005 - 2025			
	HGV 40t	MT 40t	MT 50t	MT 60t
Driving personnel	100%	100%	100%	100%
Depreciation + Interest	110%	110%	110%	110%
Tax + Insurance	110%	110%	110%	110%
Fuel	130%	130%	130%	130%
Tyres + Maintenance	100%	100%	100%	100%
Tolls	120%	120%	120%	120%
TOTAL	111%	112%	112%	112%

Table 30: Efficiency parameters

	Vehicle type				
	Rail	*HGV 40t*	*MT 60t*	*MT 50t*	*MT 40t*
Cost efficiency against HGV 40t			0.8	0.93	1.1
Energy consumption (l/1000 tkm)	12	29	24	27	30
CO2 emissions (t/1000tkm)	24	73	62	68	74
Elasticity emmision factor wrt. utilisation	-0.2	0.1	0.1	0.1	0.1
Passenger car equivalents (PCE/t)		0.32	0.23	0.3	0.4

Table 31: Other parameters

	Road	
	min.	*max.*
Mode shift carried by MT	80.0%	100.0%
Road capacity growth p.a.	1%	1%

6.3 Improvements with respect to the Excel model

The System Dynamics model is built on the analysis tool developed for the paper 'Rebound Effect of Climate Benefits from Mega-Trucks' (Doll 2008). However, it is more than just a translation from Excel to another platform. Several improvements were made in the model enriching the potential of the modelling simulation. Some of these improvements consist of the addition of more information (or more detailed information). Others take advantage of the specific features of the System Dynamics modelling. The main model enhancements and their contribution to the simulations are briefly addressed below.

Demand segmentation. With respect to the previous study, the model works with different demand segments. This has two advantages. On the one side, specific parameters can be used and therefore the simulation of demand responses is more precise. On the other side, the results can be analysed for specific market segments.

Detailed description of road costs. In the previous model, the efficiency gain of the introduction of Mega-Trucks was described in aggregate terms by means of a single parameter. In the System Dynamics model, road costs are detailed for all truck types and therefore the impact of Mega-Trucks on average road transport cost per Tkm can be simulated more precisely. Furthermore, this impact can change over time also due to exogenous effects like the growth of fuel costs or road toll costs, which could not be taken into account in the previous model.

Full simulation of feed-back loop. Developed with a dedicated software, the new model properly simulates the feed-back loops over time, while in Excel this kind of loops could only be approximated by the internal solver.

Dynamic elasticities. The new model easily allows defining dynamic elasticities, i.e. elasticities changing over time as an effect of the new market conditions. The extent to which parameters are dynamic can be easily defined by the user.

Flexibility of simulations. In the new System Dynamics model there is much more flexibility for defining alternative scenarios for the simulation. Several 'switches' are used to activate or de-activate parameters, to choose between alternative MT types, to select the higher or the lower value for the parameters, etc.

Sensitivity tests. The VENSIM® software allows users to perform extensive sensitivity tests checking the value of one or more parameters. A distribution of values for each parameter can be chosen as well as the combination of parameters of interest. The model automatically performs hundreds of simulations using alternative values or combination of values for the selected parameter(s) and providing results in graphical form to analyse at glance the distribution of possible results. This is a powerful feature to explore the boundaries of the results to be expected in the system under study.

6.4 Scenarios

The model was applied to two different scenarios defined as shown in the following table: Scenario 1 providing central estimates of all parameters and Scenario 2 showing the sensitivity of the System Dynamics model towards choosing market reaction patters in a more environmentally adverse manner.

Table 32: Scenarios in the system dynamics analysis

Scenario	*Market shares*		*Diffusion rates*		*Price / util. elasticity wrt. utilisation / costs on networks:*		*Induced demand*	*Mode shift carried by MT*
	*Rail**	*Road*	*Rail*	*Road*	*Rail*	*Road*	*Road*	
Central scenario	Vary	low	slow	fast	low	low	no	low
Climate adverse rection	vary	low	fast	slow	high	low	yes	low

Vary = vary the parameter with equal distribution between low and high values

Both scenarios were run as sensitivity tests on the value of potential market share for MT on rail market. In other words, the parameter "potential rail market share" has not been fixed but the model considered all possible values between the minimum and the maximum thresholds defined as in table 33. As far as other parameters are concerned:

- The “central scenario” is characterised by “neutral” assumptions on elasticities, market shares etc.
- In the “climate adverse" scenario” the situation is reversed. In particular, fast penetration in the rail market and slow penetration in the road market are considered.

Each scenario was run for the three different assumptions concerning Mega-Trucks gross vehicle weights 60 tons, 50 tons and 40 t.

6.5 Main Results

The results of the system dynamics model are available in several dimensions:

- Technologies: Mega-Trucks with 60 t, 50 t and 40 t gross vehicle weight. Here we will restrict to the politically relevant cases of 60 t and 50 t gross weight.
- Scenarios (central case and sensitivity for climate adverse) as described in the section above.
- Commodity groups: the results differ by the four commodity types “bulk”, including heavy industry, fertilizers and chemical products, “high value” including food, foodstuffs, agricultural products and other semi final goods, “continental container traffic” and “maritime container traffic”.

Output indicators: to keep the messages of the study clear we restrict the various output indicators of the model to the figures of CO_2 emissions. These are presented in several forms:

- Probabilities: given the wide ranges of possible market shares of Mega-Trucks the presentation of a single output value seems inappropriate. Thus, the study reports the development of probabilities to fall within a specific range of outputs. Alternatively, centre estimates are presented in case several scenarios shall be directly compared.
- Absolute versus relative values: The common form of presenting the model outputs is by showing the difference of the Mega-Truck scenarios to the base

case without Mega-Trucks. In some cases, however, the form of total emissions is presented to demonstrate the order of magnitude in which the described effects are placed.

- Annual versus cumulative values: The model outputs appear as annual CO2 emissions. To be able to compare different scenarios on their overall impact on global warming, however, cumulative values are shown for selected key variables.
- Emitter: concerning the source of CO2 emissions we distinguish between two main effects: increased road efficiency (leading to declining emissions) and modal shift impacts (leading to increasing emissions). In Figure 40 and others below the modal shift effect is entitled as “rail”, which just denotes the primary mode of transport of the corresponding freight volumes.

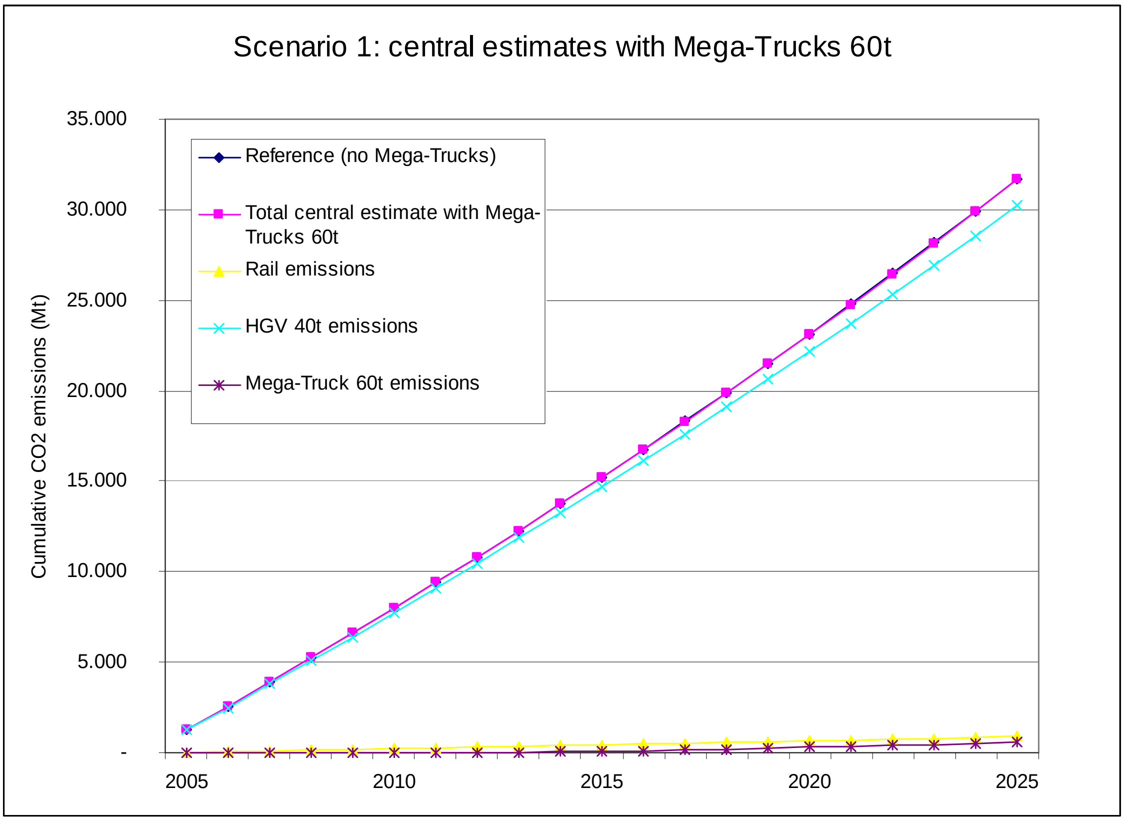
6.5.1 60 t Mega-Trucks, central scenario

60 t Mega-Trucks serve weight and size critical shipments and are thus expected to lead to the highest modal shift risk. On the other hand, their fuel and thus their CO_2 efficiency in road transport is highest among all Mega-Truck constellations. The model runs should clarify which effect is stronger, and thus how the overall CO_2 balance develops.

Figure 38 presents the cumulated CO_2 emissions for the reference case and scenario 1 (central estimates) by mode across all freight transport sectors. The difference between the reference case without Mega-Trucks (31724 Mt) and the total scenario 1 results (31667 Mt) in 2025 are that small that the difference between the two curves can hardly be visualised in the graph.

Nearly all cumulative emissions in 2025 (30213 Mt) are due to standard road freight vehicles. The share contributed by Mega-Trucks (651 Mt) ranges in the same order of magnitude as cumulative rail emissions (903 Mt) over the period 2005 to 2025.

Figure 38: Cumulative annual CO_2 emissions in scenario 1 for 60 t Mega-Trucks (absolute values).



Source: Fraunhofer-ISI based on TRT data

To better visualise the differences in specific scenarios we focus on that part of the European surface transport market, which is potentially subject to mode or vehicle shifts after the introduction of Mega-Trucks. In long distance transport this is 10 % of the bulk market (7% of total CO_2 emissions) and 30 % of medium and high quality markets (5 % of total CO_2 emissions) and 50 % of container markets (8 % of total CO_2 emissions). In short distance markets we assume these decisive market segments being half as large. Consequently, the size of the overall relevant market segment, to which changes in CO_2 emissions are related, is 15 % of the total European road and rail freight market.

For this relevant transport market Figure 39 presents the total annual CO_2 emissions in case of the introduction of 60 t Mega-Trucks in 2008 for scenario 1. Besides the scenario total the graph shows the contribution of the two broad effects:

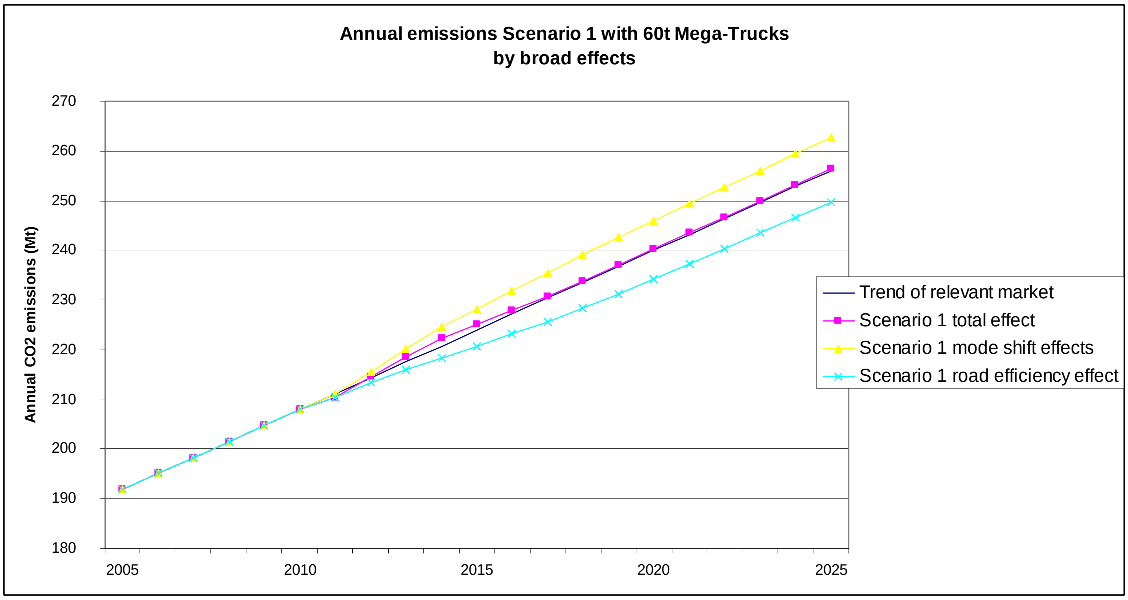
- modal shift of rail volumes to Mega-Trucks and

- efficiency gains in the road sector due to shifts from conventional HGVs to Mega-Trucks on CO_2 emissions.

Other effects like the induction of traffic due to decreasing road costs are of minor importance; thus they are presented jointly with the respective general road or rail specific effects.

The graph reveals that, even under the cautious assumptions underlying scenario 1, the modal shift effect is expected to completely counter-balance the efficiency gains expected in the road sector.

Figure 39: Total annual CO_2 emissions in scenario 1 for 60 t Mega-Trucks within relevant markets



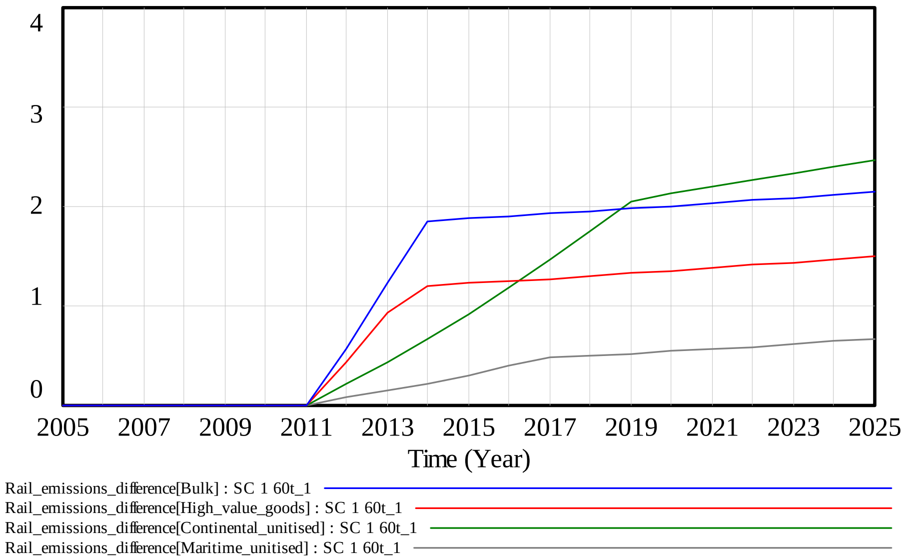
Source: Fraunhofer-ISI based on TRT data

The scale of the graph does not show the initial decline of CO_2 emissions or other details of the market reaction patterns. For this purpose in the following the difference between the Mega-Truck implementation scenarios and the reference case without Mega-Trucks is discussed.

Figure 40 shows the annual CO_2 balance due to modal shift effects. Efficiency gains in the road sector are ignored in this case. The graph reveals that the high market share of bulk goods within the rail sector makes up for the low potential market share of

Mega-Trucks. But due to the high growth rates, beyond 2018 the modal shift effect of continental combined transport exceeds emissions due by bulk goods transferred to road.

Figure 40: System dynamics Model output: additional CO_2 emissions in scenario 1 with 60 t Mega-Trucks by market segment – only modal shift effect, annual values



Source: TRT

Figure 41 presents the final output in cumulative values for central estimates of all parameters taking into account modal shift impacts and efficiency gains in the road sector. The graph reveals that even under the conditions of this central scenario the CO_2 balance is likely to worsen due to the introduction of 60 t Mega Trucks. Over the period 2005 to 2025 about 7 Mt of additional greenhouse gas emissions must be expected.

The slope of the curve shows that in the initial phase, due to the fast market entry of Mega-Trucks in road haulage, a decrease in the CO_2 emissions balance can be expected. But after 2013 the model expects a very sharp increase in the CO_2 emissions, which is much stronger than the initial decline. The risk of counter-balancing EU climate goals by the introduction of Mega-Trucks is thus considerable.

Figure 42 finally refers to the uncertainty in the estimates. Given the rather broad bandwidth of the potential market share of Mega-Trucks it is hardly likely that the overall effect is climate-friendly. This would be due to the stronger growth of road demand compared to rail traffic volumes. But this falls within a probability range below 25 %.

