

Economical and Ecological Comparison of Transport Modes: Road, Railways, Inland Waterways

Summary of Findings



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1 Introduction

Available studies and publications comparing the transport modes under the perspective of transport economics and of ecology are generally neither comprehensive nor sufficiently differentiated regarding the system of inland shipping and waterways. Due to unrealistic assumptions the relative position of inland shipping is not assessed adequately. Based on an initiative of the Association of European Inland Shipping and Waterways (Verein für europäische Binnenschifffahrt und Wasserstraßen VBW) the German Federal Water and Shipping Administration (WSV), represented by the Water and Shipping Directorate East, has commissioned this study. The aim of the study is to present an up-to-date comparison of transport modes which is sufficiently differentiated and substantiated. Main results are presented in this summary.

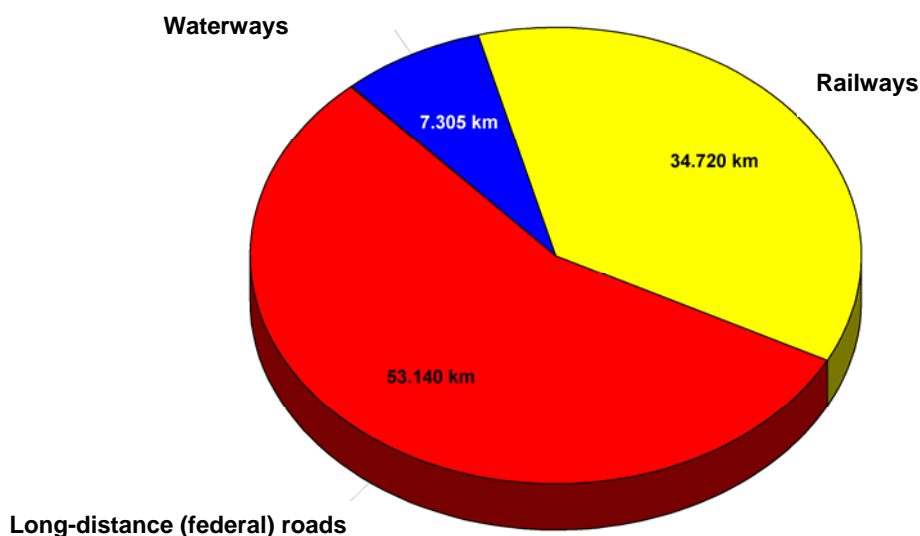
2 Infrastructure Networks

A high-quality transport infrastructure is conditional to a well functioning economy and society. It determines the competitiveness of production locations, the quality of life and general well-being.

2.1 Current Infrastructure Networks, Their Quality, Investments and Costs

The total length of inland waterways is significantly smaller than that of roads or railways. The length of the railway network is five times that of inland waterways. The factor for long-distance roads (federal highways and roads only) is more than seven.

Figure 1: Total Length of Transport Networks in Germany (2004)



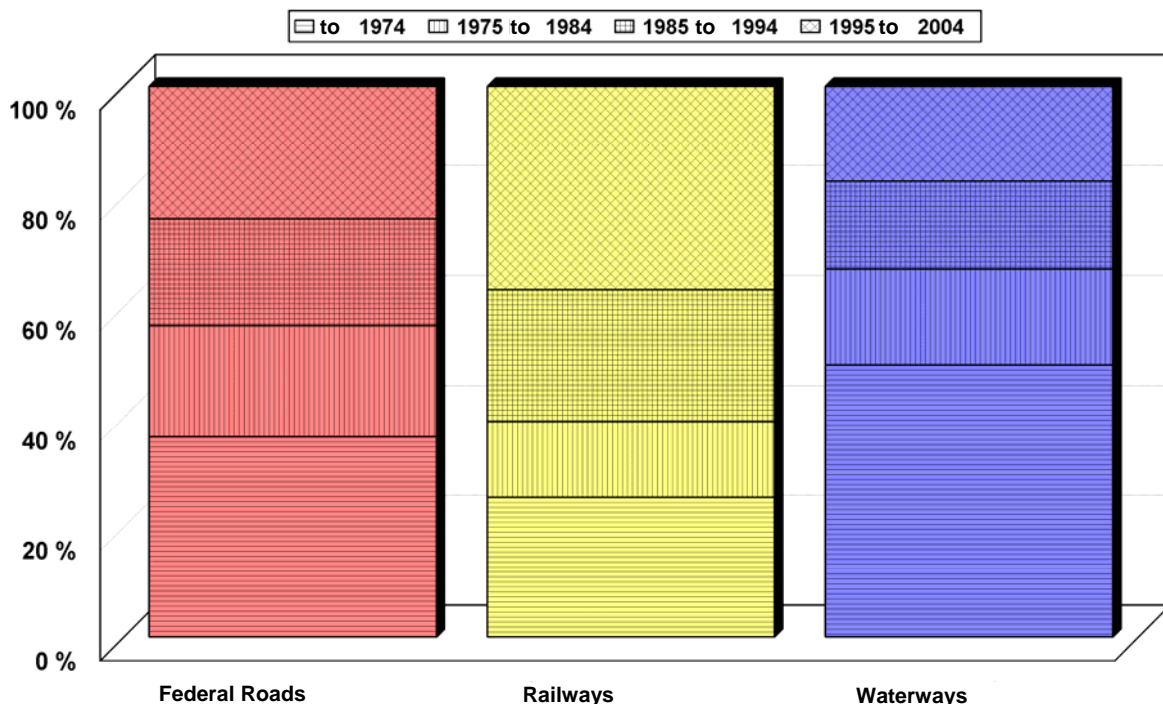
For all three modal networks new sections were added in past decades, and existing sections have been improved. In the period 1991 to 2004, the total length of the inland water-

ways with international significance (waterway classes IV and higher) was extended to 5.073 km (by 340 km). To a similar extent, the length of lower-class waterways was reduced.

The quality of the railway network benefited from additional lanes and progressing electrification. The long-distance road network was improved by introducing both further sections and additional lanes.

Total gross investments into waterways were not only far lower than for roads and railways, but also developed at lower growth rates: While the total growth of investments in the period 1991 to 2004 was +12.4% for waterways (coastal and inland), it was +32.4% for railways and +38.4% for long-distance roads. As a consequence the age structure of waterways is clearly less favourable than of railways and roads. There is a risk that this quality disadvantage impacts intermodal competition to the disadvantage of waterways. Where this quality disadvantage affects operational safety, negative consequences for waterways transport can be significant: While road transport can often shift to other routes, such alternatives are usually not available for waterways.