Figure 41: System Dynamics Model output: additional CO_2 emissions in scenario 1 with 60t Mega-Trucks, all market segments, cumulative results

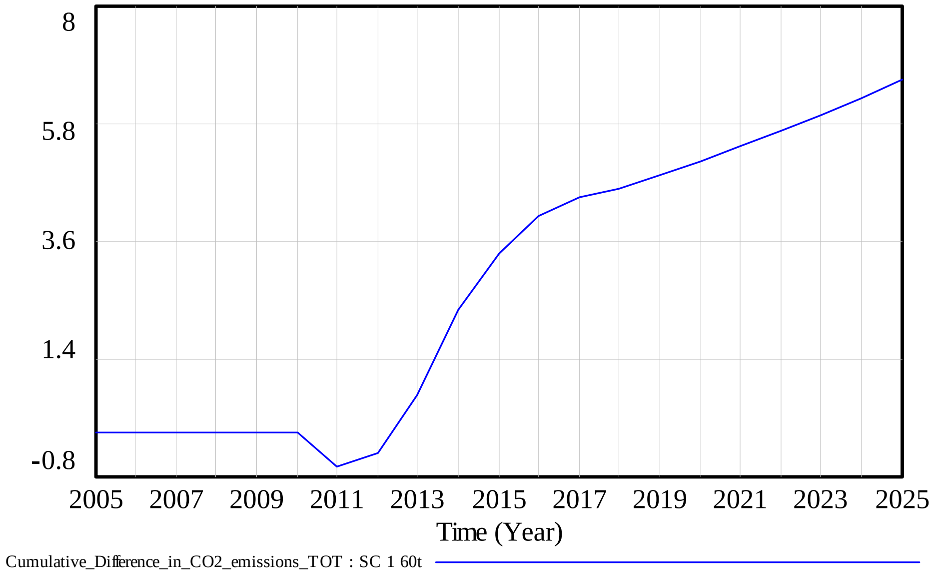
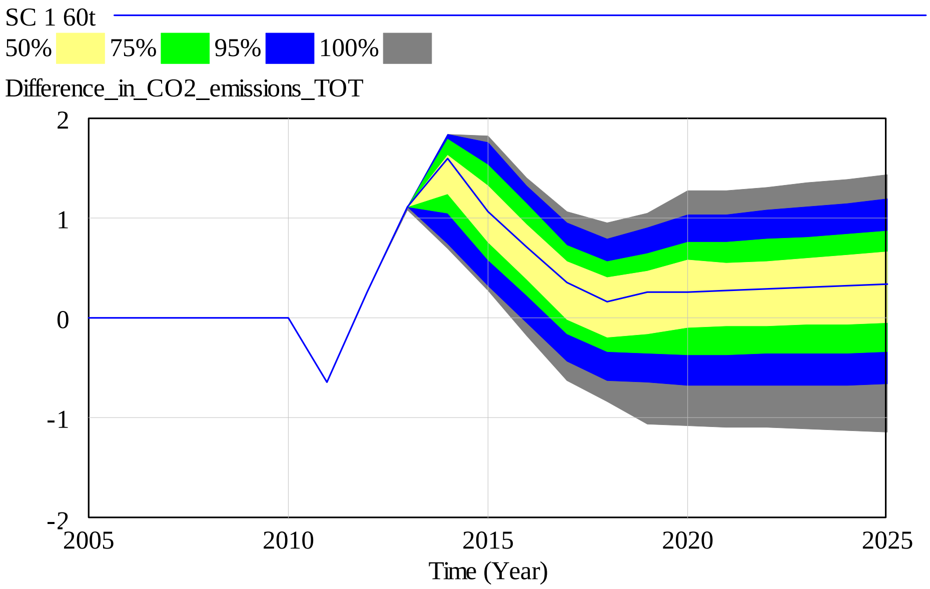


Figure 42: System dynamics Model output: additional CO_2 emissions in scenario 1 with 60 t Mega-Trucks, all market segments, probability distribution of annual emissions

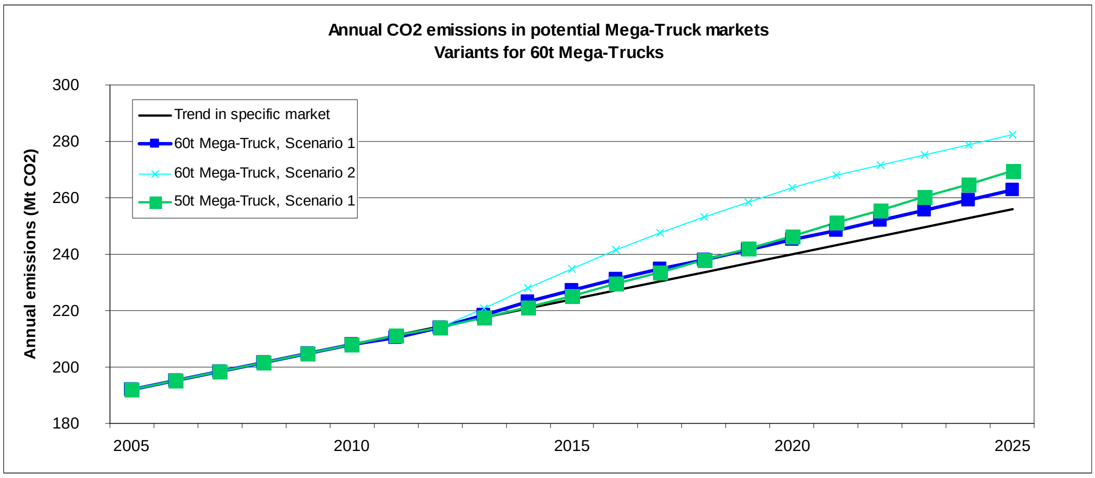


Source: TRT

6.5.2 60 t Mega-Trucks – sensitivity for climate-adverse market reactions

Scenario 2 assumes a more controversial setting of model parameters – but still within realistic expectations. The parameters have been set such that the danger of modal shifts is highlighted and positive developments in the road sector are less expressed. Total annual emissions of CO_2 of the reference scenario, the sensitivity test (Scenario 2) and – for information – the central scenario for 50 t Mega-Trucks are depicted in Figure 43. To amplify the reaction patterns the emissions have been related to the relevant markets as defined in the previous section.

Figure 43: Total annual CO_2 emissions in scenarios 1 and 2 for 60 t Mega-Trucks within relevant markets

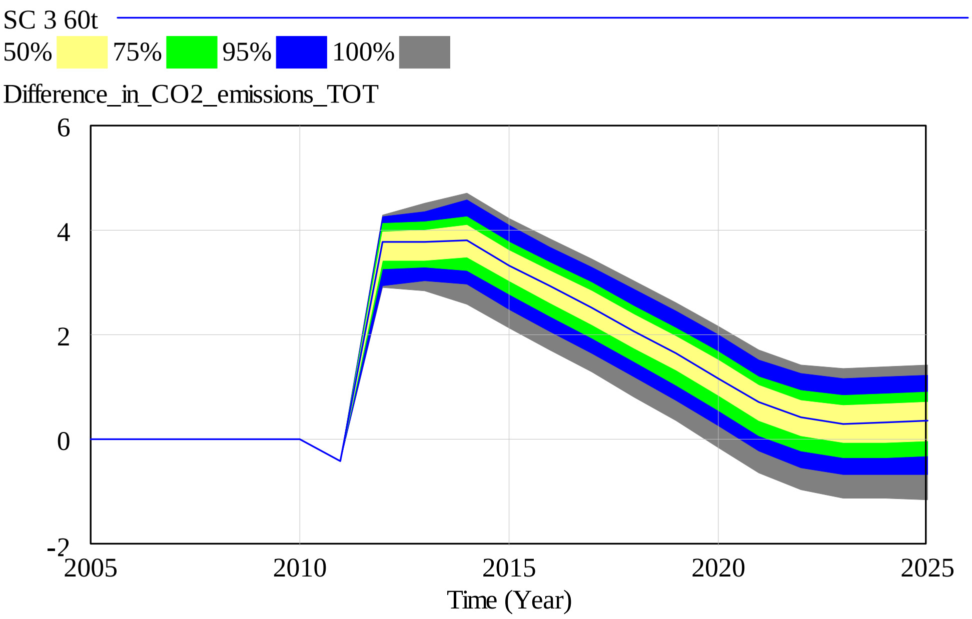


Source: Fraunhofer-ISI based on TRT data

The impact of the climate-adverse scenario 2 is constant and strong. The clear message arising from this sensitivity analysis is thus, that the possibly overall positive effects of Mega-Trucks on energy consumption and climate emissions in transport has to be acknowledged, but that there is a high risk of failure by totally counter-balancing this development through modal shift impact.

Figure 44 shows the probability distribution of reaching an overall positive or negative annual CO_2 balance under the conditions of scenario 2 (climate adverse sensitivity). While the message from scenario 1 is a rather narrow spectrum of probabilities around a rather stable downwards path of CO_2 emissions against the reference case, the strong initial increase of additional emission under scenario 3 conditions underlines the warning formulated above.

Figure 44: Annual CO_2 balance for Mega-Trucks 60 t, climate adverse scenario



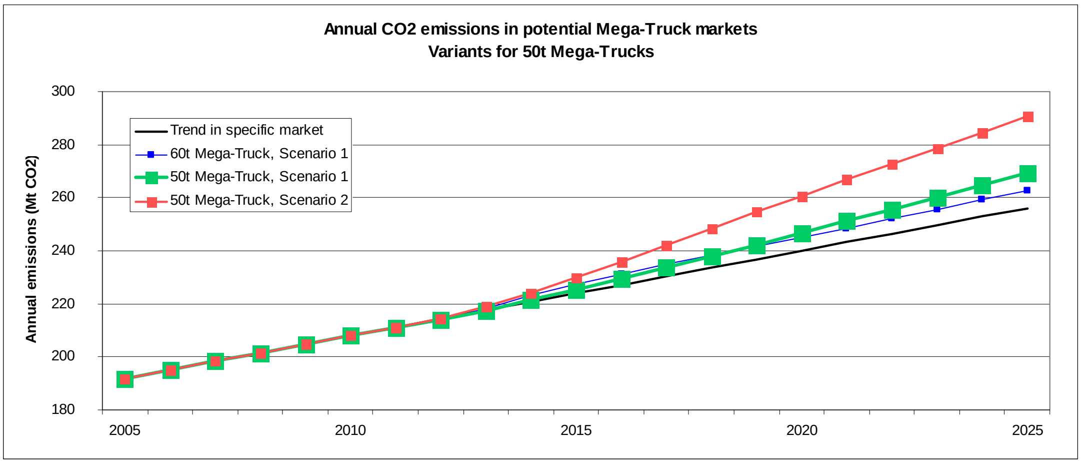
Source: TRT

6.5.3 50 t Mega-Trucks

To respond to concerns on safety and infrastructure damage by heavy Mega-Trucks, the reduction of the maximum permissible weight form 60 t to 50 t is considered by the EC and some national governments. This means less loading capacity and thus less energy and CO_2 efficiency for weight-sensitive goods. On the other hand, these goods are commonly affine to rail, which means that the pressure for modal shifts from rail to road relaxes to some extend. The current 50 t scenario investigates, which trend is stronger and what are the likely climate impacts of the two Mega-Truck concepts in comparison.

Figure 45 presents the two scenarios (central assumptions and climate adverse sensitivity test) as defined above for 50 t Mega-Trucks. In addition the trend line for the relevant markets plus the central scenario for 60 t Mega-Trucks are plotted. The figure clearly reveals that the central scenario (Scenario 1) for 50 t Mega-Trucks will lead to considerably higher annual CO_2 emissions. The difference to the trend development of the relevant markets appears considerably higher than in the case of 60 t Mega-Trucks. The difference between the central scenario and the climate-adverse case of Scenario 2 for 50 t Mega-Trucks is more expressed than for 60 t vehicles.

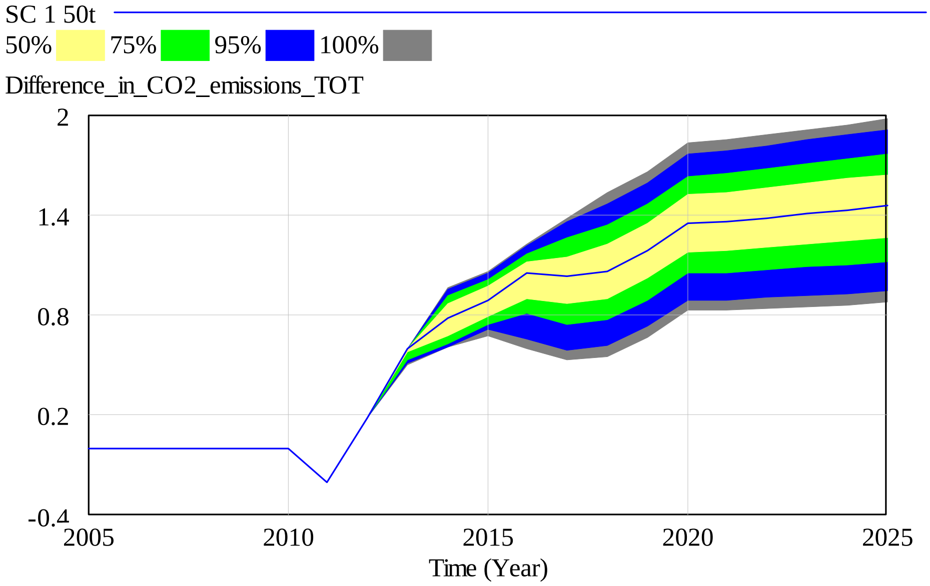
Figure 45: Total annual CO_2 emissions in scenarios 1 and 2 for 50 t Mega-Trucks within relevant markets



Source: Fraunhofer-ISI based on TRT data

The probability distribution depicted in Figure 46 underlines this conclusion. With regard to climate protection policy, 50 t Mega-Trucks appear to be the even more harmful solution than the 60 t variant.

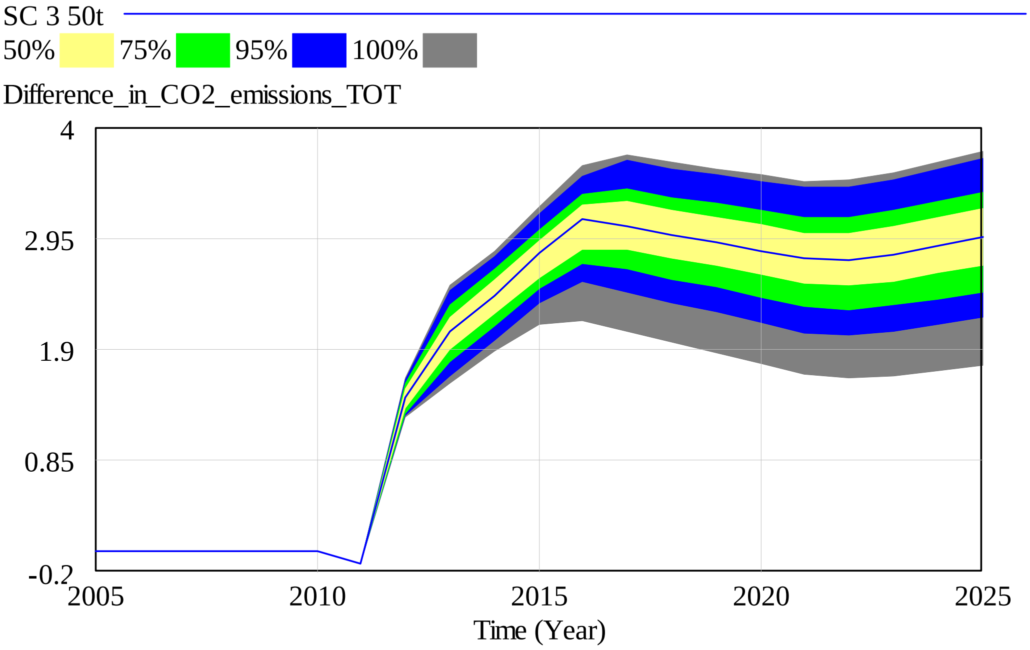
Figure 46: Annual CO_2 balance for Mega-Trucks 50t, central scenario



Source: TRT

The central scenario and the strong development in the climate adverse case (Figure 47 for Scenario 2) indicate that counter-balancing of climate protection goals by introducing 50t Mega-Trucks has a high likelihood.

Figure 47: Annual CO_2 balance for Mega-Trucks 50 t, climate adverse scenario



Source: TRT

6.6 Chapter conclusions

The analyses with the System Dynamics model demonstrate that there is an initial decline of CO_2 emissions when introducing Mega-Trucks, as the road haulage sector can react more quickly on this concept than forwarders using complex, intermodal transport chains. However, negative impacts on energy consumption and climate gas emissions appear quickly after this decline with a much more expressed amplitude. In the long run the slightly stronger growth of road volumes compared to rail give road-side efficiency gains more importance.

Final impacts of Mega-Trucks on climate-gas emissions appear negative. I.e. the modal split effect in the medium to long run remains stronger than the road side efficiency gains. The intense initial deterioration of the climate gas emission balance and the final output of the central scenarios should give enough warning not to consider the introduction of Mega-Trucks an element of climate protection policy.

The uncertainty on parameters is high. In particular the potential (or risks) for modal shifts, which assume a variety of dependencies and impacts from markets, policy and technology, show a high discrepancy between minimum and maximum assumptions. The probability distributions of those scenarios emphasising modal shift effects are broad and show even some likelihood for a finally positive CO_2 balance in the central Scenario 1. But this likelihood appears small and does not alter the line of conclusions developed in the preceding paragraphs.

Very strong is the result on the climate impacts of 50 t Mega-Trucks. Due to their lower energy and CO_2 efficiency and a high share of size sensitive goods in the railway market, their CO_2 balance appears even worse than for 60 t Mega-Trucks. In the central Scenario 1 there does not appear a positive possibility of declining relative CO_2 emissions. Thus, from a climate policy perspective the concept of 50 t Mega-Trucks must be rejected based on these results.

7 Conclusions and Recommendations

The following paragraphs summarise the conclusions taken at the end of each chapter.

7.1 Conclusions on available evidence

The review of existing studies and field tests of longer and heavier vehicles show the following results:

- Experience from German field tests and simulations for the UK reveal that Mega-Trucks may take 20 % of HGV goods volumes if they are restricted to motorways. If allowed on all roads, this share may increase to 30 %.
- In long distance road haulage the cost saving potential of extra long trucks (25.25m) ranges between 18 % and over 25 % against standard HGVs if loading factors are sufficiently high. In the case of loading factors equal to 40 t trucks the cost balance can well become negative.
- Mega-Trucks appear to be a strong competitor rather than a supplement to combined rail-road transport as their cost saving potential in long-distance unimodal road haulage is much higher than in terminal access.
- Besides container markets Mega-Trucks are also expected to take some share of rail bulk goods markets. Given the specific industry structure in the UK, here a range between 5 % and 10 % is estimated for potential modal shift.
- Like cost efficiencies, environmental advantages of Mega-Trucks are related to their load rate. Under ideal conditions 30 % of CO_2 emissions may be saved. This is, however, still far above the specific emission rate of rail transport.
- Analytical studies for Germany and the UK uncover rather high impacts of Mega-Trucks on road – rail modal shares. The highest effected market segment is container shipments, where losses of rail demand up to 50 % are predicted. This, however, depends highly on assumptions of operational and service-related responses of the carriers due to declining demand.
- Actual implementation of Mega-Trucks in Sweden and field tests in the Netherlands and Germany have so far led to much lower modal shift effects due to restrictions of Mega-Trucks to motorways in national traffic only and to specific exceptional permissions. Real impacts thus are expected to range between current practical evidence and theoretical findings.

The review has identified a number of omissions of current studies and field tests:

- The impact of road charges and the development of fuel prices and other operating and personal costs will impact the profitability of Mega-Trucks both upwards and downwards.
- The real loading capabilities of Mega-Trucks can only take certain combinations of containers. This makes them less attractive in maritime and combined transport plus
- The very limited road access capacity of many major seaports may help to protect the sensitive container goods markets from massive modal shifts.
- Insufficient infrastructure quality to carry Mega-Trucks particularly in the New Member States will limit their applicability in some regions for a certain period of time.
- Door-to-door transport may require splitting of Mega-Trucks away from motorways and thus make the concept far more costly.
- The rail protection policy of Switzerland and Austria, which will most probably be maintained, will prevent massive modal shifts on the highly important Trans-Alpine corridor.
- The possible weakening of regulatory standards for Mega-Trucks over time to serve the needs of the forwarding industries, will be in favour of modal shifts.
- Restrictions due to complex logistics patterns mean that in practice real modal shift will be below technical potential.

The real market potential of Mega-Trucks will therefore be somewhat below the values found by the analytical desktop studies but still considerably above the findings of current field trials.

7.2 Case study findings

The case studies revealed:

- Mega-Trucks play the biggest role on highly frequented transport axes and in high quality logistics. Of particular relevance for modal split are the segment- of high quality logistics and of systemic transports.
- Bulk goods on port hinterland relations are commonly carried by short sea shipping in case of availability. The remaining rail cargo thus consists of higher proportion of high-value goods which are more sensitive to modal shift.

- But: road access capacity and size of consignments (large ships = long trains) limit the resulting modal shift potential in port hinterland traffic.
- Most affected regions are north-western continental Europe, the UK and Trans-Alpine connections (“blue banana”). Here congestion impacts are the most sensitive.
- Regulation decisions, e.g. restriction to motorways and road quality standards are decisive for the profitability of Mega-Trucks relative to standard HGVs, but less important for modal shift. Restrictions may be abolished in the medium to long-term.
- Rail service quality constitutes a very decisive factor for the size of modal shift effects. The potential of the currently implemented European Rail Transport Monitoring System (ERTMS) is thus expected to be considerable.

Mega-Trucks play the biggest role on long distances; above 1300 km they might fully replace standard HGVs in high quality markets.

7.3 Evidence for applying the LOGIS geographical logistics model

The results of applying the LOGIS model indicate as follows:

- A significant share of road cargo volumes is taken by Mega-Trucks from conventional road trucks. The market share of Mega-Trucks increases significantly with the distance.
- Mega-Truck traffic concentrates along major European corridors and thus becomes particularly important for international traffic.
- But Mega-Trucks markets are also privileged markets for combined transport: longer distances of international transport take place along major European corridors

Therefore Mega-Trucks will take a significant share of the expected combined transport market in 2020: this has consequences in terms of environmental impact.

The development of Mega-Trucks might prevent opening of intermodal services and therefore endanger the development of intermodal transport (unable to reach a critical size for EU coverage and increase in productivity of rolling stock): even with a voluntary intermodal policy, intermodal transport would not develop significantly.

It is clear that these strong results would need looking at in more depth:

- Concerning the authorisation of circulation of Mega-Trucks: location of parking places close to motorways or industrial areas (presently there are 1000 points for entry and exit of motorway systems; such hypothesis can be analysed more in depth.
- Concerning the impact on the environment: this can be measured very precisely (global and local impact) with the simulation tool used.

The model totally confirms literature results on the competition between Mega-Trucks and standard HGV, say that the Mega-Trucks might gain a share of 20 % of ton kilometres of road haulage. Concerning the shift of demand from combined transport to road the LOGIS model shows even higher results than available studies. This can partly be explained by the truck-friendly mode environment, but this is partially taken into account when setting the parameters for the later development of the System Dynamics model.

7.4 Evidence by the System Dynamics model

The application of the System-Dynamics model yields the following conclusions:

- The impact of Mega-Trucks takes place in three phases: (1) initial decline of CO_2 emissions due to road efficiency, (2) high increase as modal shift effects set in and (3) fall and, in most cases, convergence to lower level due to faster growth of road than rail traffic.
- In the scenarios analysed final impacts of Mega-Trucks on climate gas emissions appear to be negative. The intense initial deterioration of the climate gas emission balance and the final output of the central scenarios should give enough warning not to consider the introduction of Mega-Trucks as an element of climate protection policy.
- The uncertainty of the parameters is high. The presumable distributions of those scenarios emphasising modal shift effects even show some likelihood for finally positive CO_2 balance, but this seems to be small.

- Due to their lower energy and CO_2 efficiency the CO_2 balance of 50 t Mega-Trucks appears even worse than for 60 t trucks.

7.5 Conclusions on medium to long term impacts

Three phases of development can be observed:

- The road sector accepts Mega-Trucks rather quickly, which leads to a decrease of CO_2-emissions due to efficiency gain on the road (3 to 6 years, 0.5 Mt CO_2/a).
- If Mega-Trucks are established in road haulage, modal shift tendencies set in the rail sector. With a high degree of certainty modal shift effects will counter-balance CO_2 reduction targets. Within 5 to 20 years an additional emission of 2 Mt CO_2 per year is expected due to the introduction of 60 t Mega-Trucks.
- Road grows faster than rail demand. Thus, in the long run efficiency gains in the road sector might play a role for overall CO_2 reductions. This is expected to happen within a time frame of 15 to 30 years.
- In most scenarios negative impacts in the medium run are much stronger than initial positive effects.
- Reducing the maximum gross weight of Mega-Trucks from 60 t to 50 t will increase the likely adverse climate impacts of Mega-Trucks due to lower efficiency gains in the road sector. These results of the System Dynamics model are very strong.
- The study finds strong evidence that most likely the introduction of Mega-Trucks will end in a negative climate gas balance in the medium term. Thus, the authors reject longer and heavier road freight vehicles as a suitable element of climate protection policy.

7.6 Remarks on the robustness of the results

According to available studies, other impacts of Mega-Trucks, such as air pollution and noise will show a similar development. Rebound effects due to induced traffic demand and modal split will limit or counter-balance the initial advantage of Mega-Trucks.

Traffic safety constitutes a highly important issue for assessing modal shifts as fatality rates are much higher in road haulage, in particular for long and heavy vehicles, than for the safer rail mode.

The assessment framework of the present study was based on 4 independent pillars:

- Literature and field test observations
- Two representative European case studies
- The TRT system-dynamics model containing the available knowledge
- The NESTEAR module of the New Opera Model for GIS-based analyses

Although this broad methodological approach should eliminate bases in single assessment elements, some ranges of uncertainty remain as reliable observations with Mega-Trucks are missing for some market segments. An example is the segment of food and semi final products and the case of single wagon rail transport. But even then reaction patterns get clear and the risk of a negative climate gas balance due to the introduction of Mega-Trucks in the medium term is serious. Further insight can only be gained via micro simulation techniques considering the complex decision structures of contemporary logistics service providers.

8 References

Aarts, L. and G. Feddes: Experiences with longer and heavier vehicles in the Netherlands. Working paper, Ministry of Transport, Department for Road Transport, Netherlands.

Berndt, T (2001): Schienengüte4rverkehr, Vieweg+Teubner Verlag, Wiesbaden 2001

Doll, C. (2008) Rebound Effect of Climate Benefits from Mega-Trucks. Short study prepared for the Community of European Railways and Infrastructure Companies (CER), Karlsruhe, March 2008 (unpublished).

EC (1996): Council Directive 1996/53/EC of 25 July 1996 laying down for certain road vehicles circulating within the Community the maximum authorized dimensions in national and international traffic and the maximum authorized weights in international traffic. The Council of the European Union, Brussels.

EC (2008): EU Energy and Transport in Figures. Statistical Pocketbook 2007 / 2008. European Commission DG Energy and Transport, Brussels, 2008

Ecotransit (2008): http://www.ecotransit.org

EU (2006): Energy and Transport in Figures 2006. European Commission, Brussels

FGSV (1997): Empfehlungen für Wirtschaftlichekeitsstudien an Straßen (EWS). Forschungsgesellschaft für Straßen- und Verkehrswesen, Köln.

FIS (2008): Auswirkungen größerer Transportgefäße - Lastzugkombinationen ("Gigaliner"/EuroCombi). Forschungs-Informations-System Mobilität, Verkehr und Stadtentwicklung (FIS) of the Federal Ministry for Transport, Building and Urban Devellopment (BMVBS), Berlin. URL: www.forschungnsinformationssystem.de accessed 16.3.2008

Infras / IWW (2004): External Costs of Transport. Update 2000. Study fort he International Union of Railways (UIC), Paris. C. Schreyer, M. Maibach (Infras, Zurich), C. Doll, D. Schmedding, W. Rothengatter (IWW, Uni Karlsruhe).

ISI / TIS.pt / Infras / EE (2006): Analysis of the contribution of transport policies to the competitiveness of the EU economy and comparison with the United States (COMPETE). Final report to the European Commission, DG Transport and Energy. W. Schade, C. Doll (Fraunhofer-ISI), M. Maibach, D. Suter (Infras), F. Crespo (TIS.pt), A. Lillco (Europe Economics). Project co-ordination: Fraunhofer-ISI, Karlsruhe, October 2006.

IVH (2007): Auswertung des niedersächsichen Modellversuchs zum Einsatz von “Giga-Linern”. Study on behalf of the Ministry for Economy, Labour and Transport Lower Saxony. Friedrich, B., S. Hoffmann and F. Bräkelmann, Institut für Verkehrswirtschaft, Straßenwesen und Städtebau, Leibnitz University Hannover.

K+P (2007): Verkehrswirtschaftliche Auswirkungen innovativer Nutzfahrzeugkonzepte. Study commissioned by the Federal Ministry for Transport, Building and Urban Development (BMVBS). Kessel und Partner, Freiburg and Studiengesellschaft für den kombinierten Verkehr (SGKV), Frankfurt.

Manzos and Capros (2006): European Transport and Energy Trends to 2030 – Update 2005. European Commission Publication Service, Luxembourg.

ProgTrans (2007): Freight Transport in Germany 2050. Study on behalf of the Federal Ministry for Transport, Building and Housing (BMVBS), Berlin. ProgTrans AG, Basle

TIM (2006): Wettbewerbswirkungen der Einführung des Gigaliners auf den kombinierten Verkehr. TIM Consult, Frankfurt, Kombiverkehr, Frankfurt, UIRR, Brussels.

TML, TNO, LCPC, RWTH Aachen (2009): Effects of adapting the rules on weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC”, Study co-ordinated by Transport Mobility Leuven) on behalf of the European Commission. Leuven.

TRL (2008): Longer and/or Longer and Heavier Goods Vehicles (LHVs) – a Study of the Likely Effects if Permitted in the UK. Final Report. A. Knight, W. Newton, Prof. A. McKinnon et al., Transport Research Laboratory (TRL). Published Project Report PPR285. London.

UBA (2007): Länger und schwerer auf Deutschlands Straßen: Tragen Riesen-Lkw zu einer nachhaltigen Mobilität bei? Position of the Federal Environment Agency (UBA) on the environmental friendliness of Mega-Trucks. Dessau, March 2007

UIC (2007): International railway statistics 2006. Maps and graphs – Europe. International Union of Railways (UIC), Paris.

UIRR (2007): Statistics 2007. International union of combined road-rail transport companies (UIRR), Brussels.

Uniconsult (2007): Europäische Hinterlandverkehre auf der Schiene – Anforderungen und Entwicklungsperspektiven. Presentaiton to the Union of German Transport Undertakings (VDV). J. Ninnemann, Hamburg.

Annex: Detailed results NESTEAR logistics model

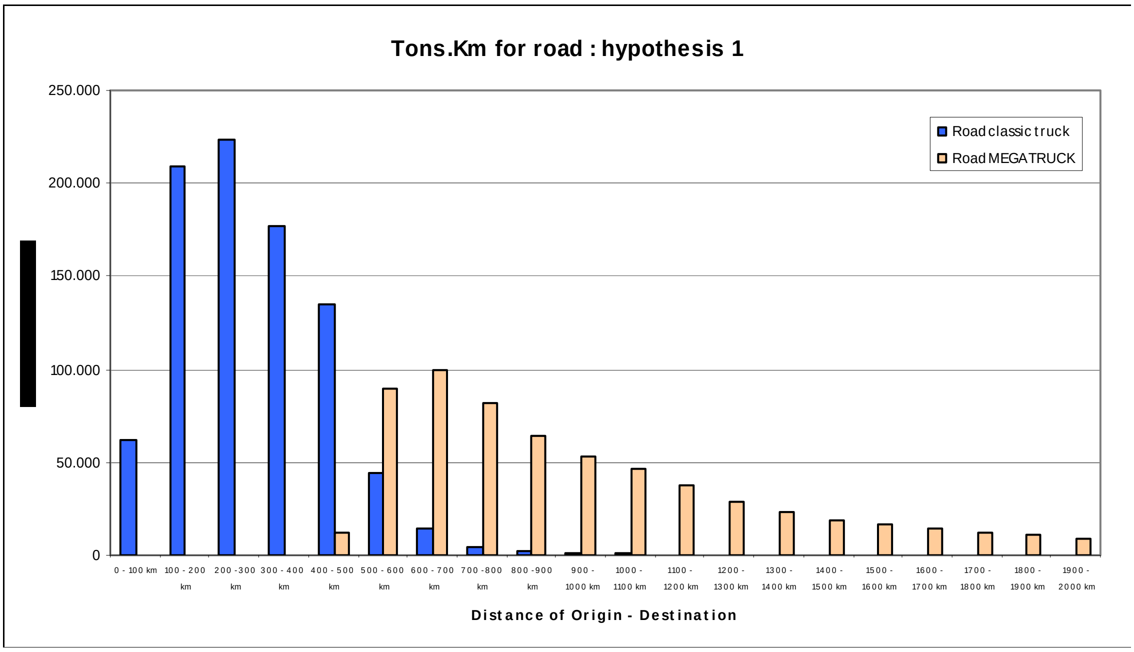
The material presented in this annex provides details to the results of the LOGIS regional freight transport model applied by NESTEAR to the question of market shares of Mega-Trucks within the road sector and between road and combined transport.

1. Detailed results for road – road competition

Remarks:

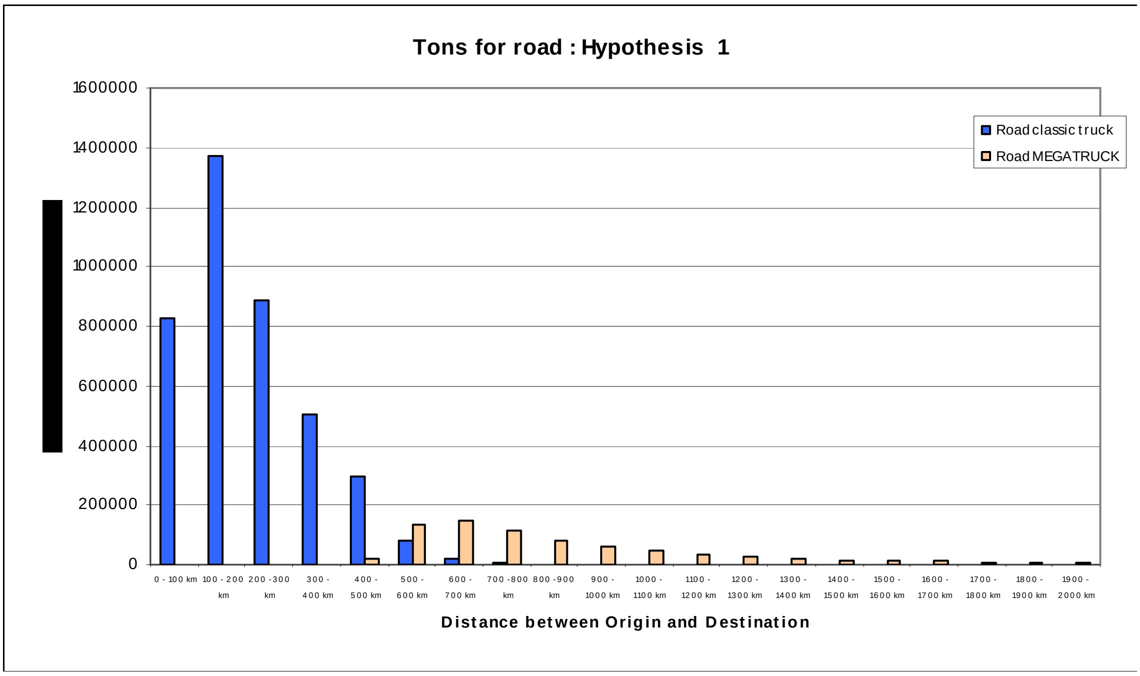
- Ton-km by road mode and by distance (simulation 1): The distance is terrestrial: it does not take into account the ferries
- Tons by mode and by distance (simulation 2)
- The mode is considered Mega-Trucks if one km of distance between origin and destination is carried out by Mega-Trucks

HYPOTHESIS 1



TONS.KM by road mode and by distance (simulation 1)