Figure 2: Gross Value of Infrastructure Networks of Waterways, Railways and Federal Roads in 2004, by Years of Investments



By confronting the expenditure with the respective revenues for the use of federal roads, railways and waterways, the degree of cost recovery can be shown. These figures give an indication on the implementation of the user-pays principle. But they do not allow to assess the economical profitability. Detailed calculations for the year 1987 for freight transport

show that for all three inland modes only part of the infrastructure cost is recovered. The value of unrecovered costs, per 1,000 ton-km, was € 11.53 for inland shipping. This is significantly better than for rail transport (€ 41.80).

Percentage-wise, road freight transport had the highest cost recovery ratio in 1987 (56.3%). For railways and waterways, respective ratios were 13.7% and 8.5%. More recent figures are not available. It is to be assumed that the cost recovery ratio for road freight has further improved due to the step-wise increase of fuel taxes (as part of ecological taxation) and due to the introduction of a truck toll on highways. In this context it is important to note that, different from other modes, waterways have significant non-transport-related functions and benefits.

Furthermore, infrastructure costs represent only a fraction of total social costs which are more relevant for defining optimum user charges which achieve the highest social welfare. To give an example: The social costs of road accidents alone in Germany clearly exceed total infrastructure costs of inland waterways.

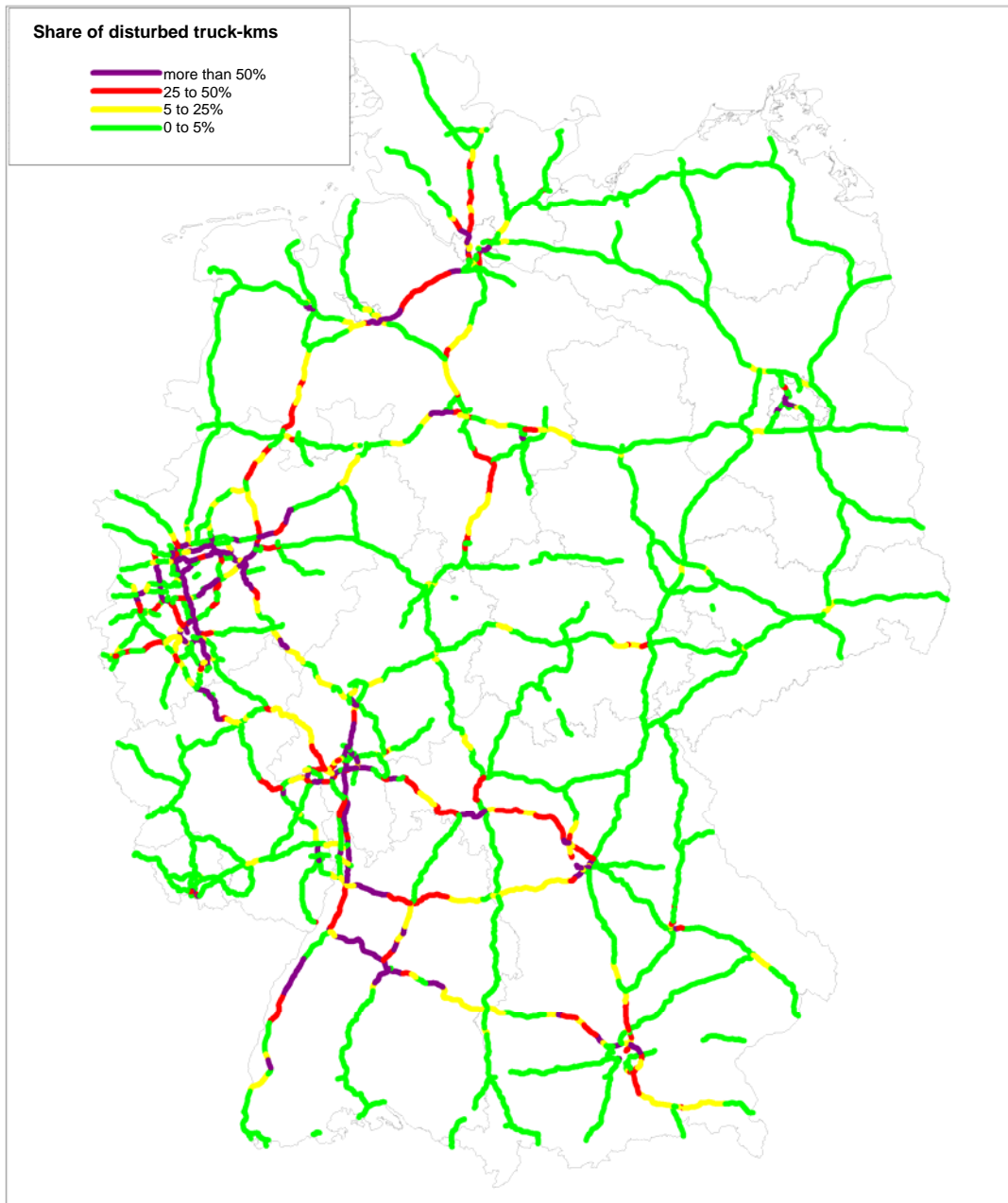
2.2 Capacity Utilisation of Infrastructure

Over past thirty years, both passenger and freight transport increased significantly in Germany. Traffic volumes on federal roads experienced the highest growth rates. Forecasts prepared for the Federal Transport Infrastructure Plan of 2003 (BVWP 2003) show a clear further growth of traffic volumes. Therefore, the issue becomes ever more important, whether and to which extent the different transport modes can absorb additional traffic loads.

Federal Roads

Traffic loads on many sections of German highways have reached a level which does not allow undisturbed flows. In 2005, 1,050 km of highways showed bottlenecks leading to significant disturbances of truck movements. Most affected highways are in the agglomerations of Hamburg, Berlin, Rhine-Ruhr, Frankfurt and Munich, furthermore the A1 (Hamburg-Bremen and long sections of its continuation to Cologne), A5 south of Gießen, A3 (section Frankfurt to Nürnberg), A6 (Heidelberg to Nürnberg) and A8 (section Karlsruhe to Munich) – see mauve and red sections in the figure below.