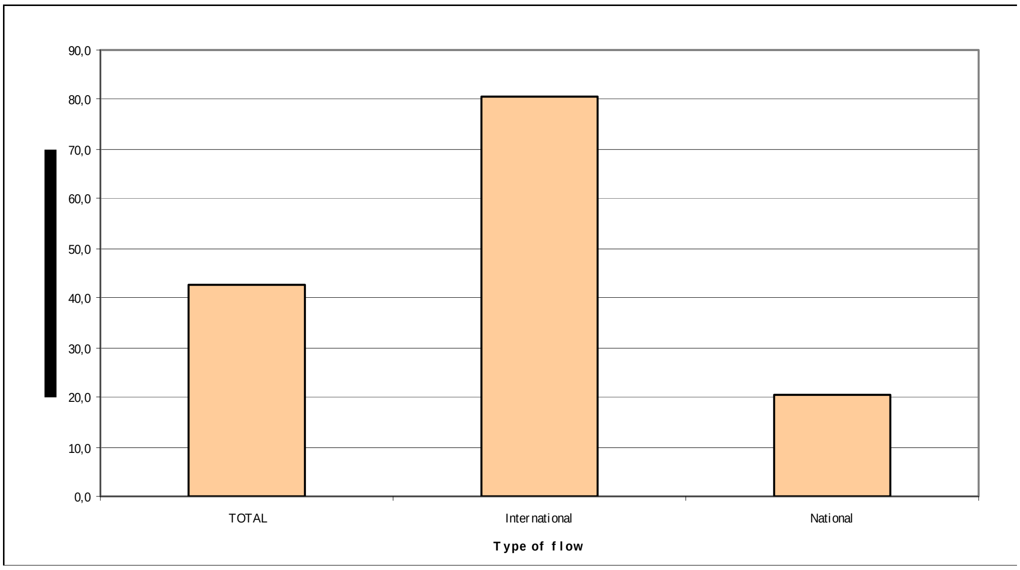
The distance is terrestrial: it does not take into account the ferries

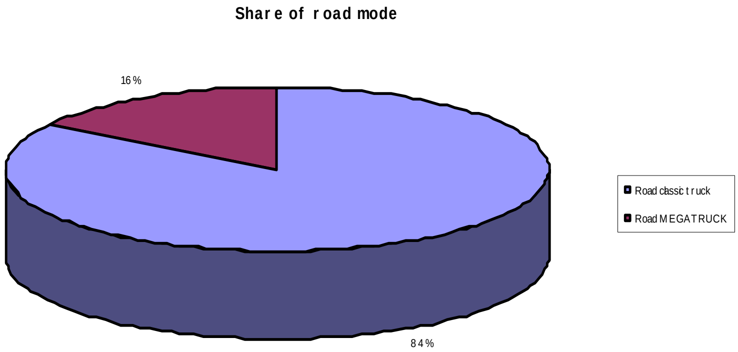


Tons by mode and by distance (simulation 2)

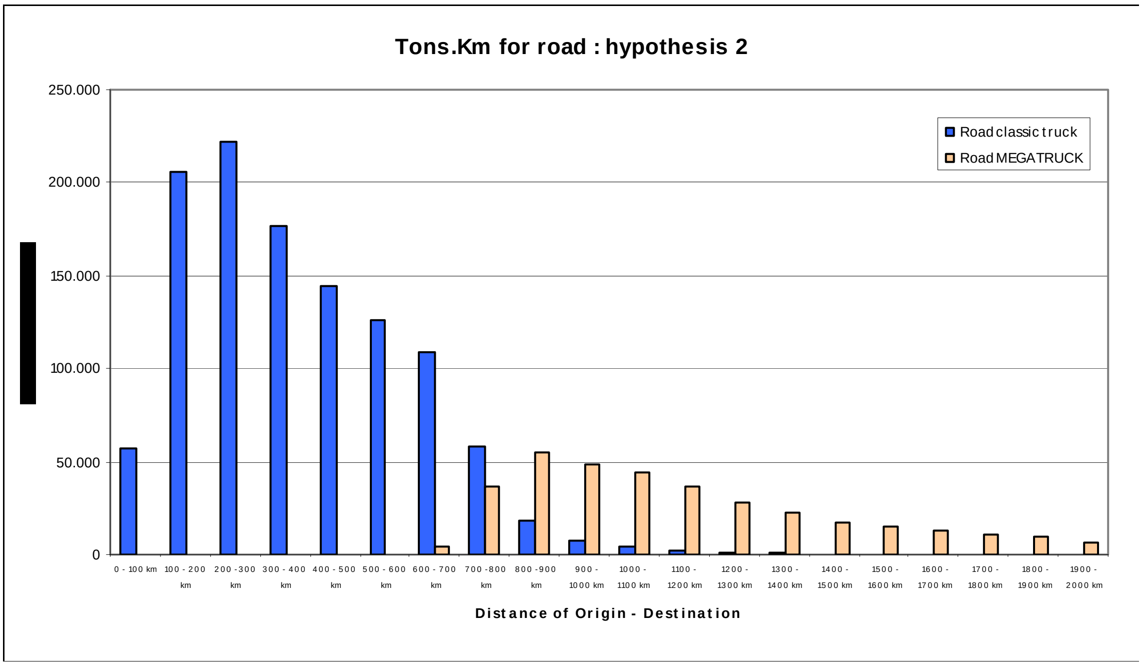
The mode is considered in MEGATRUCK if one km of distance between origin and destination is effectuated in MEGATRUCK

Measure	**In million Tkm**			**In 1000 tons**
Distance	**TOTAL**	**International**	**National**	**National**
Road conventional HGV	873 932	110 759	763 173	3 993 204
Road Mega-Truck	654 969	459 177	195 792	744 705
TOTAL	1 528 901	569 936	958 965	4 737 909
Share by Mega-Trucks	**42,8**	**80,6**	**20,4**	16

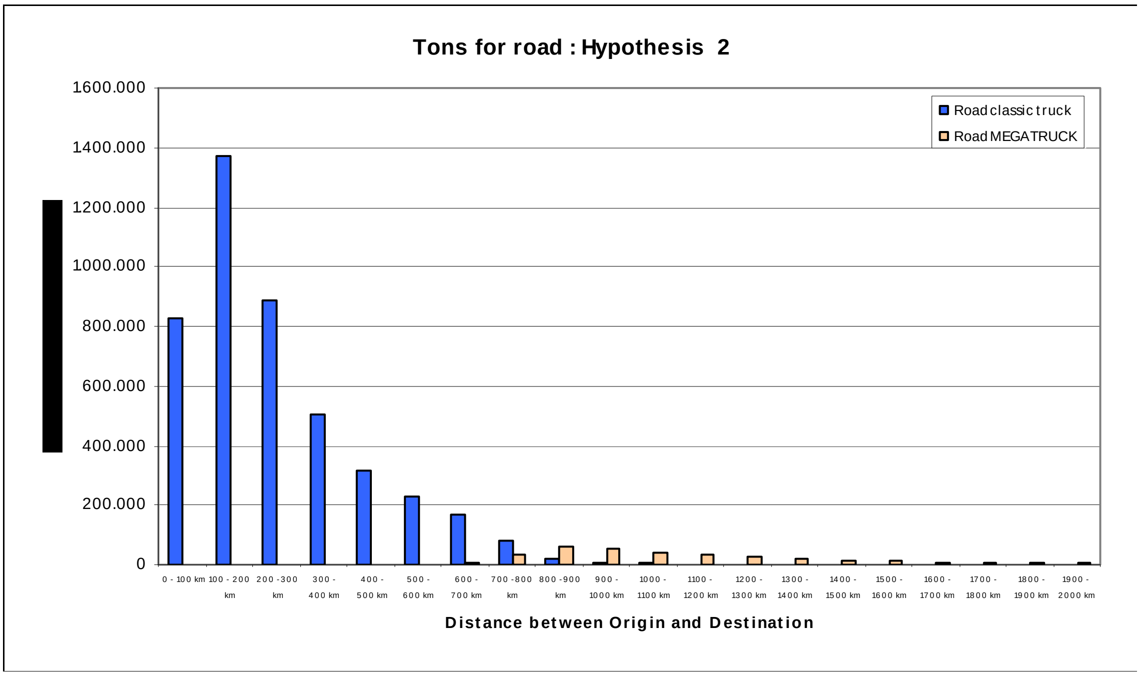




HYPOTHESIS 2:



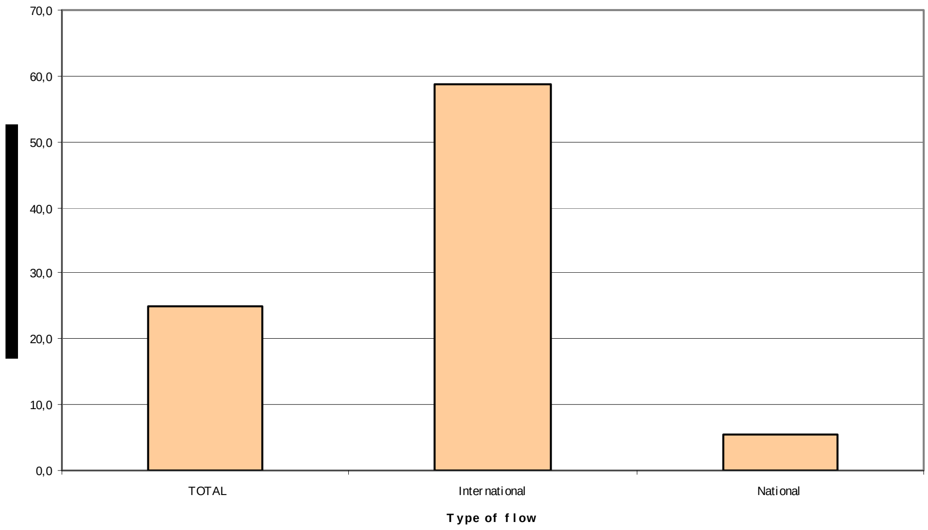
TONS.KM by road mode and by distance (simulation 2)



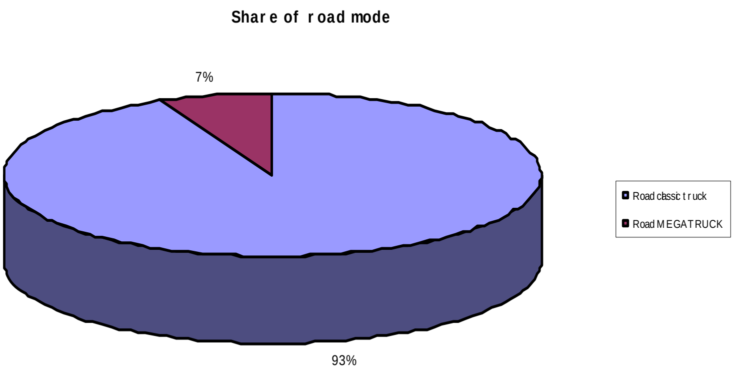
Tons by mode and by distance (simulation 2)

The mode is considered in ‘Mega-Truck’ if one km of distance between origin and destination is effectuated by Mega-Trucks.

Measure	In million Tkm			In 1000 tons
Distance	**TOTAL**	**International**	**National**	**National**
Road conventional HGV	1 134 280	231 279	903 006	3 993 204
Road Mega-Truck	380 201	328 015	52 186	744 705
TOTAL	1 514 481	559 294	955 192	4 737 909
Share by Mega-Trucks	25,1	58,6	5,5	16

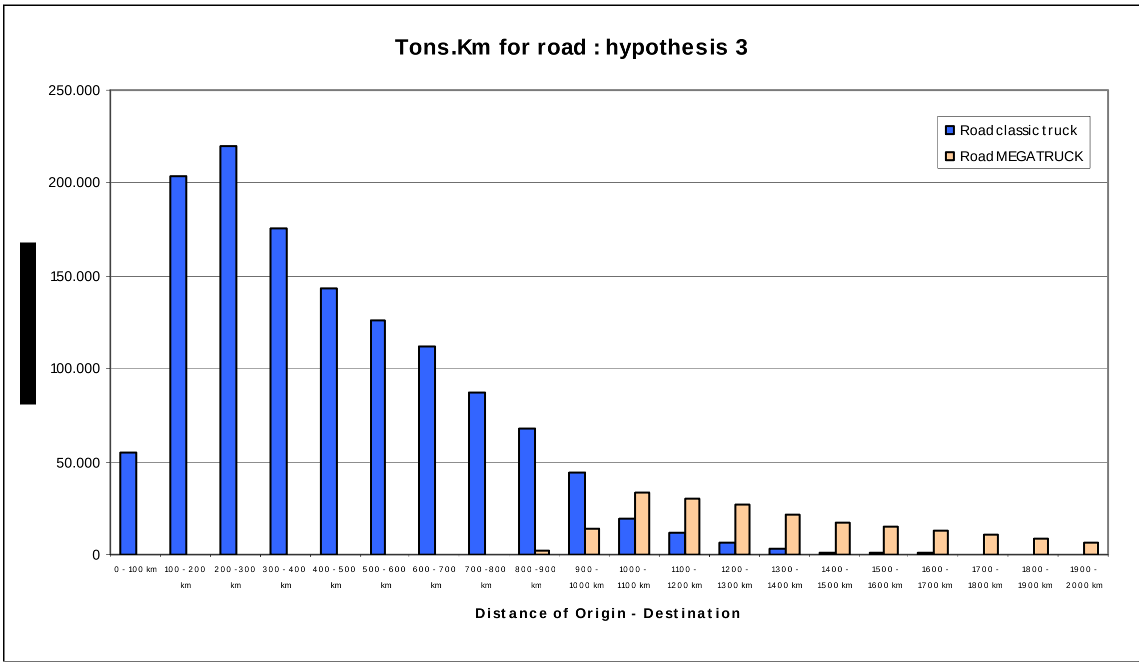


Share of Mega-Trucks in Tons

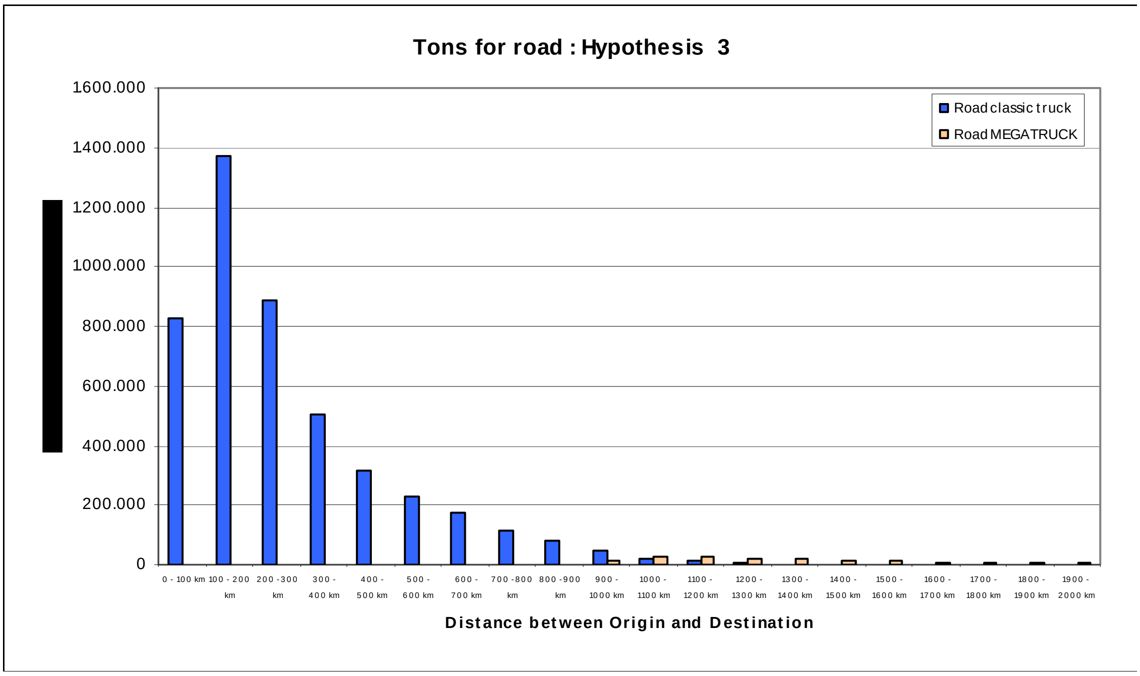


Share of MEGATRUCK in Tons

HYPOTHESIS 3:



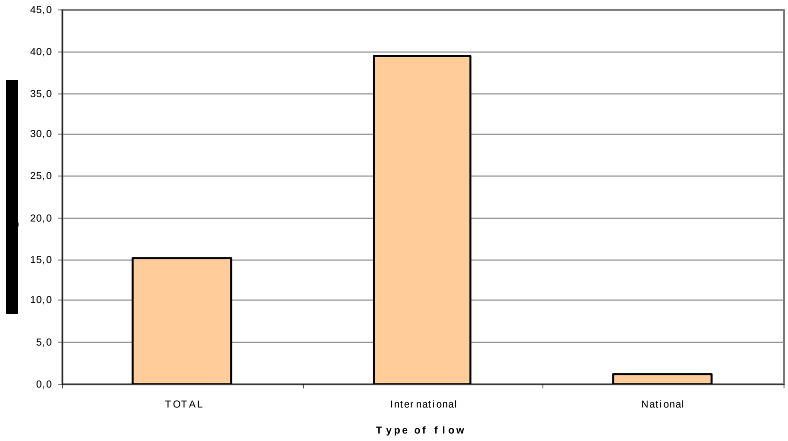
TONS.KM by road mode and by distance (simulation 3)



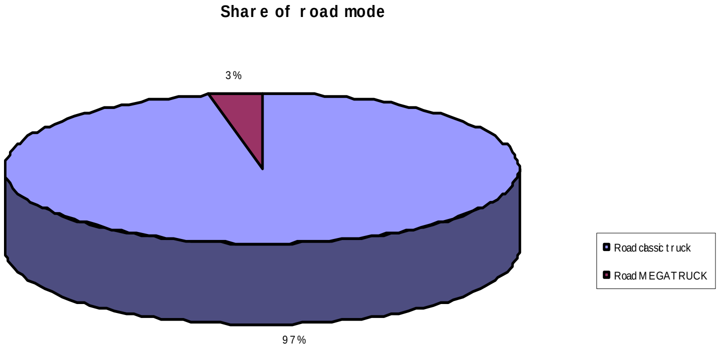
Tons by mode and by distance (simulation 3)

The mode is considered in ‘Mega-Trucks’’ if one km of distance between origin and destination is effectuated by Mega-Trucks.

Measure	In million Tkm			In 1000 tons
Distance	**TOTAL**	**International**	**National**	**National**
Road conventional HGV	1 279 710	336 271	943 438	4 589 561
Road Mega-Truck	230 600	219 533	11 067	152 349
TOTAL	1 510 310	555 804	954 505	4 741 910
Share by Mega-Trucks	15,3	39,5	1,2	3

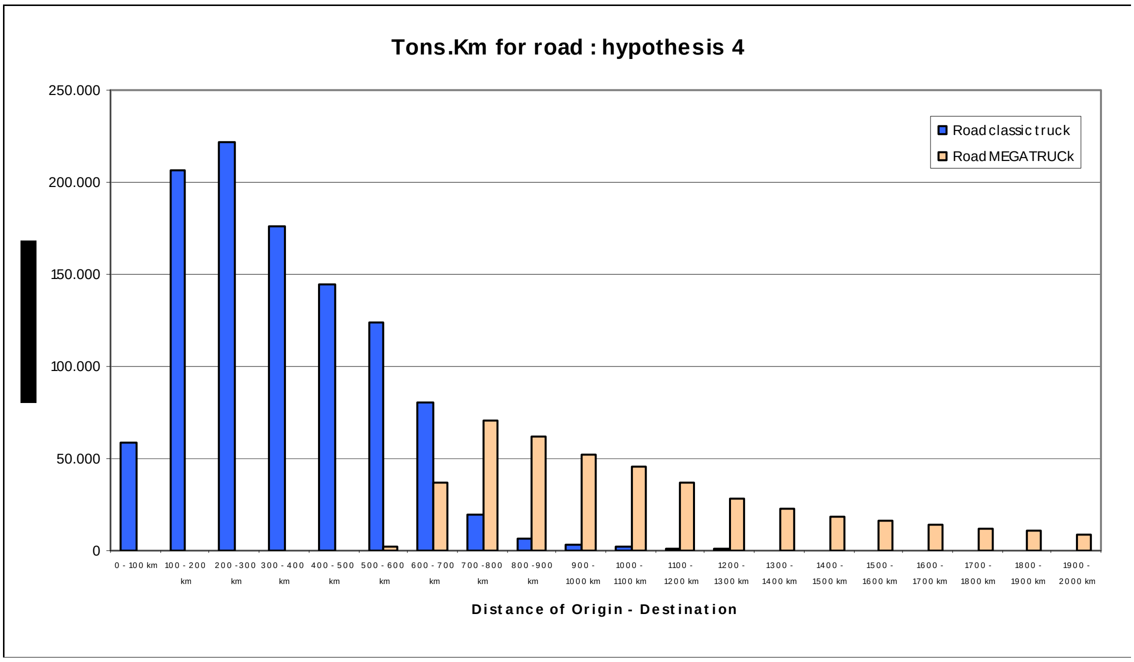


Share of Mega-Trucks in TK

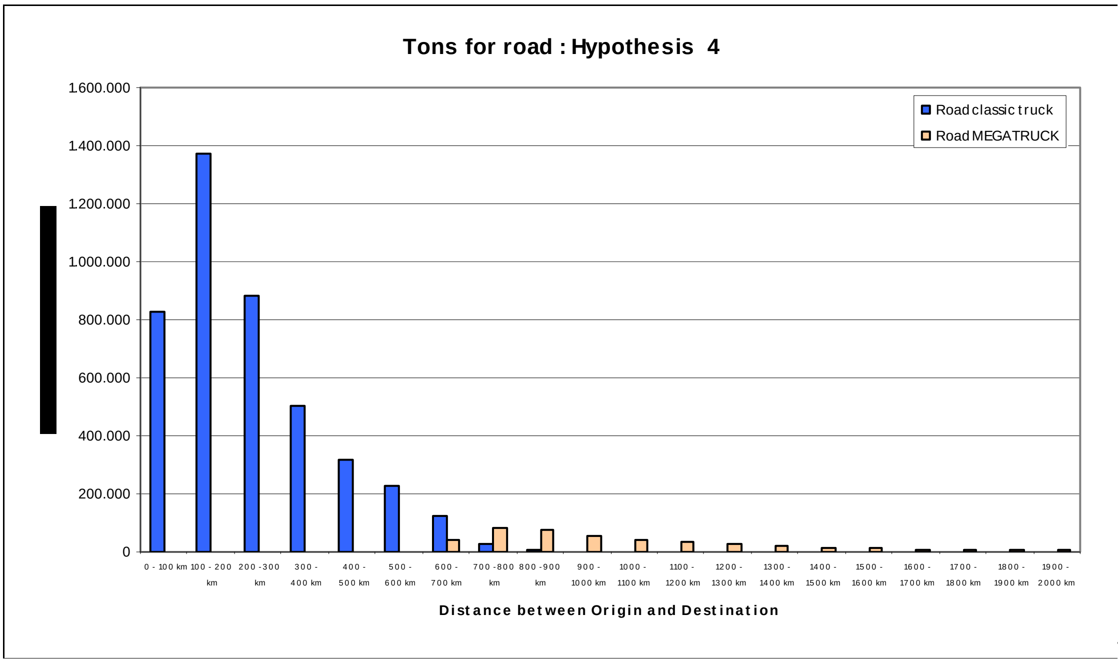


Share of MEGATRUCK in Tons

HYPOTHESIS 4:



TONS.KM by road mode and by distance (simulation 4)

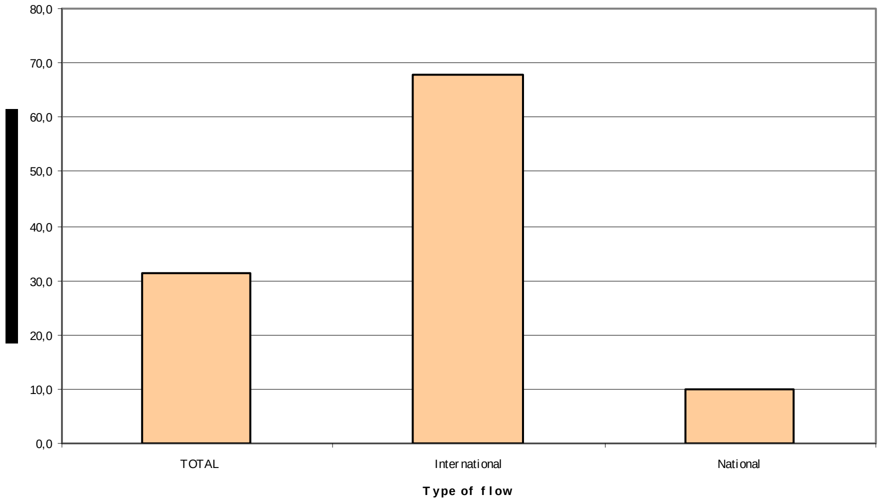


T

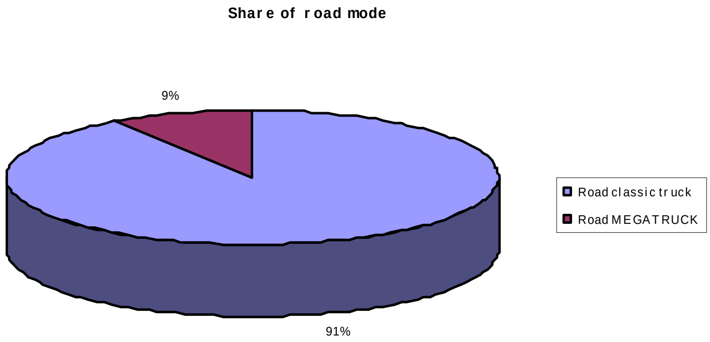
ons by mode and by distance (simulation 4)

The mode is considered in ‘Mega-Truck’ if one km of distance between origin and destination is effectuated by Mega-Trucks.

Measure	In million Tkm			In 1000 tons
Distance	**TOTAL**	**International**	**National**	**National**
Road conventional HGV	1 045 930	183 123	862 807	4 295 199
Road Mega-Truck	477 208	383 557	93 651	442 785
TOTAL	1 523 138	566 680	956 458	4 737 985
Share by Mega-Trucks	31,3	67,7	9,8	9

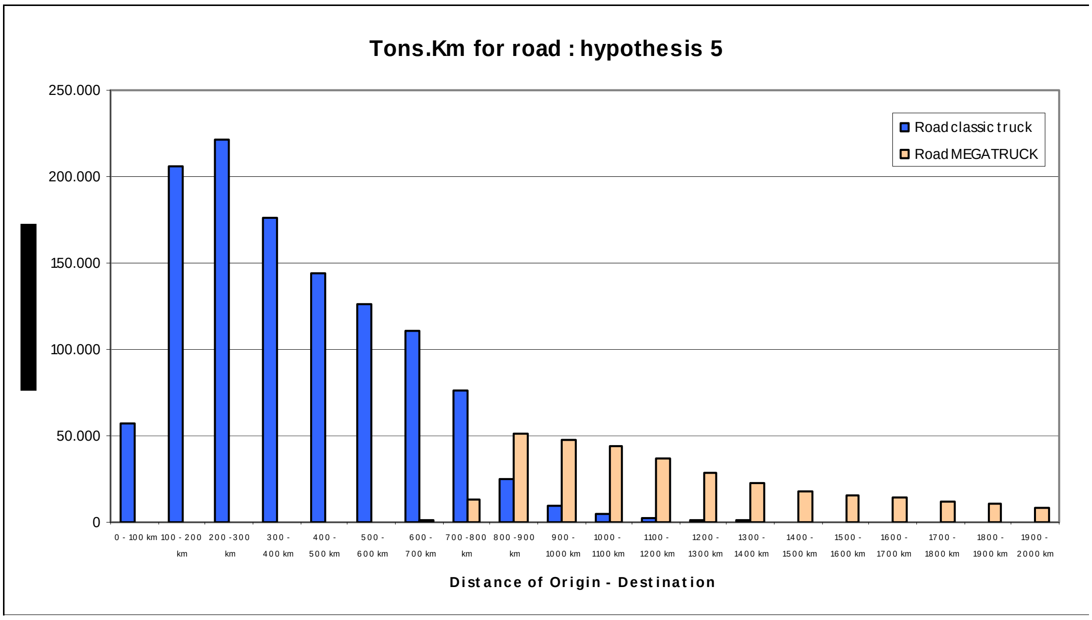


Share of Mega-Trucks in TK

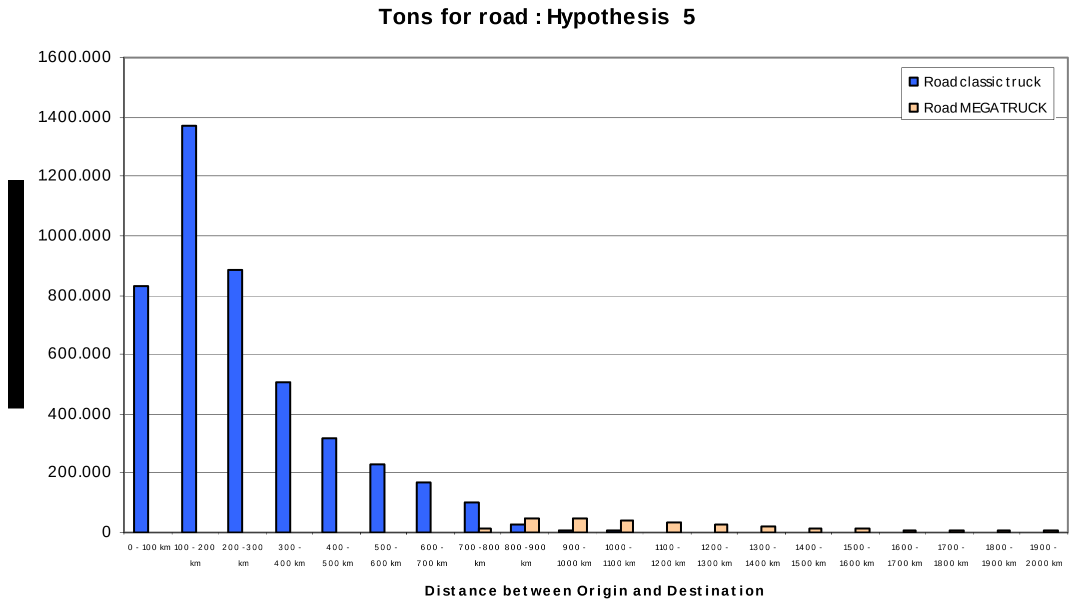


Share of MEGATRUCK in Tons

HYPOTHESIS 5:



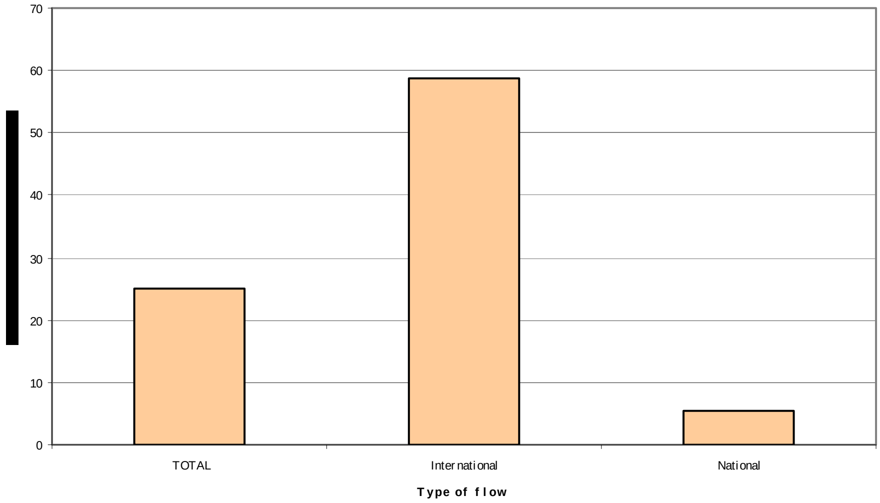
TONS.KM by road mode and by distance (simulation 5)



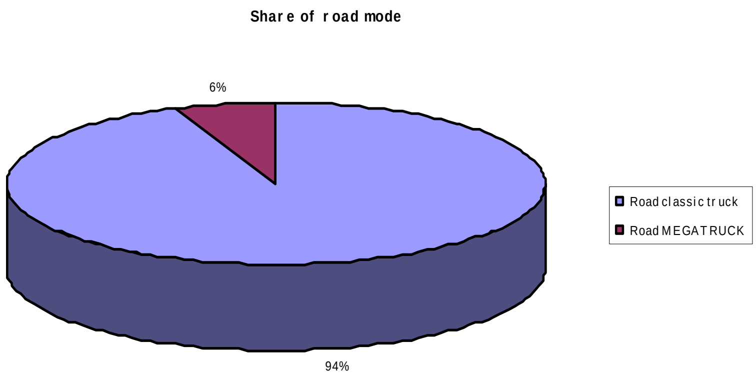
Tons by mode and by distance (simulation 5)

The mode is considered in 'Mega-Truck' if one km of distance between origin and destination is effectuated by Mega-Trucks.

Measure	In million Tkm			In 1000 tons
Distance	**TOTAL**	**International**	**National**	**National**
Road conventional HGV	1 134 280	231 279	903 006	4 454 859
Road Mega-Truck	380 201	328 015	52 186	284 443
TOTAL	1 514 481	559 294	955 192	4 739 302
Share by Mega-Trucks	25,1	58,6	5,5	6

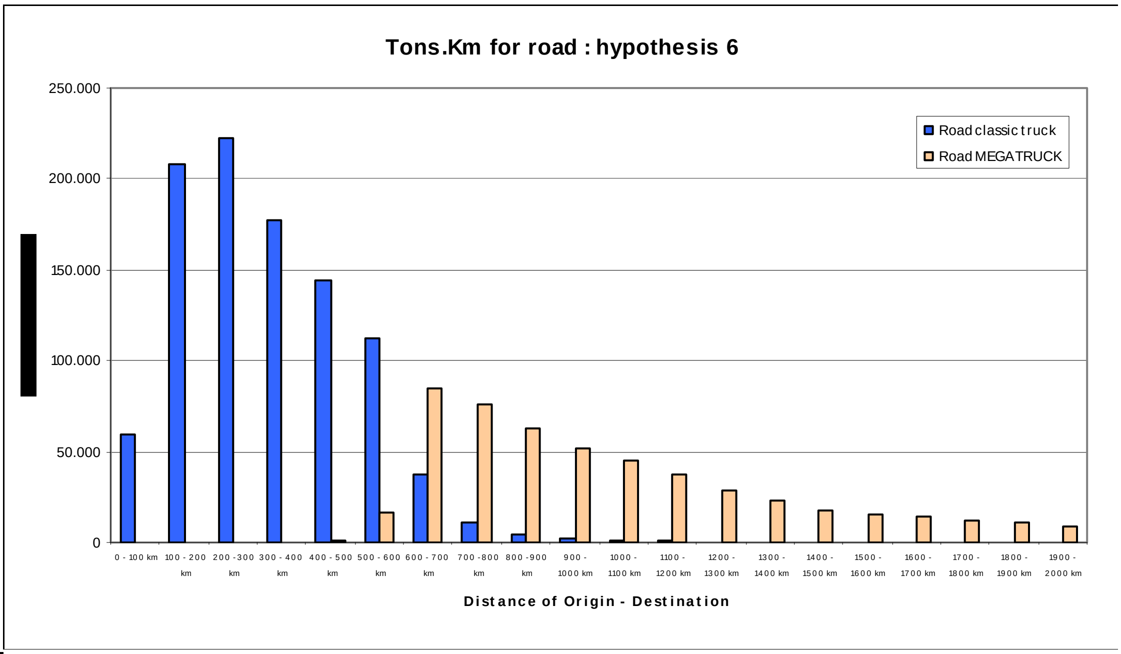


Share of Mega-Truucks in TK

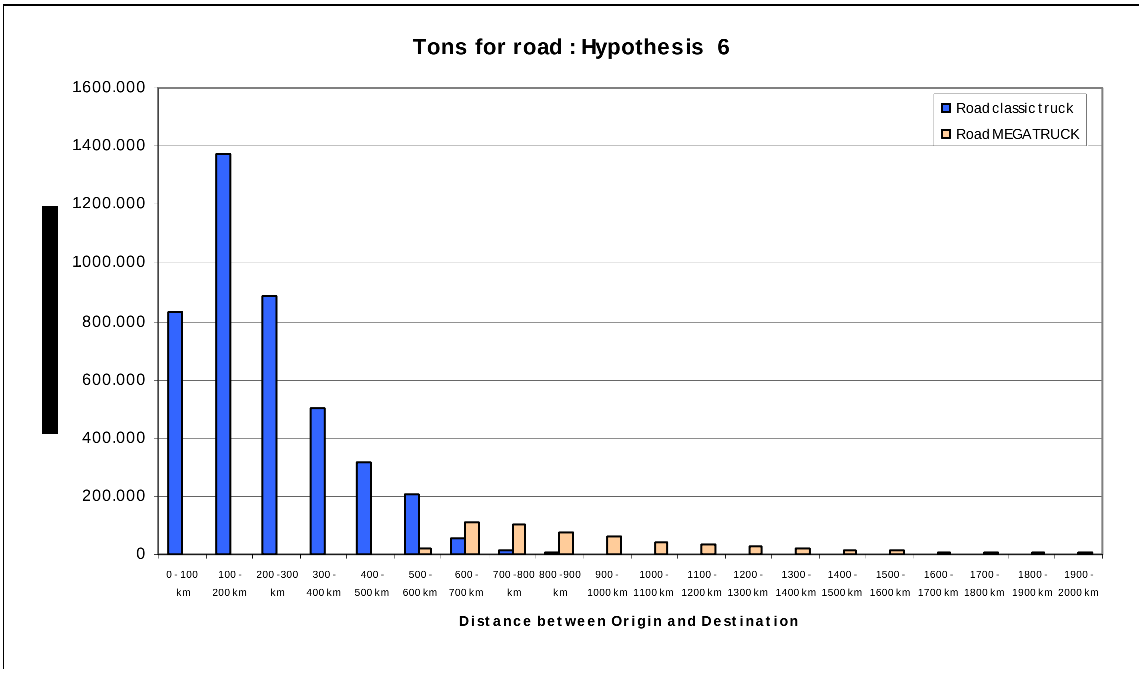


Share of Mega-Trucks in Tons

HYPOTHESIS 6:



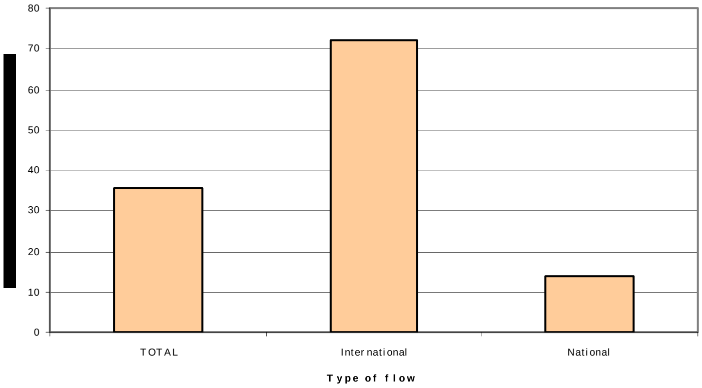
TONS.KM by road mode and by distance (simulation 6)



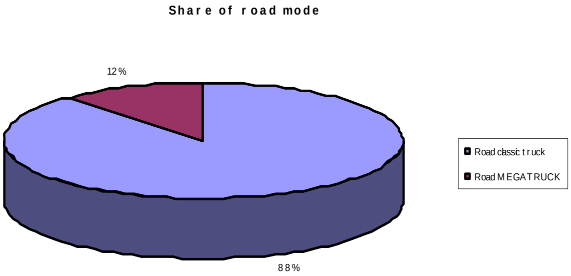
Tons by mode and by distance (simulation 6)

The mode is considered in ‘Mega-Trucks‘ if one km of distance between origin and destination is effectuated by Mega-Trucks.

Measure	In million Tkm			In 1000 tons
Distance	TOTAL	International	National	National
Road conventional HGV	983 548	156 873	826 676	4 190 055
Road Mega-Truck	538 464	408 287	130 177	549 181
TOTAL	1 522 012	565 160	956 853	4 739 236
Share by Mega-Trucks	35,4	72,2	13,6	12



Share of Mega-Trucks in TK

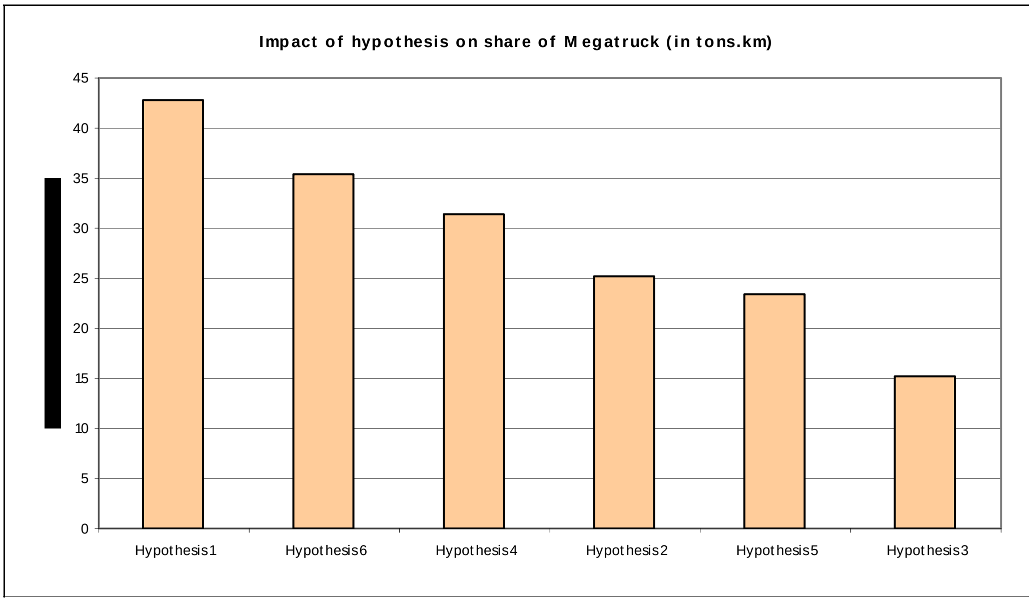


Share of Mega-Trucks in Tons

SYNTHESIS

Freight performance 2020 (1000 million tkm)	Road con-ventional HGV	Road Mega-Truck	TOTAL	Share by Mega-Trucks (%)	Increase in tkm (Hypothesis less reference) (1000 million)
Hypothesis 1	874	655	1 529	**43**	**33**
Hypothesis 6	984	538	1 522	**35**	**26**
Hypothesis 4	1 046	477	1 523	**31**	**27**
Hypothesis 2	1 134	380	1 514	**25**	**18**
Hypothesis 5	1 161	356	1 517	**23**	**21**
Hypothesis 3	1 280	231	1 510	**15**	**14**
Road reference	1 496	0	1 496	**0**	**0**

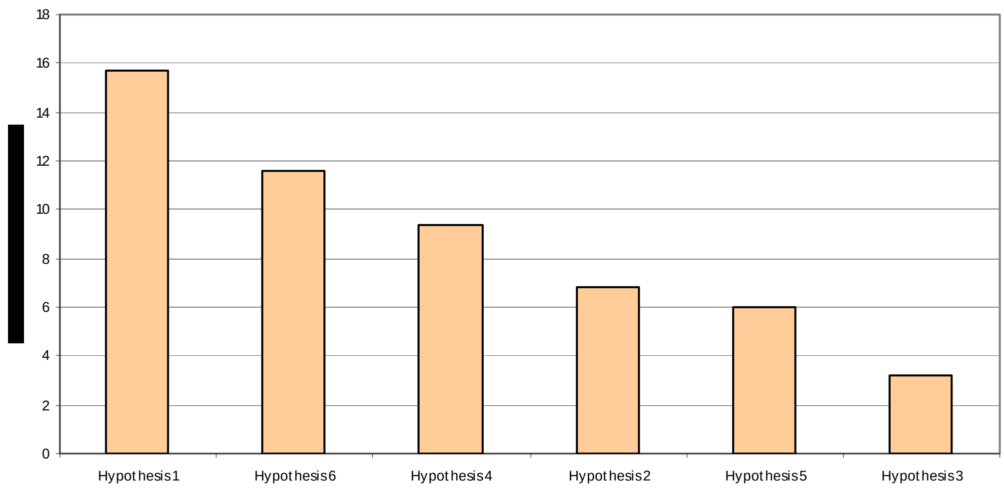
The growth of the share of MEGATRUCK causes a prolongation of distance travelled. The increase is not negligible in absolute and must be taken into account in the environmental and energy balance sheet.



Freight demand 2020 (million tons)	Road conven-tional HGV	Road Mega-Truck	TOTAL	Share by Mega-Trucks (%)
Hypothesis 1	3 993	745	4 738	**16**
Hypothesis 6	4 190	549	4 739	**12**
Hypothesis 4	4 295	443	4 738	**9**
Hypothesis 2	4 417	325	4 742	**7**
Hypothesis 5	4 455	284	4 739	**6**
Hypothesis 3	4 590	152	4 742	**3**

Total increase is due to Origin Destination who are close to 2000 km

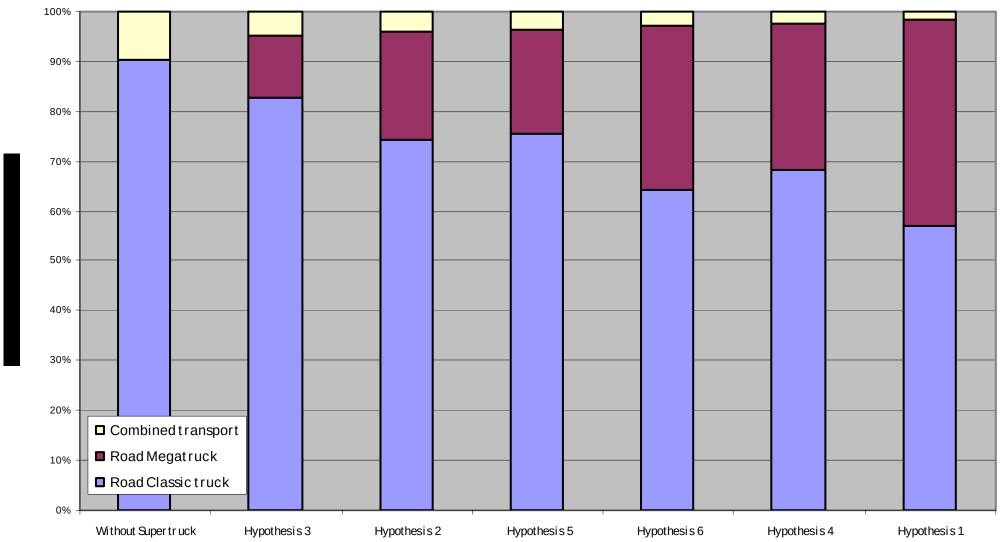
Impact of hypothesis on share of Megatruck (in tons)



2. Detailed results for road – CT competition

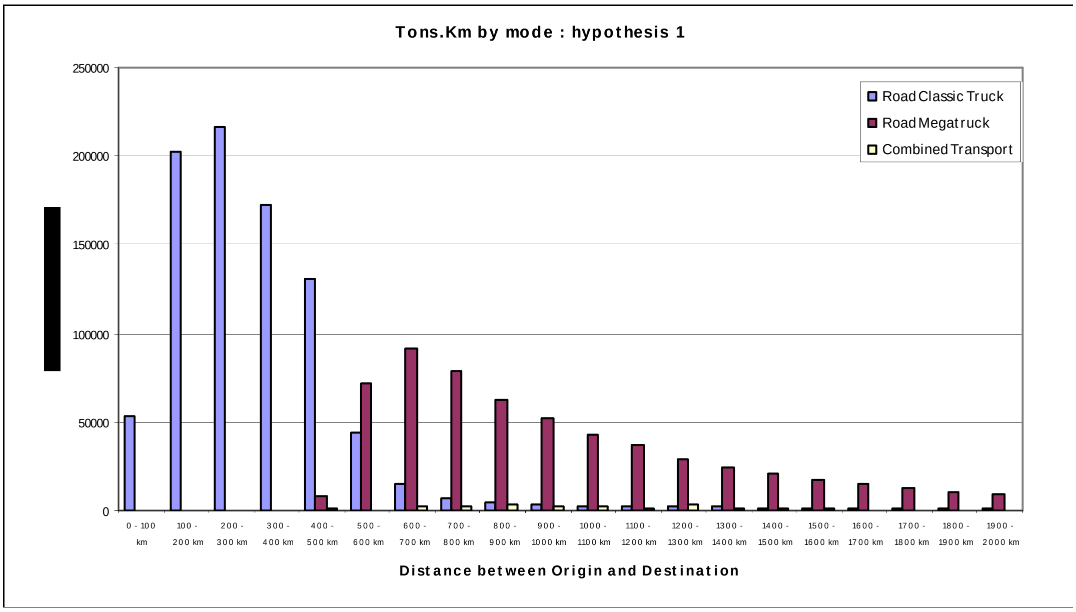
Remarks:

- Share at tkm by mode (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely)
- TK by mode and distance (included post and pre shipment in classic truck or Mega-Truck for combined transport, a shipment by Mega-Truck is possible but very likely)
- The distance is terrestrial: it does not take into account the ferries



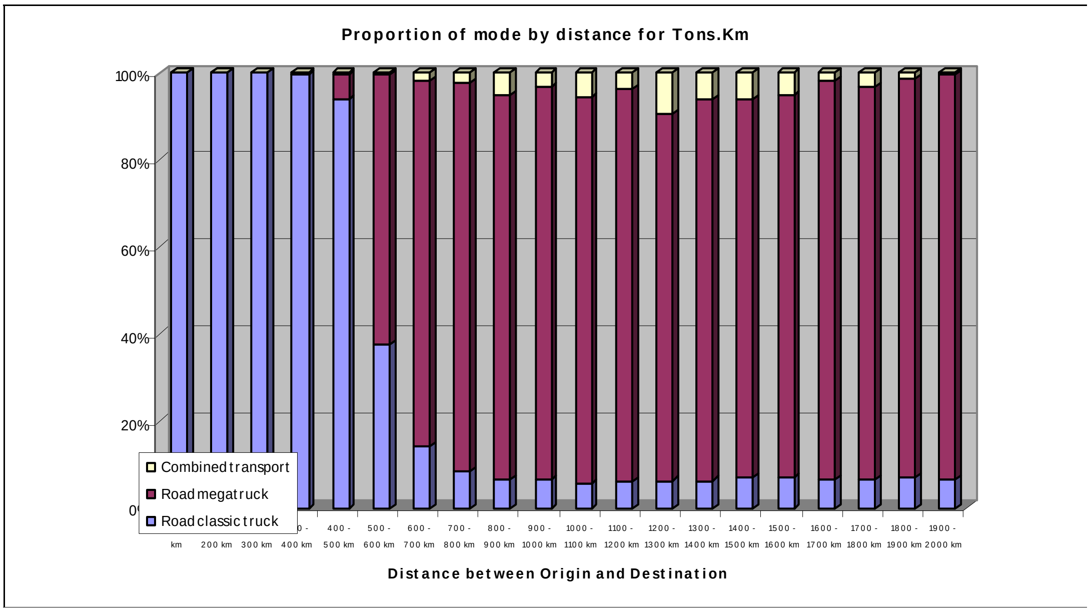
PROPORTION OF TK by mode (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely)

HYPOTHESIS 1:



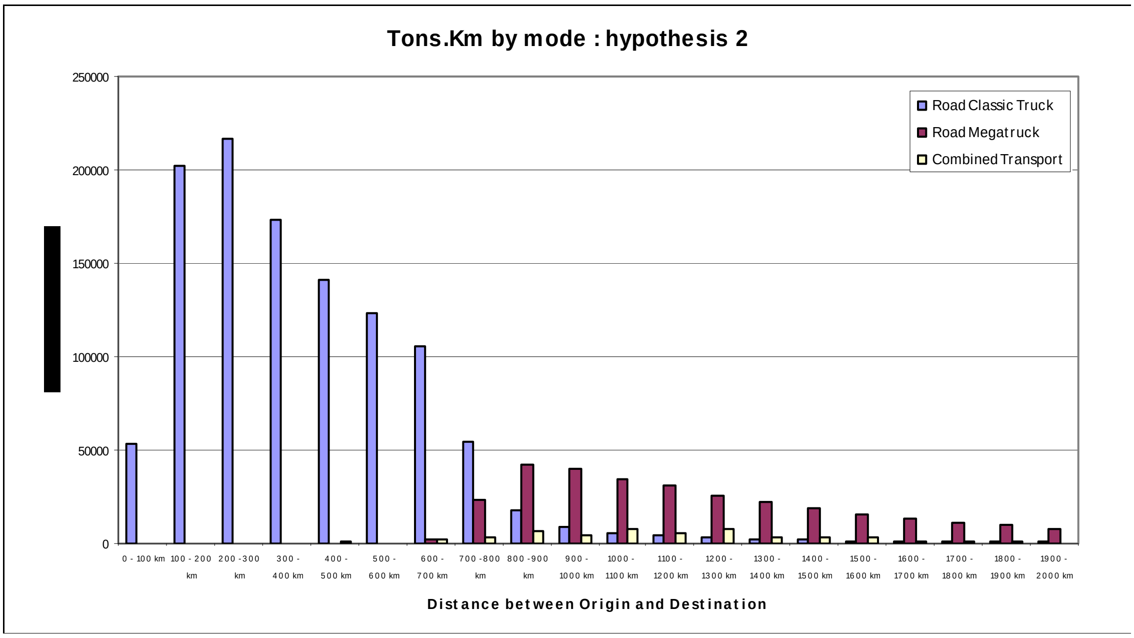
TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely)