Figure 3: Intensity of Traffic Disturbances for Trucks on German Highways in 2005



Over the next decade, similar growth rates of traffic loads on German highways are expected as during last 10 years. Therefore, a general improvement of traffic conditions may not be expected. On the contrary, a further deterioration at large sections of the highway network must be assumed, even if further network extensions and improvements as planned according to the BVWP 2003 are taken into consideration.

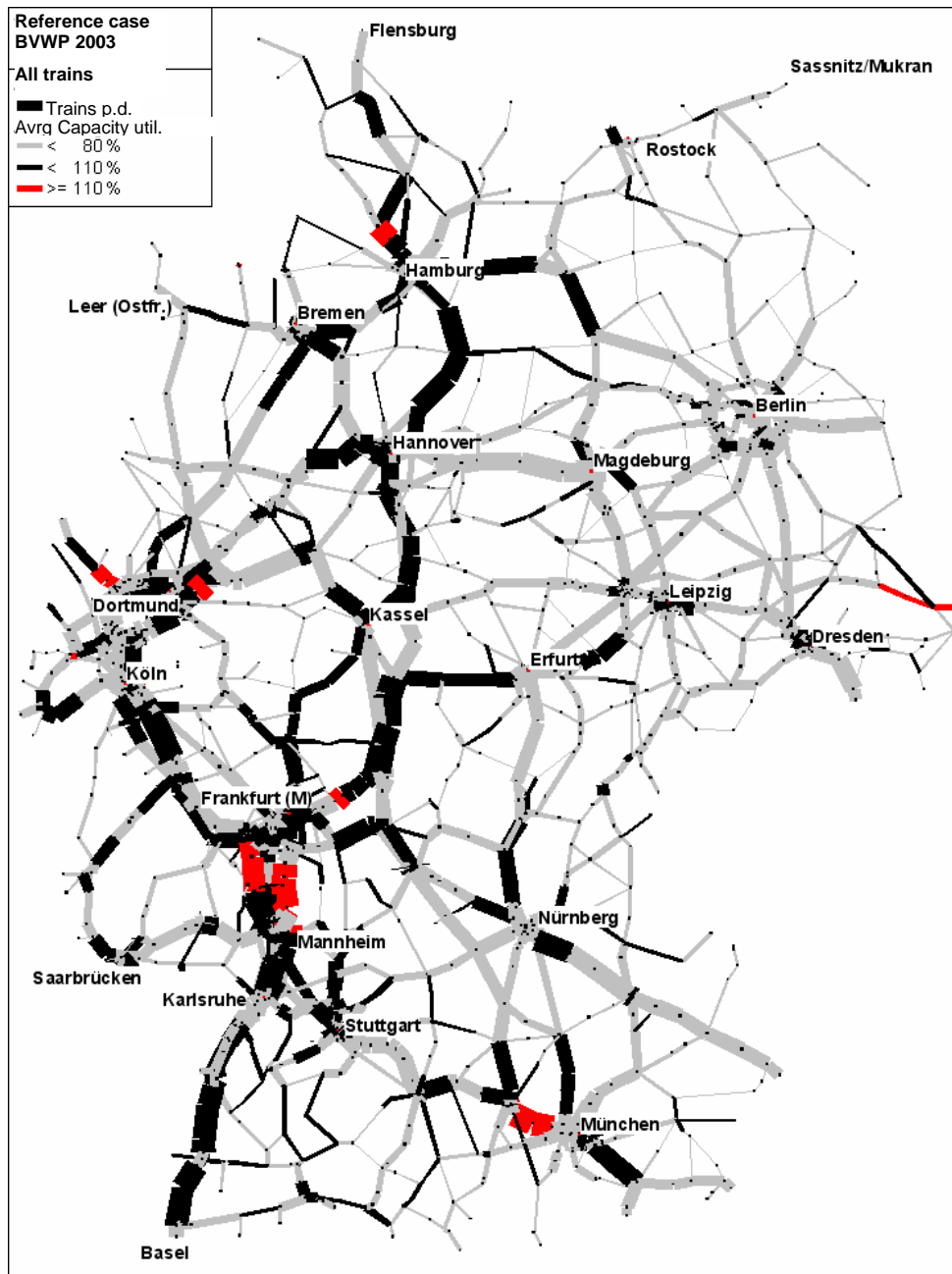
Railway Network

On the railway network, too, freight transport is not undisturbed. According to information from the Network Council of DB Netz AG, of May 2007, critical sections exist e.g. on the lines Hamburg - Hannover, Karlsruhe – Basel, and Emmerich – Duisburg. Furthermore, many nodes are overloaded. This conclusion is in line with results of an enterprises survey arranged by the Association of German Transport Companies: Alone in the long-distance network and in metropolitan regions the DB-AG network includes 53 sections where capacities are overloaded. Overstrained nodes include Bremen, Hamburg, Hannover, Hamm, Cologne, Frankfurt (Main), Leipzig, Nürnberg/Fürth and Munich.

Currently planned network extensions and capacity improvements according to BVWP 2003 will relieve a number of overloaded sections. But even on the major routes, a high number of sections will remain with capacity utilisation rates between 80 and 110 %, with negative impacts on freight trains. For the latter, current plans do not include any network extensions or improvements.

Transit times for freight trains start to grow progressively due to extended waiting times, if capacity utilisation rates exceed 80%. Utilisation rates between 80 and 110% of nominal capacities therefore indicate a low service quality. For example, transit time at a utilisation rate of 95% is by 20% longer than for a route with a low capacity utilisation level.

Figure 4: Traffic Load and Capacity Utilisation of the German Railway Network in 2015 According to BVWP 2003 (Reference Case without New Investments)



Federal Inland Waterways

Contrary to roads and railways, inland waterways have significant reserve capacities in all major corridors. According to recent calculations, this applies not only for the current situation, but also for 2015, with due consideration of expected increases in traffic volumes. Of 21 analysed locks, the lock of Lauenburg at the Elbe-Lübeck Canal had the lowest reserve capacity based on traffic volumes of 2005. But even this reserve capacity (of + 2.5 million freight tonnes) would allow an increase of traffic volumes by a factor of 5.

Table 1: Reserve Capacities of Inland Waterway Locks in 2015 for the Major Transport Direction (million tons p.y.)

Waterway	Lock	Transport volume 2005	Effective capacity 2015	Capacity reserve 2015 compared to volume in 2005
Wesel-Datteln Canal WDK	Friedrichsfeld	10,3	17,7	7,4
Rhein-Herne Canal RHK	Oberhausen	8,5	35,9	27,4
Dortmund-Ems Canal DEK	Münster	5,9	22,5	16,6
Datteln-Hamm Canal DHK	Hamm	0,6	5,3	4,7
Mittellandkanal MLK	Anderten	7,1	17,2	10,1
Weser	Minden	1,3	8,5	7,2
Küstenkanal	Dörpen	2,4	6,1	3,7
Elbe-Seiten-Kanal	Lüneburg	6	13,6	7,6
Elbe-Lübeck-Kanal	Lauenburg	0,5	3,1	2,6
Main	Kostheim	12,4	27,1	14,6
Main	Obernau	4,7	14,9	10,2
Main-Donau Canal MDK	Kelheim	3,4	11,5	8,1
Donau	Jochenstein	4	12,9	8,9
Neckar	Feudenheim	5,6	22,4	16,8
Mosel	Koblenz	8,9	29,2	20,3
Elbe	Geesthacht	6,6	17,0	10,4
Elbe-Havel Canal EHK	Hohenwarthe	1,9	17,3	15,4
Untere Havel Waterway UHW	Brandenburg	2,2	33,8	31,6
Spree-Oder Waterway SOW	Charlottenburg	0,5	6,1	5,6
Teltowkanal TeK	Kleinmachnow	0,6	8,9	8,3
Havel-Oder Canal HOW	Spandau	1,6	8,3	6,7

3 Taxation

Over past years, taxable bases and tax rates were modified repeatedly in Europe, without EU-wide coordination. Regulations concerning tax exemption and taxation preferences were introduced, often against the background of economical or international policy considerations.

In freight transport, competition disparities for German companies competing internationally are caused by different social insurance contributions, motor vehicles tax rates and specific subsidies (particularly for fuel). Dutch tax regulations are generally more favourable than the German ones. For example, the German motor vehicle tax is double the Dutch one, fuel tax is 11 Cents higher. As a result, in Germany the annual tax load for a 40-tons truck performing 135,000 km p.y. is 30% higher than in the Netherlands.

Similarly, for rail freight transport, German companies are disadvantaged compared to their Dutch competitors. While in Germany the full fuel tax is charged, Dutch railway operators are fully exempted from this tax. Similar disparities at the European level exist for electricity taxation.

For inland shipping, too, German companies are burdened with competition distortions at the European level. Numerous taxation and financing privileges helped companies in the Netherlands and in Belgium over the 90s to modernise their vessel fleets significantly faster than their German competitors, leading to a major advantage in market strength.

German Railways often declare a competition disadvantage compared to inland shipping due to the latter's exemption from fuel charges. Indeed, in Germany 269,000 tons of tax-privileged diesel fuel were supplied to inland vessels. Compared to the normal tax of 47 €-Cents per litre, the total saving amounts to € 144 million. This corresponds to a competitive advantage of 0.22 €-Cents per ton-km.

This tax disadvantage of rail transport must be seen in the context of significantly higher differences in external costs. Comparative calculations (see chap. 6.6) show an average advantage of inland shipping compared to railways transport of €-Cent 0.85 per ton-km of bulk cargo. In other words, the difference in fuel taxation offsets only 25% of the opposite differences in external costs which would have to be charged according to the user-pays principle.

4 Transport Volumes and Forecasts

Current forecasts indicate a further significant growth for freight traffic volumes in Germany. For example, the German Federal Transport Infrastructure Plan (BVWP) 2003 is based on an expected increase of freight transport performance (ton-km) in Germany by 63% in the period 1997 to 2015 (does not include short-distance freight). High increases are foreseen for international freight. While domestic performance will grow by 34%, cross-border performance, including transit, will almost double (+97%).

For inland shipping only cross-border freight is expected to grow (+61%), while domestic freight will slightly decline (by 4%). This will result in a growth of total performance by 44%.

Table 2: Development of Freight Transport Performance of Inland Shipping in Germany, 1997 to 2015

Transport Performance (bln. ton-km)	1997	2015	Change
Domestic	16,3	15,6	- 4 %
Cross-border	45,9	74,0	61 %
Total	62,2	89,6	44 %

Source: Transport Forecast 2015 for the German Federal Transport Investment Plan 2003

For road transport, recent years showed a high conformance with the forecast of BVWP 2003. Total traffic volumes in 2004 were just 3% below the forecast. A breakdown by commodity groups shows major deviations. Some commodities developed faster than expected (cereals and foodstuff, iron & steel & scrap metal, gravel and stones). Others developed slower, e.g. machinery & equipment, containers.

In rail freight, too, volumes of transported machinery & equipment as well as containers developed at slower rates than expected. 2004 volumes remained 10% below expectation. The same applies for bulk cargo. Higher-than-expected growth was noted for iron ores, for iron & steel & scrap metals, and for mineral oil products. Slower-than-expected developing products were cereals and animal foodstuffs, gravel and stones, chemical products and fertilisers.

Regarding inland shipping, similar as for railways, forecast volumes could not be reached generally. This is particularly true for bulk commodities such as mineral oils, iron ores, iron & steel & scrap metal, gravel & stones, chemical products and fertilisers. Minor differences occurred for cereals and animal feed. In contrast, coal transport in 2004 was significantly above expectations. Particularly for consumer goods, machinery & equipment and containers, inland shipping accounted for much higher increases than forecast (with a difference actual/forecast in 2004 of +32%).

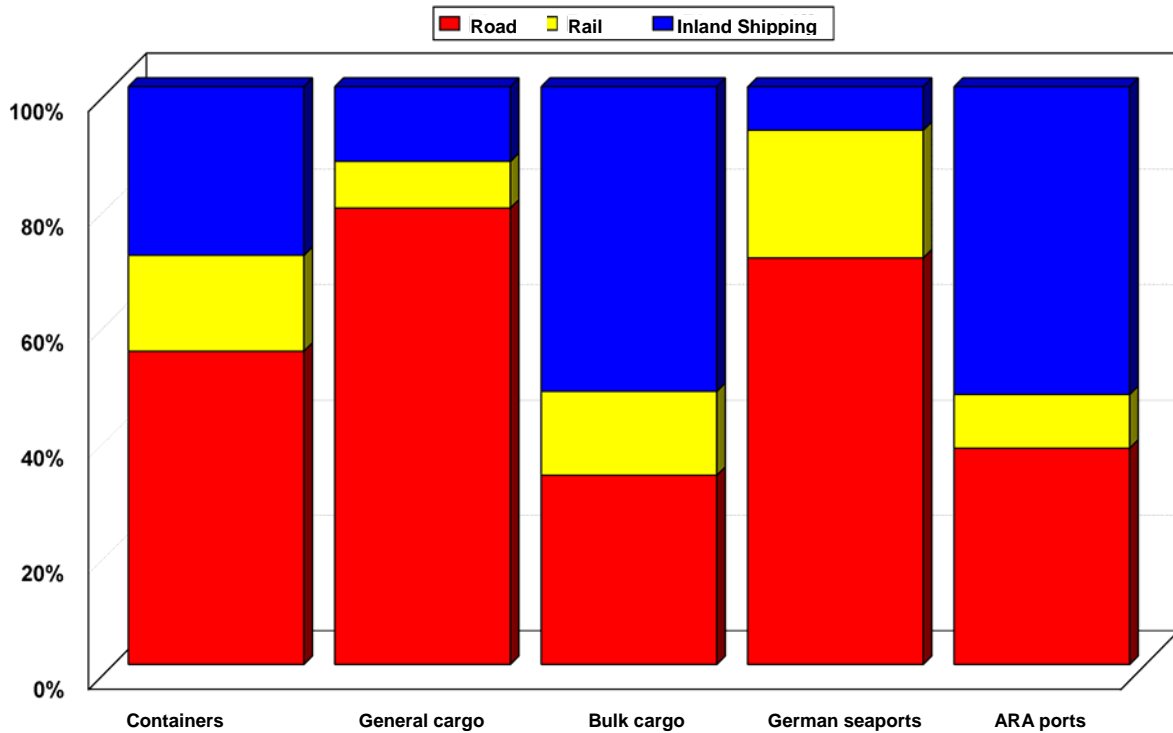
This demonstrates that inland shipping is not negatively affected by commodity composition of freight transport, as was expected some years ago. On the contrary, the development was much better, e.g. in the container market, than forecast – different from competing modes where real figures did not meet expectations.

Seaport hinterland transport, amounting to 130 million tons in 2004 is the most important market for inland shipping. Besides bulk cargo where inland shipping absorbs 53% of total volumes, container shipping has gained importance. In 2004 more than 29% of all containers to and from seaports were carried by inland vessels (road: 54%; rail: 16%).

In this market, the quality of waterways decides on the modal share of inland shipping. Transport relations linked excellently to the ARA ports (Amsterdam, Rotterdam, Antwerp) on the Rhine river provide much better chances for inland shipping than hinterland links to German seaports. As a consequence, inland shipping has gained a market share of 63%

(bulk cargo) resp. 49% (containers) in the hinterland regions of ARA ports, but only 19% resp. 2% in the hinterland regions of German seaports.

Figure 5: Modal Shares in Seaport Hinterland Transport 2004



An important segment for inland shipping is the transport of hazardous goods. Here, inland shipping being the safest transport mode has a prominent role. Particularly for highly flammable liquid goods - the leading commodity in this context - inland shipping absorbs the major part of the market.

Significant growth potentials for inland shipping, apart from containers, exist for imported coal. Continued price increases for oil combined with the termination of domestic coal mining are expected to generate +52 million tons (+52%) increase if seaport hinterland transport volumes of this commodity until 2030. Other segments with good perspectives for inland shipping include: passenger cars, scrap metals, and heavy lift cargo.

5 Energy Consumption

Current discussions on the environmental impacts of transport by different modes concentrate not only on traffic emissions, but also on energy consumption. Energy consumption is also relevant for estimating the amount of emissions.

Sound calculations of energy consumption by different transport modes must consider the specific conditions of transport. This includes: technical characteristics of vehicles, load factors of these vehicles, infrastructure characteristics and specific traffic conditions.

As an example, for road freight transport the traffic flow is decisive. According to complex model calculations, the average fuel consumption of trucks and truck-trailer combinations on German highways in 2005 was as follows:

- Unrestricted traffic flow: 29.2 litres per 100 km
- Medium level of traffic disturbances: 30.8 litres per 100 km
- Significant traffic disturbances: 31.8 litres per 100 km
- Stop and Go : 61.9 litres per 100 km

The transition to stop-and-go leads to a drastic increase in fuel consumption by trucks (more than double the consumption with free, unrestricted traffic flows).

As to the future development of diesel fuel consumption by **trucks/ truck-trailers**, several estimates have been prepared. In TREMOD 2005 it is assumed that heavy trucks will, on the average, reduce their specific energy consumption by 18% in the period 2002 to 2020. In contrast, the handbook on emission factors of road traffic, assumes a slight increase of energy consumption per vehicle-km for 2020 compared to 2005, averaging all road types and all traffic situations.

Aggregated values for the specific energy consumption in **railway freight transport** are available from various sources, for different definitions and dimensions. Specific conditions of different transport cases are not adequately reflected by such average figures. This is particularly relevant for purposes of comparison with inland shipping in bulk freight transport where applicable train weights are between 1,700 and 5,000 tons. Calculations of final energy consumption in railway freight transport, prepared in this study for selected origin-destination (OD) pairs (see chapter 7), used the programme package Train Check which allows to reflect conditions of specific transport cases. Such specific conditions include: technical specifications of locomotives, number of wagons per train, train length, train gross weight, ratio of net to gross train weight, and train speed. Furthermore, specific conditions of selected routes (e.g. topography) and number of stops can be considered.

As regards future specific energy consumption, TREMOD 2005 expects that new rolling stock will allow further savings. An average reduction by 1% per 5-years period is assumed averaging all types of trains and of operations. For the period 2005 to 2020 this corresponds to a total saving by 3%.

For **inland shipping**, too, it is essential to base energy consumption figures on differentiated calculations. Many publications have over-estimated these figures, particularly for bigger vessels. Such over-estimations are due to too simplified assumptions and averages. It is essential to base energy consumption calculations for inland shipping on realistic profiles of ship performance and velocity according to conditions of specific waterways.

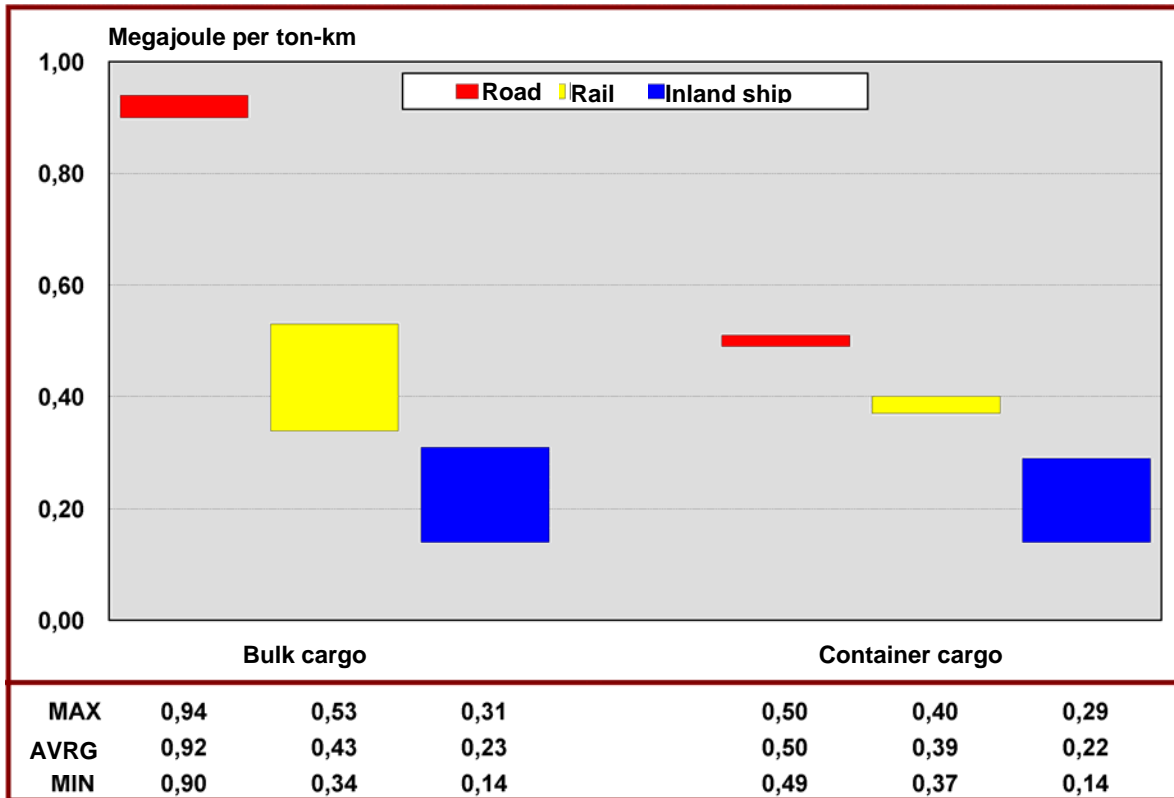
The interrelationship between energy input and vessel speed is reflected by a performance-speed diagram. A comparison of the *Big Motor Vessel* GMS (length 80-110m, width 11.45 m) with the vessel type *Johann Welker* (length 67-80m, width 8.2m) shows that the energy demand decreases for larger vessels, for a given draft, water depth and vessel speed. This is also valid for the specific energy consumption per freight ton.

Assuming a uniform vessel draft of 2.5m, the Big Motor Vessel carries 490 resp. 790 tons more than smaller vessels of Johann Welker resp. Gustav Koenigs types, while needing less energy. Thus, there is a multiple advantage of bigger vessels. If waterways allow a draft of more than 2.5 m, then the advantage of bigger to smaller vessels per freight ton increases further. The additional freight more than outweighs the required additional energy input.

Existing studies also underestimate the potential for future reductions of specific energy consumption in inland shipping. The future structural change of the vessel fleet alone (with growing shares of more energy-efficient Big Motor Vessels) will allow a reduction of specific energy consumption until 2025 by 9%.

According to such differentiated comparative calculations for selected routes (O-D pairs), today's inland shipping has the lowest specific energy consumption of three considered modes. On seven of eight selected bulk freight routes, and on all chosen container routes, inland ship transport has a lower energy consumption than railway transport. The highest energy consumption occurs generally with truck transport. The figure below demonstrates the spread by routes and the average values of primary energy consumption per ton-km.

Figure 6: Spread and Averages of Primary Energy Consumption on Selected Transport Relations



6 External Cost

External costs are defined as non-compensated impacts by transport agents on not involved third parties. 'External' means: the negatively affected third party receives no (no full) compensation. In the transport sector external effects occur in following fields:

- Transport safety,
- Noise,
- Climate gases,
- Air pollution,
- Landscape dissection and area consumption.

6.1 Transport Safety

Current discussions on the comparison of external costs in freight transport often neglect the social cost of traffic accidents fully, or they use too generalised basic data.

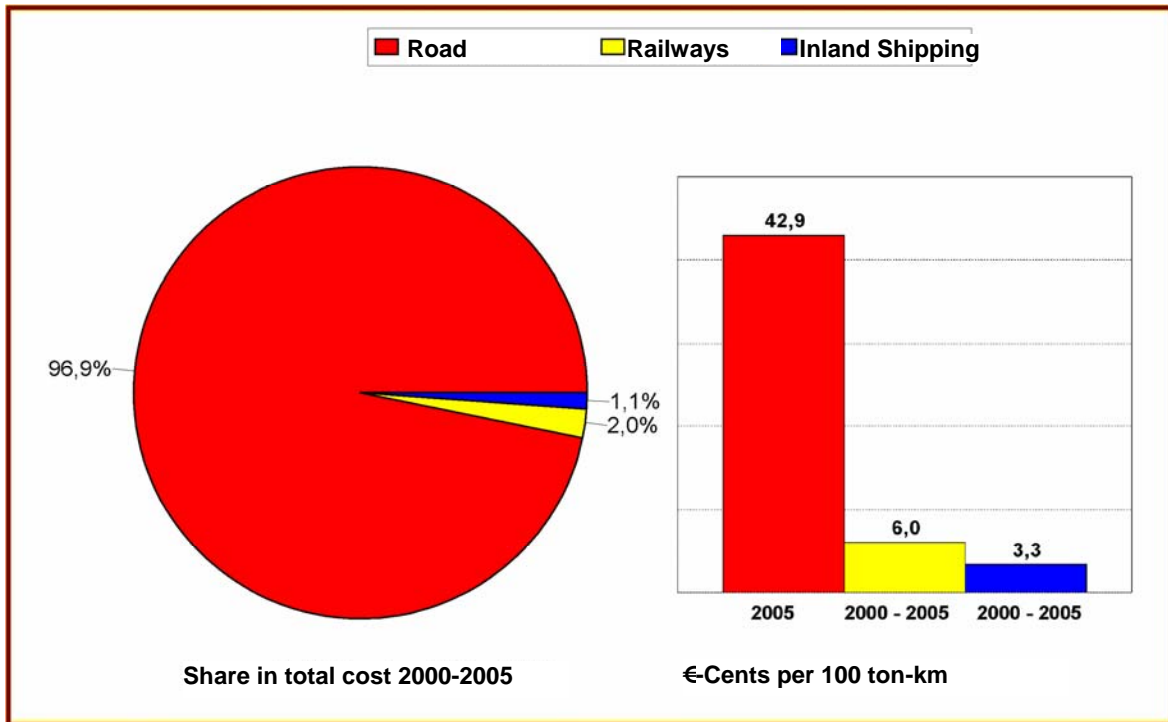
The calculations presented in this study are based on significantly improved data. When separating accidents which are due to freight transport, a uniform criterion has been applied: the involvement of freight vehicles. Calculations include all accidents on the transport infrastructure in Germany. Available statistics allowed comparative calculations for the years 2000 to 2005.

These analyses and calculations confirm the position of inland shipping as the safest transport mode compared to road and railways. On the average, in the years 2000 to 2005 accidents with the involvement of freight vessels caused 0.04 death cases. For railway freight, the comparative figure is 0.28, and 2.48 for road freight

Of all economic costs caused in Germany by freight transport accidents in the period 2000 to 2005, 96.9% are due to trucks, 2.0% to railways and 1.1% to inland shipping.

The specific economic accident cost per 100 domestic ton-km is €Cents 42.9 for road freight (2005), 6.0 for railway freight (average 2000-2005) and 3.3 for inland shipping (average 2000-2005). Unit accident costs of road freight transport exceed those of inland shipping by a factor of 13; those of railway freight are 80% higher than for inland shipping.

Figure 7: Total and Unit Economic Costs of Accidents in Freight Transport on Road, Rail and Inland Waterways



6.2 Traffic Noise

Freight transport on roads, railways and inland waterways causes noise emissions which affect populations in adjacent areas. The level of emissions responsible for that immission load varies significantly among trucks, trains and inland vessels.

The difference of noise emissions per unit of freight, between road and rail, measured along road resp. railway lines is only small. Inland shipping causes only lower emissions, with a difference of -10 dB(A). This difference represents 50% lower immission loads as perceived by people.

These differences of noise loads on population caused by the different transport modes are further accentuated by different physical characteristics of traffic infrastructure. For example, on the edge of railway lines, the immission load per freight unit exceeds the one on the edge of waterways by more than 15 dB(A). The difference between highways and waterways is 12 dB(A).

In accordance with the lower level of noise emissions and immissions caused by inland shipping, the maximum immission levels stipulated by the 16th Federal Regulation on Immission Protection for Roads and Railways can be observed by inland shipping with no further protection measures – contrary to roads and railways.

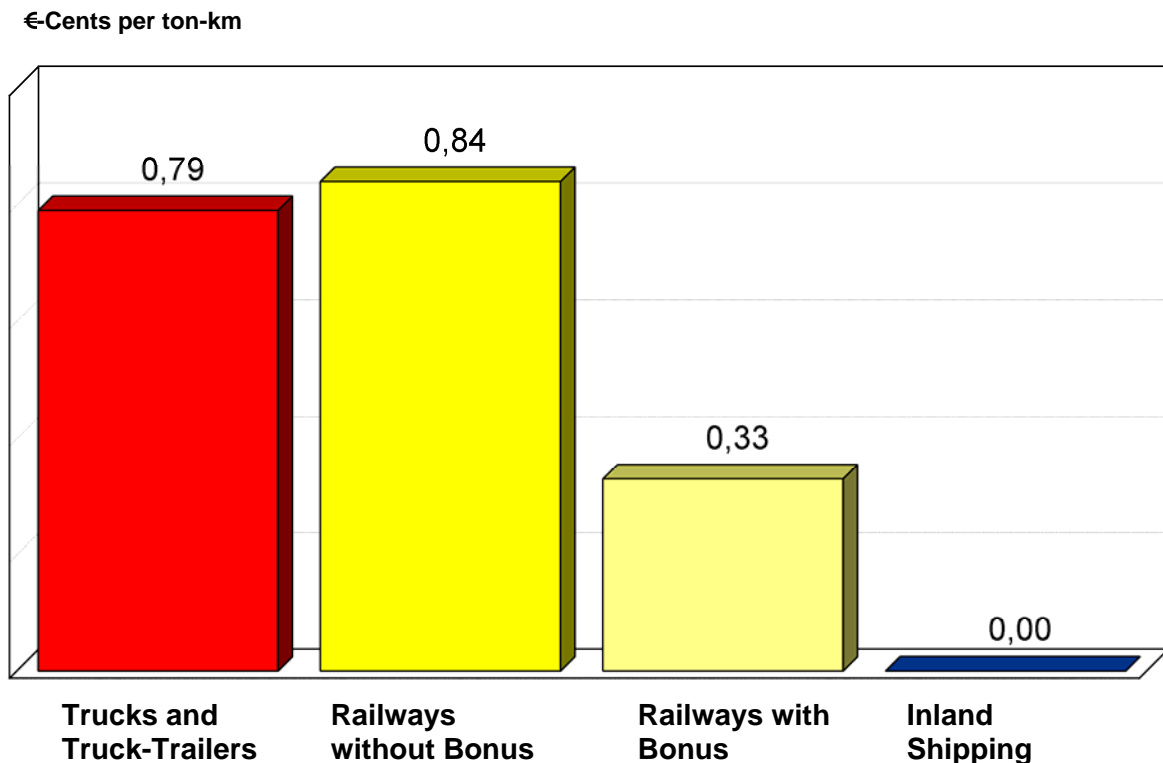
A first step to identify the external costs of traffic noise is to quantify the number of affected people. Based on the regular national survey INFRAS 2007, the Federal Environmental

Agency (Umweltbundesamt) has made such calculations for road and railway traffic in 2005, broken down by different noise classes. Inland shipping was not seen as a relevant noise polluter which conforms to the results briefly presented in the paragraphs above.

To evaluate the negative impact of noise on the affected populations, the INFRAS report analyses various studies on the willingness to pay, of the affected people, for reducing noise levels. The report also considers the increased risk of heart attacks and of treating cardiovascular diseases due to continued exposition to noise. Combined with the number of affected people, INFRAS arrives at average costs of noise per tonne-km of €-Cents 0.79 for trucks and 0.33 for railways.

INFRAS justifies this lower level of noise costs of railways compared to road transport also by an assumed lower subjective nuisance level of the same average level of physical immission from railways compared to noise from road traffic. The standard practice is to assign to railways a bonus of 5 dB(A). Independently from a scientific justification of that bonus it may be discussed whether the bonus can be justified for an evaluation based on a population survey. This survey of the Federal Environmental Survey identifies that part of the population which feels disturbed or heavily disturbed by road resp. railway noise. Differences in subjective nuisance levels are therefore already accounted for. To introduce an additional bonus for railways means that differences in subjective nuisance levels are incorrectly considered twice. If this bonus is excluded, the average external noise costs of freight transport on railways is €-Cents 0.84 per ton-km.

Figure 8: Average External Costs of Traffic Noise



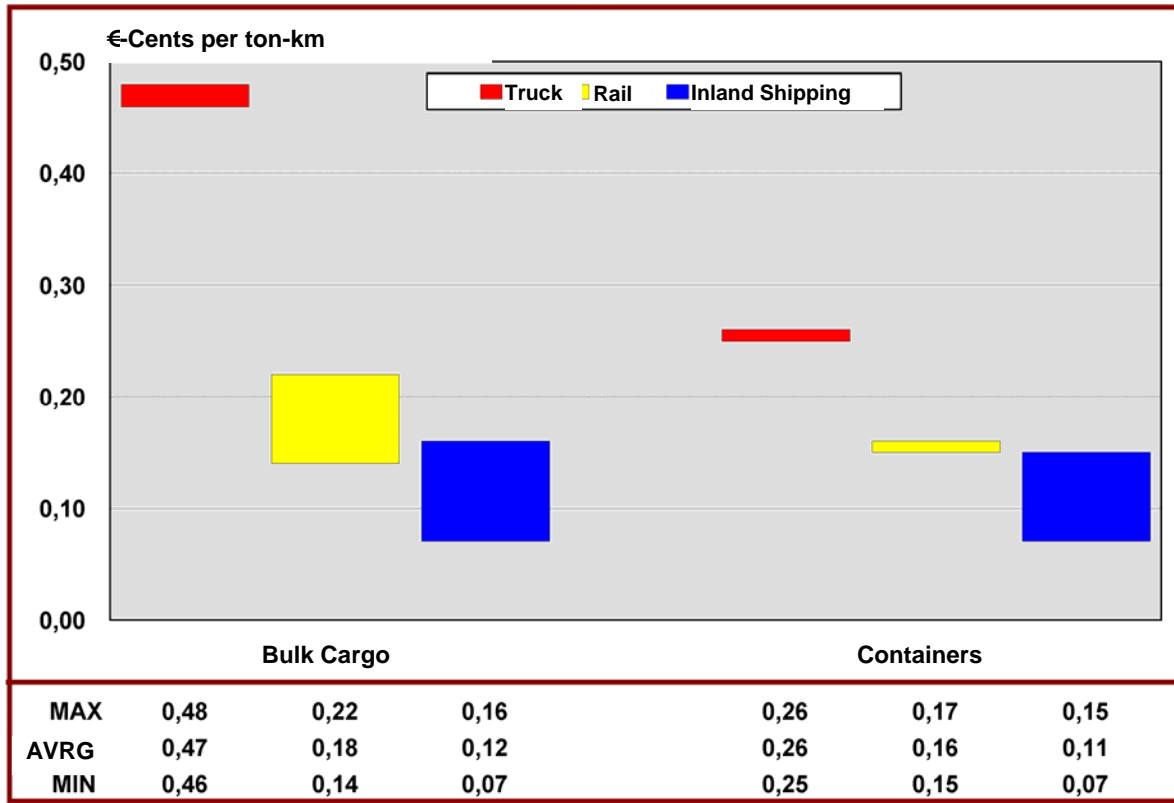
6.3 Climate Gases

The amount of CO₂ emissions which are particularly relevant for climate change can be directly derived from the amount of energy consumption. These emissions result from burning of fuel by motors of trucks, diesel locomotives and inland vessels. For electrical locomotives, emissions are caused by corresponding power generation. The lowest CO₂ emissions per unit of energy occur with electrical trains. Their future development depends on the structure of primary energy used for electricity generation. As regards trucks and inland ships, future emissions depend on the development of specific fuel input.

The monetary evaluation of the cost of climate change caused by CO₂ emissions is quite uncertain. This uncertainty refers to the further trend of climate change and to the (economic) impacts of such change. It leads to a considerable variety of estimated damage values. The Federal Environmental Agency, after analysing existing studies and following broad discussions, recommends in their methodological convention for the economic assessment of the economic costs of CO₂ emissions, to adopt a standard value of € 70 per ton of CO₂ emitted. This value has also been used in this report.

Calculations have been prepared for selected OD pairs (routes). Clearly, the highest specific CO₂ emissions are caused by road trucks. This remains valid if the additional collection and distribution transport by trucks is considered for containers carried by railways or ships on their main route section. For five of eight analysed bulk freight transport cases, inland shipping causes lower CO₂ emissions than railways. As regards container transport in the Rhine corridor, the CO₂ emission per TEU of inland shipping is by 19% to 55% lower than for railways. For the Elbe river, railways have an advantage by 15% per TEU, if compared to pusher-lighter combinations on the river. The following figure shows the spread and average values of climate costs for selected transport routes.

Figure 9: Spread and Averages of External Costs of Climate Gas (CO₂) for Selected Transport Routes



6.4 Air Pollution

Numerous studies have prepared extensive estimates of pollution caused by road and railway transport. Inland shipping gained less attention, and related estimates are based on highly aggregated figures. Such calculations referring to the aggregated vessel fleet do not allow reliable conclusions. Often, the level of emissions caused by inland shipping is over-estimated.

The level of exhaust emissions by trucks depends largely on the traffic situation. With growing level of traffic disturbances, exhaust emissions per vehicle-km increase significantly.