The distance is terrestrial: it does not take into account the ferries

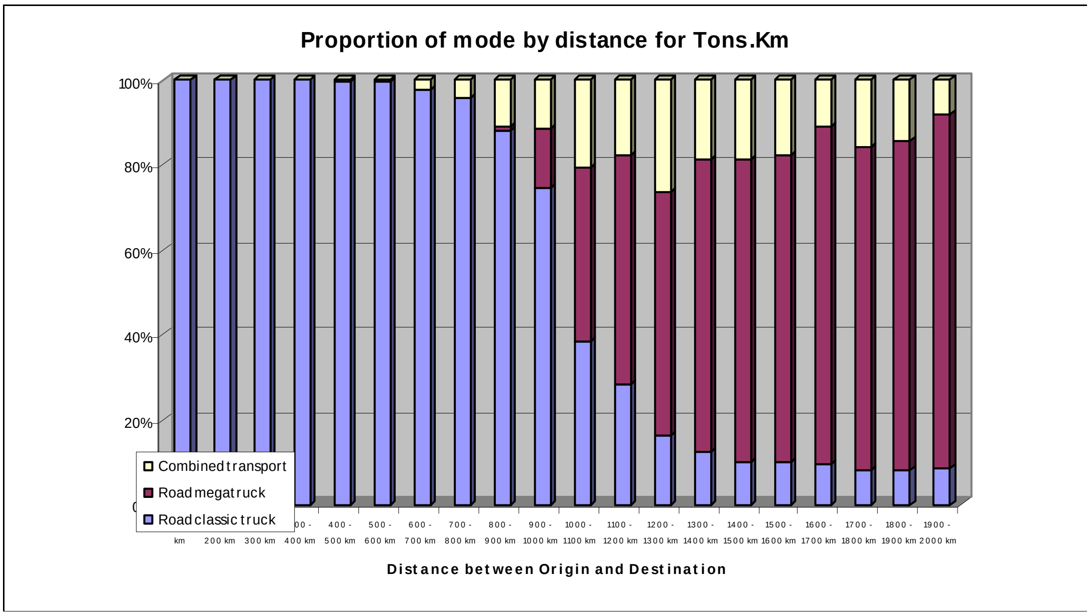


TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely) The distance is terrestrial: it does not take into account the ferries

HYPOTHESIS 2:

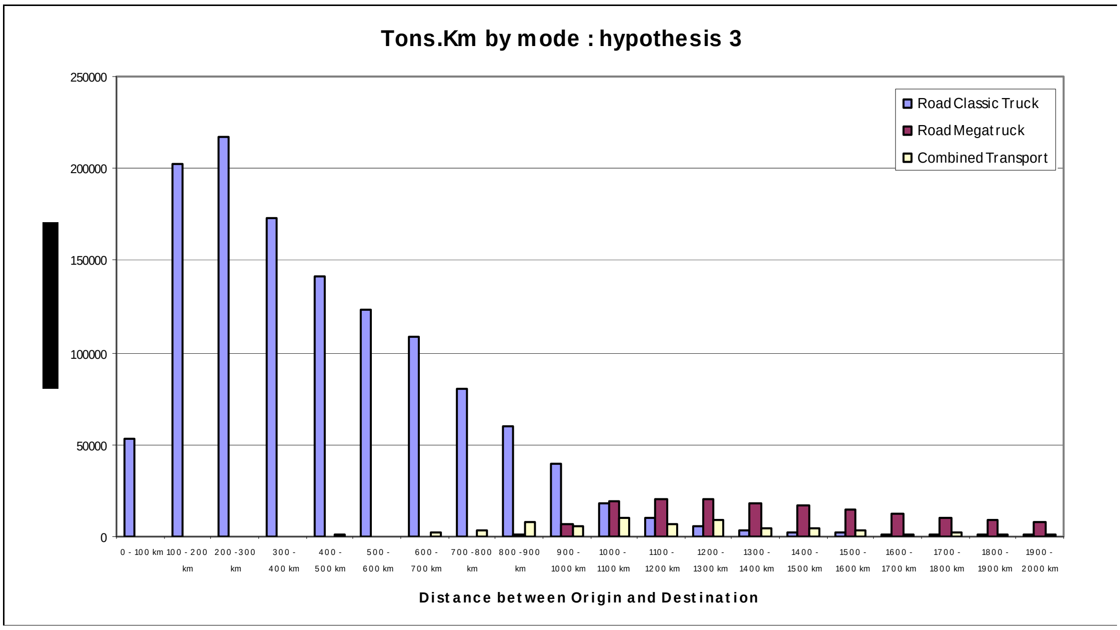


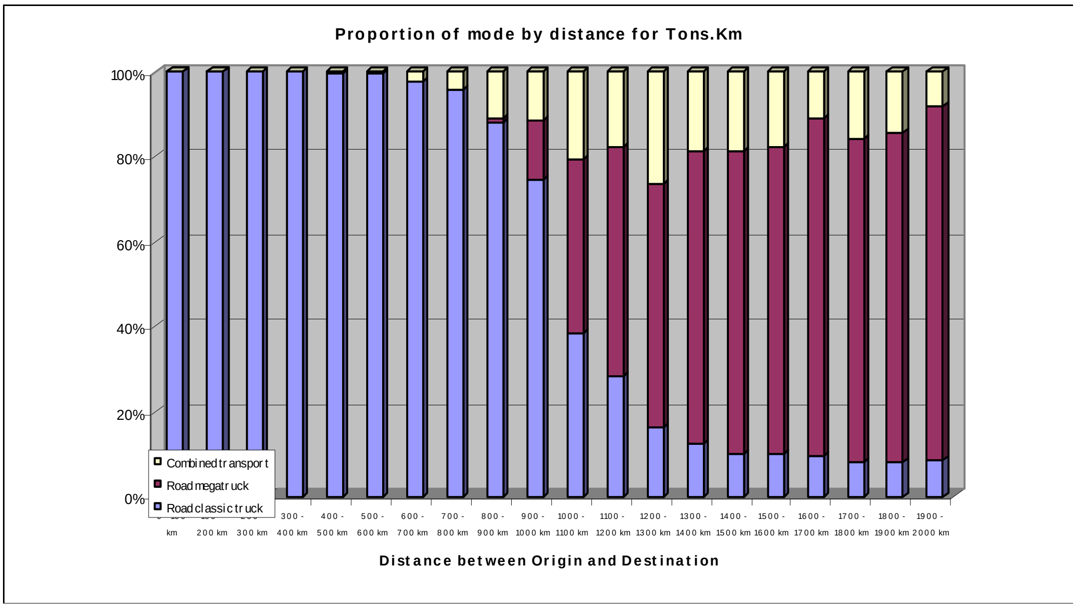
TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely) The distance is terrestrial: it does not take into account the ferries



TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely) The distance is terrestrial: it does not take into account the ferries

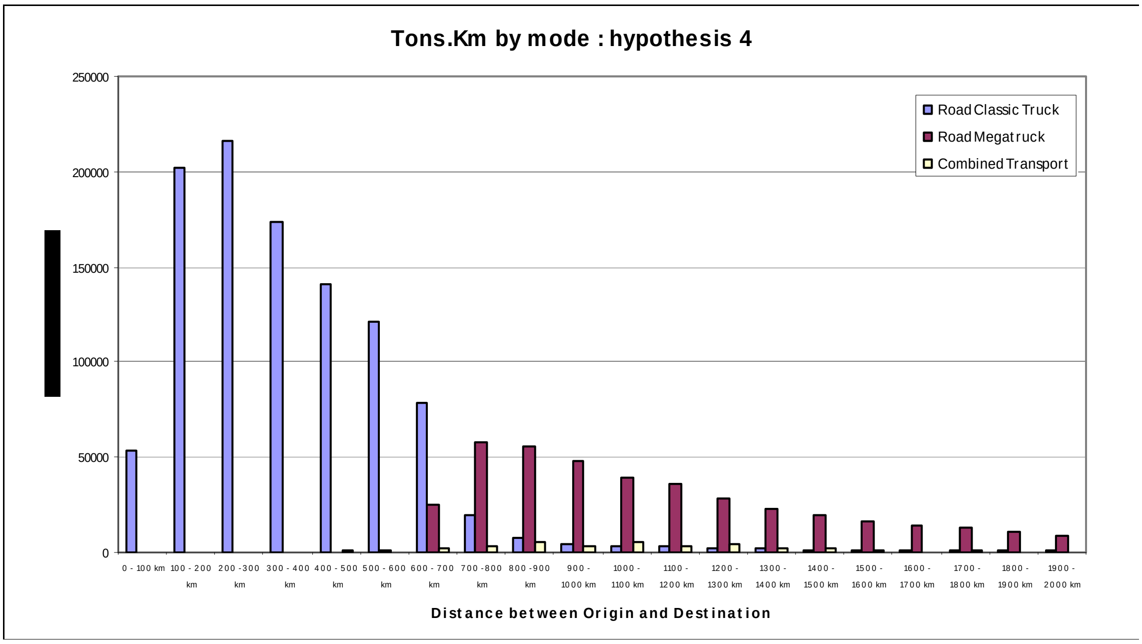
HYPOTHESIS 3:





TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely). The distance is terrestrial: it does not take into account the ferries.

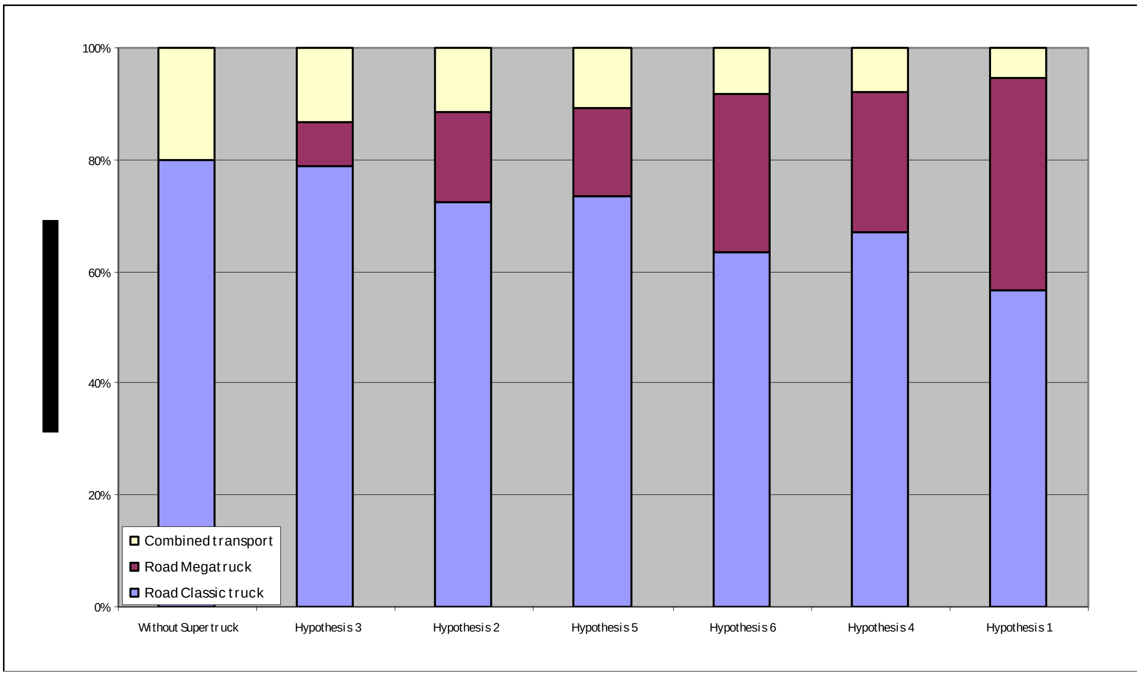
HYPOTHESIS 4:



TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely).The distance is terrestrial: it does not take into account the ferries.

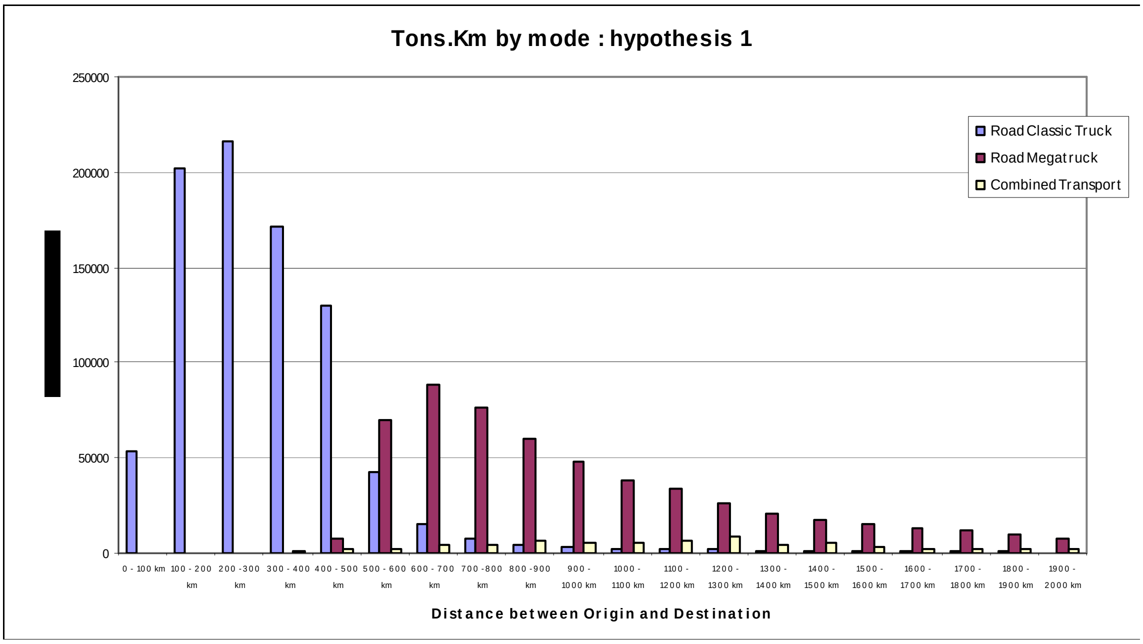
3. Detailed results for road – CT competition (sensitivity)

Performance 2020 (million tkm)	**Road HGV**	**Road Mega-Truck**	**Comb. Transp.**	**TOTAL**	**Share HGV (%)**	**Share Mega-Truck (%)**	**Share Comb. tr. (%)**
Without Mega-Trucks	1 231	0	307	1 538	80	0	20
Hypothesis 3	1 199	118	203	1 519	79	7,8	13,3
Hypothesis 2	1 098	248	174	1 520	72	16,3	11,5
Hypothesis 5	1 119	237	165	1 521	74	15,6	10,8
Hypothesis 6	967	430	126	1 523	63	28,2	8,3
Hypothesis 4	1 023	381	119	1 524	67	25,0	7,8
Hypothesis 1	864	584	80	1 527	57	38,2	5,2



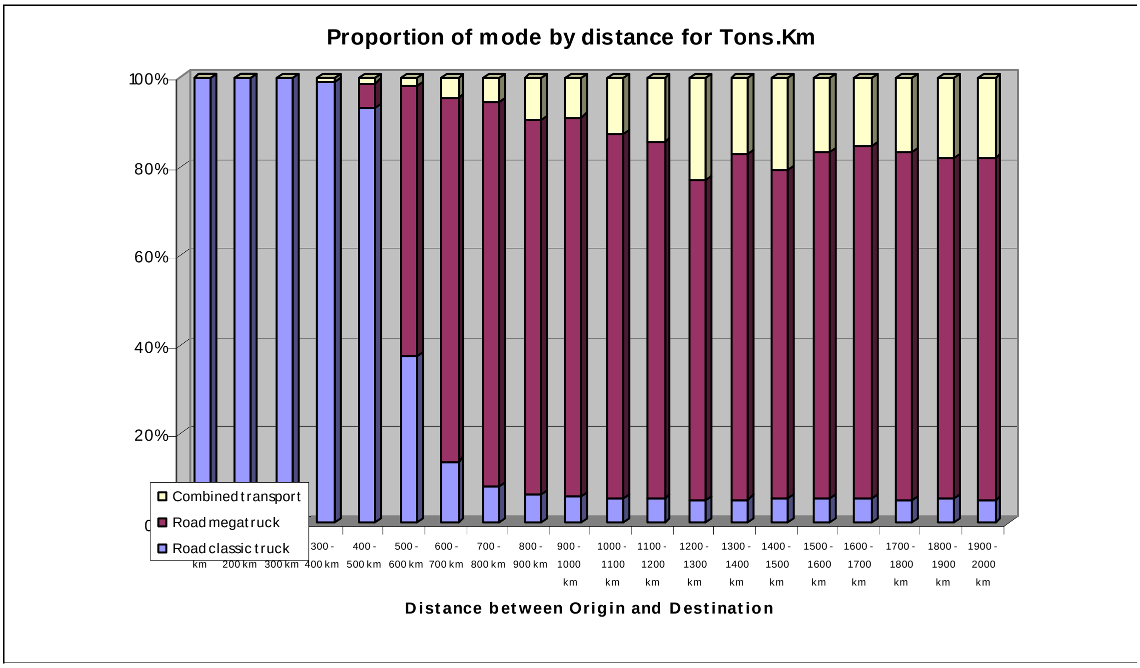
PROPORTION OF TK by mode (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely)

HYPOTHESIS 1:

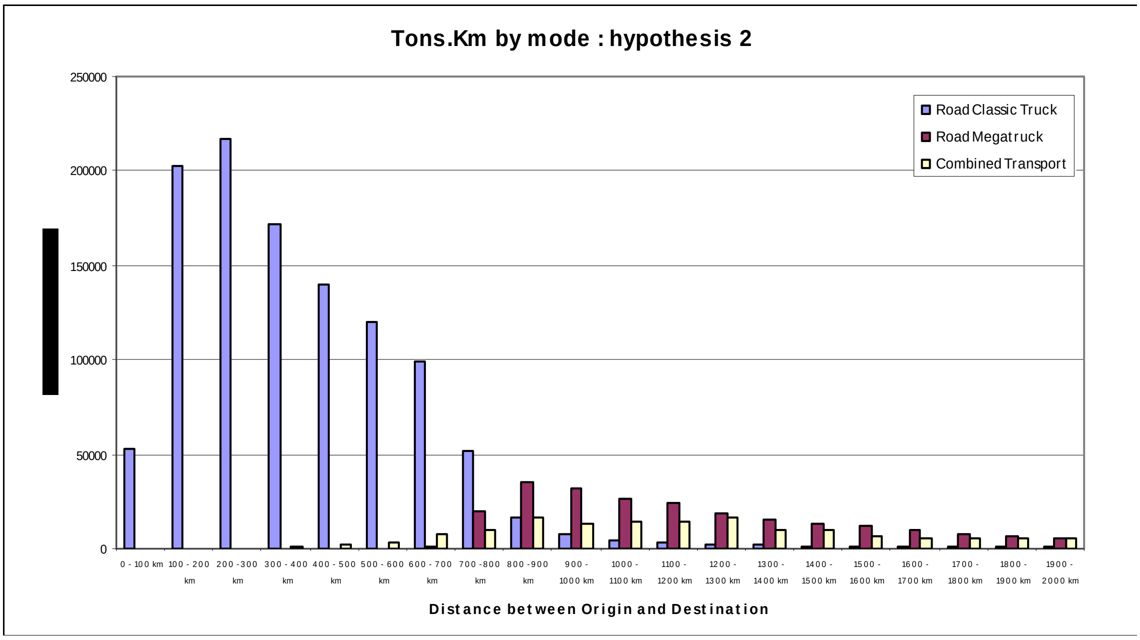


TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely)

The distance is terrestrial: it does not take into account the ferries

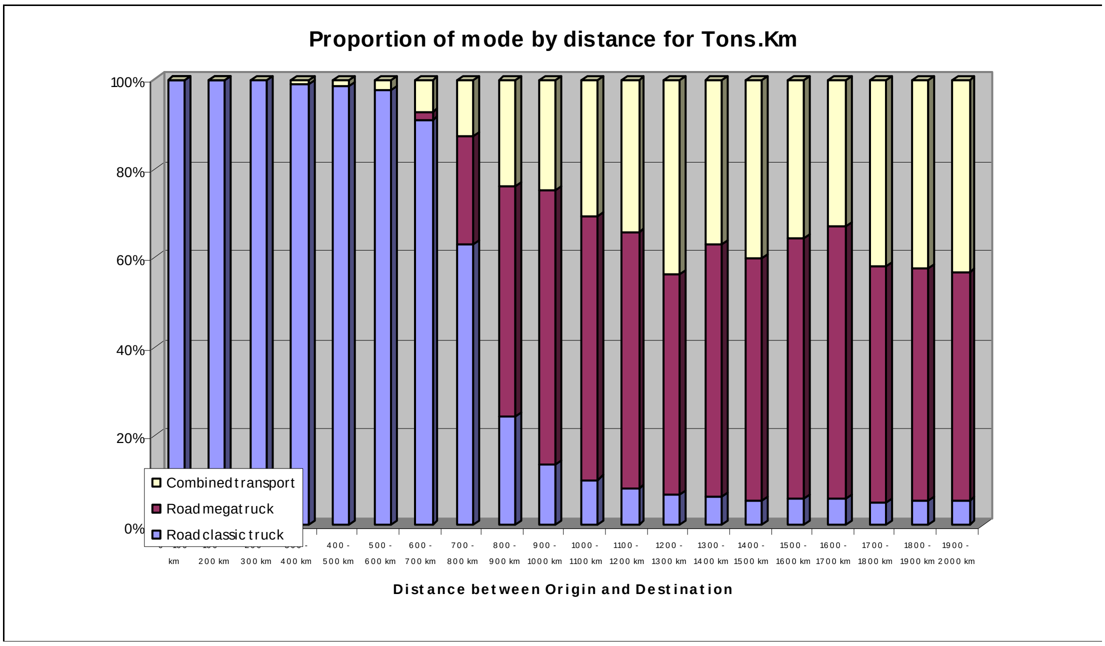


HYPOTHESIS 2:

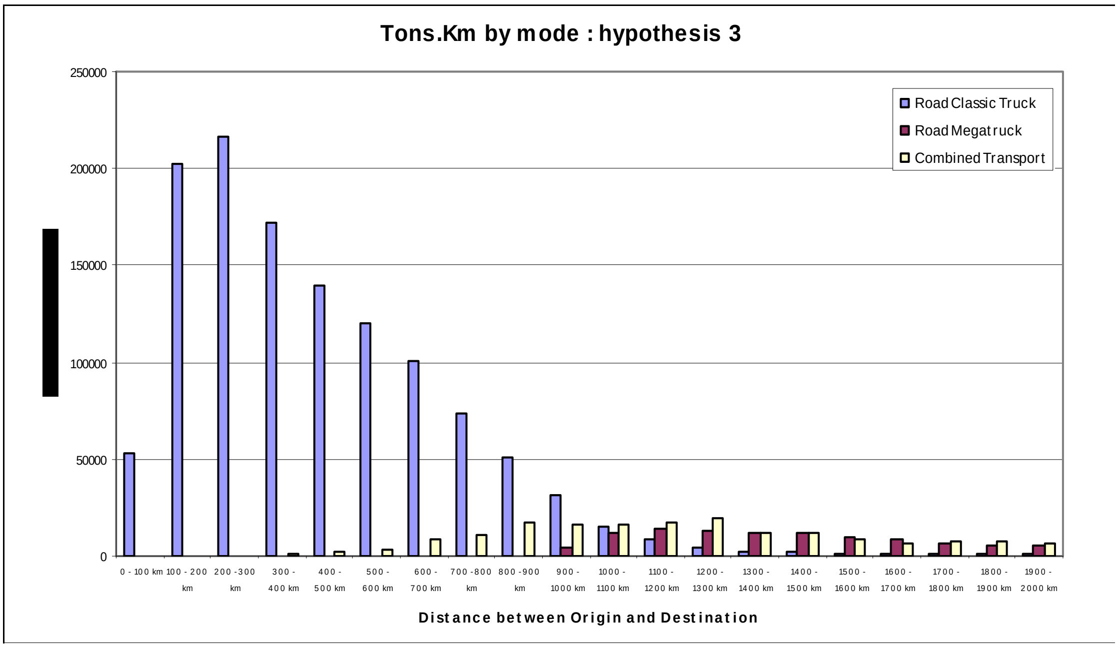


TK by mode and distance (included post and pre shipment in classic truck or megatruck for combined transport, a shipment by megatruck is possible but very likely)

The distance is terrestrial: it does not take into account the ferries

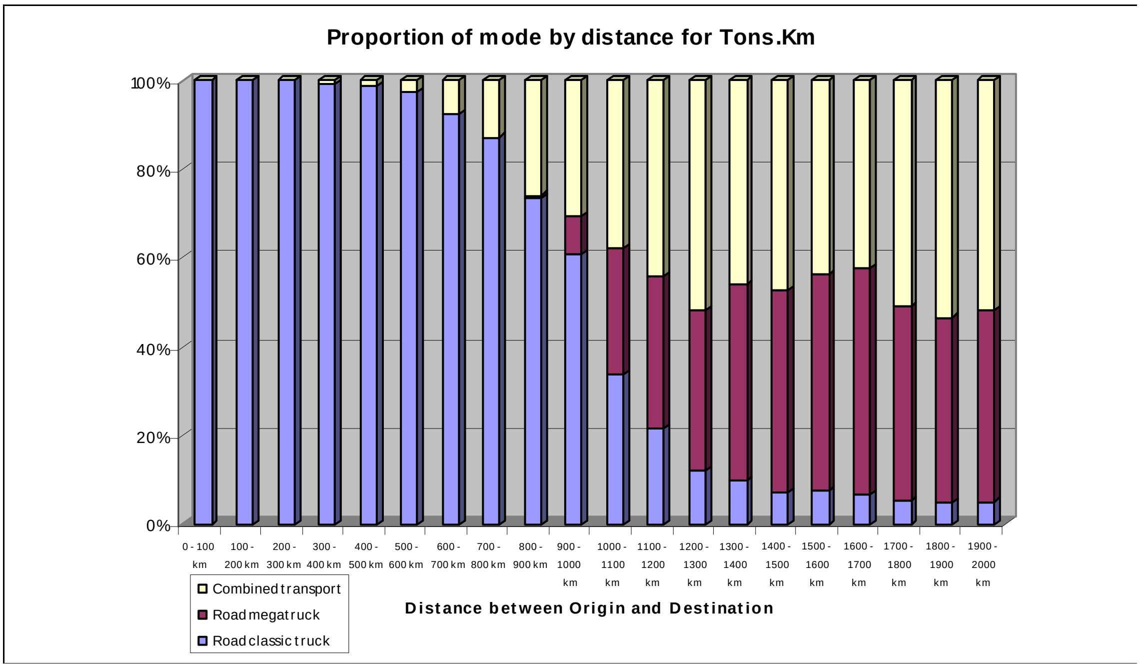


HYPOTHESIS 3:

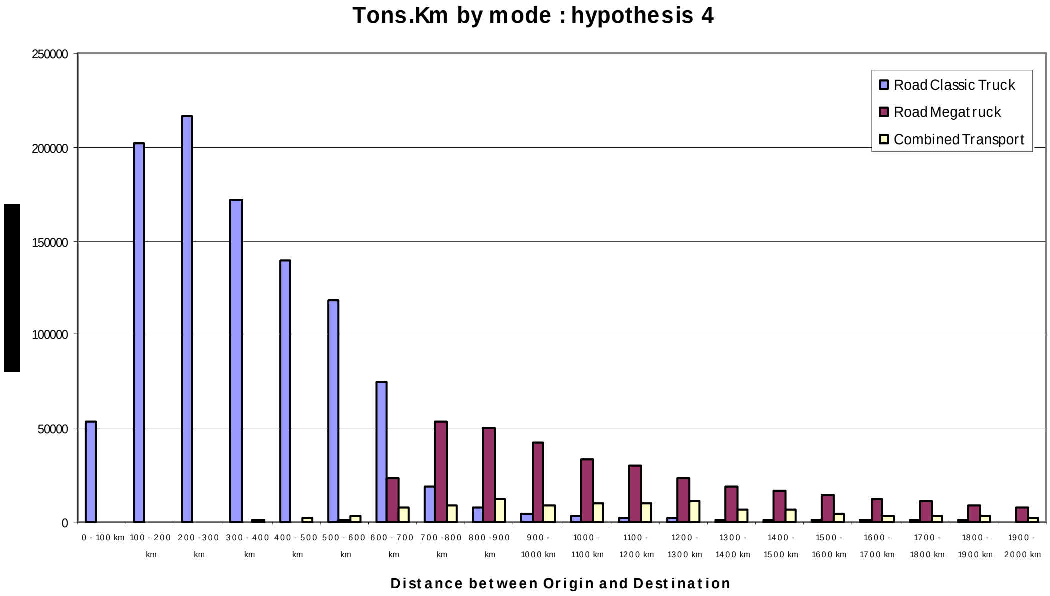


TK by mode and distance (included post and pre shipment in classic truck or Mega-Truck for combined transport, a shipment by Mega-Truck is possible but not very likely)

The distance is overland: it does not take into account ferries

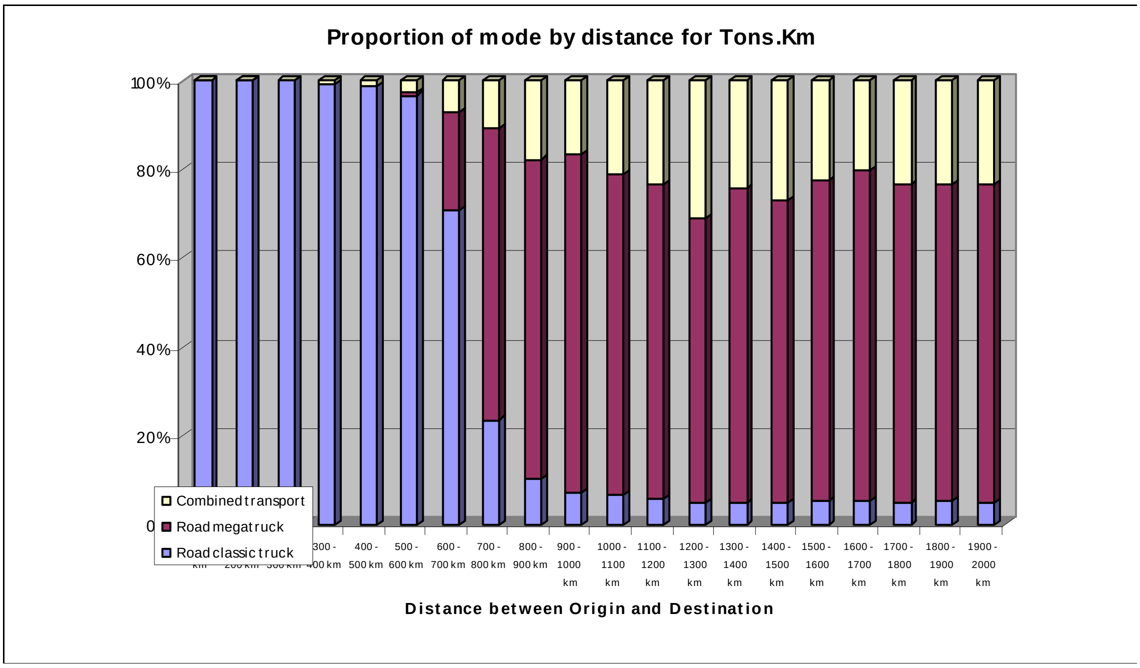


HYPOTHESIS 4:

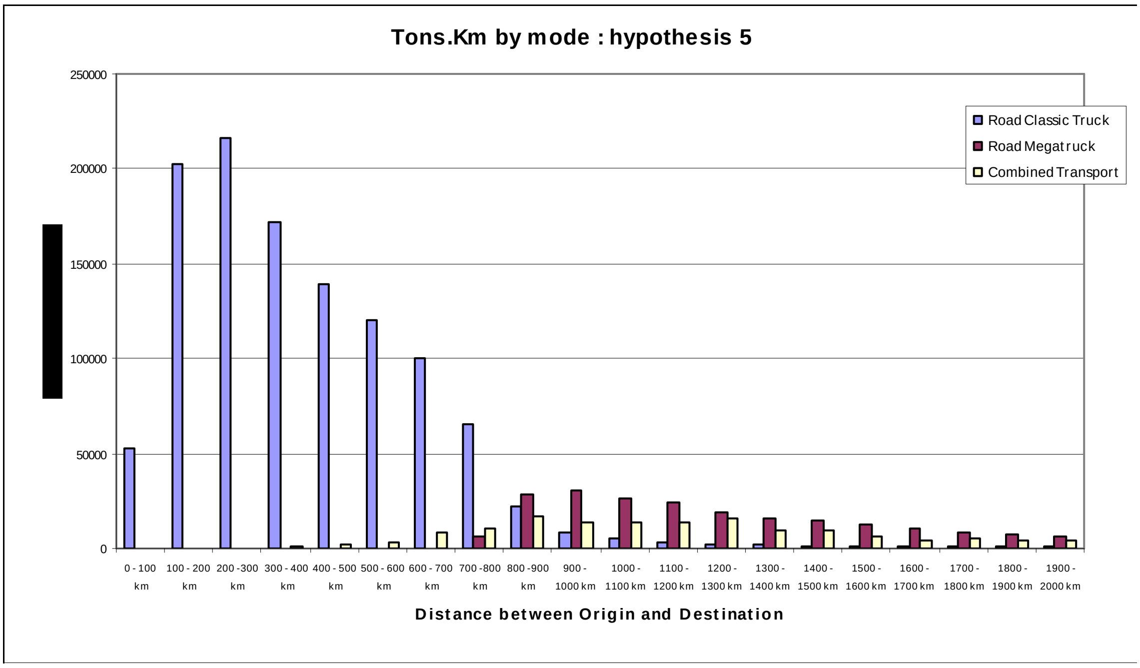


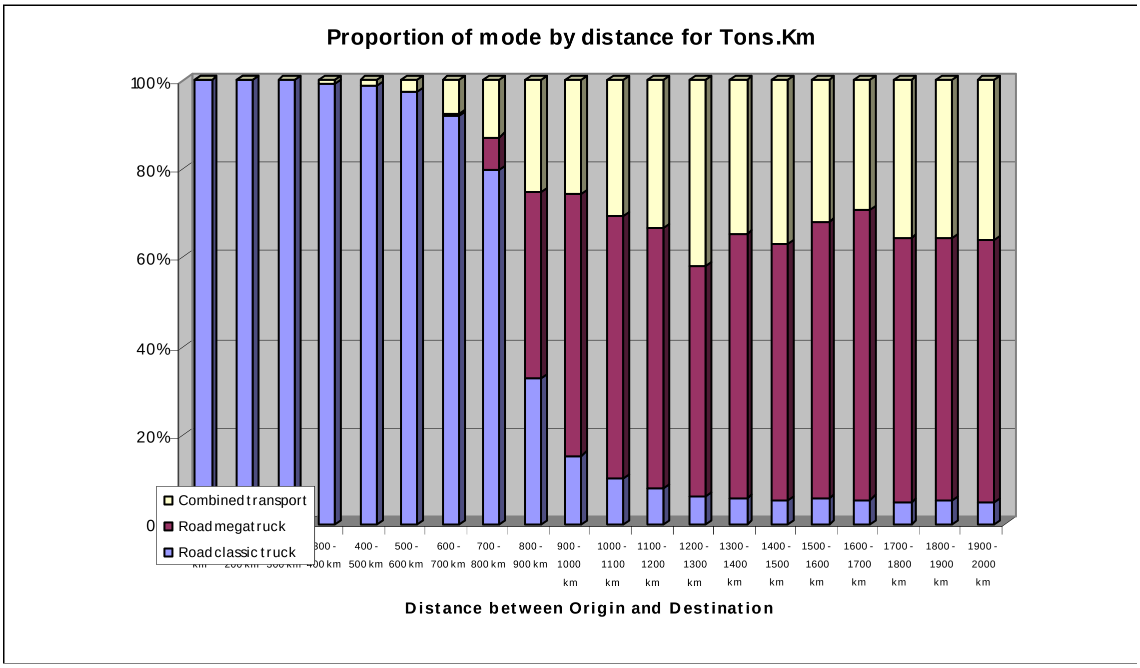
TK by mode and distance (included post and pre shipment in classic truck or Mega-Truck for combined transport, a shipment by Mega-Truck is possible but not very likely)

The distance is overland: it does not take into account ferries



HYPOTHESIS 5:





HYPOTHESIS 6: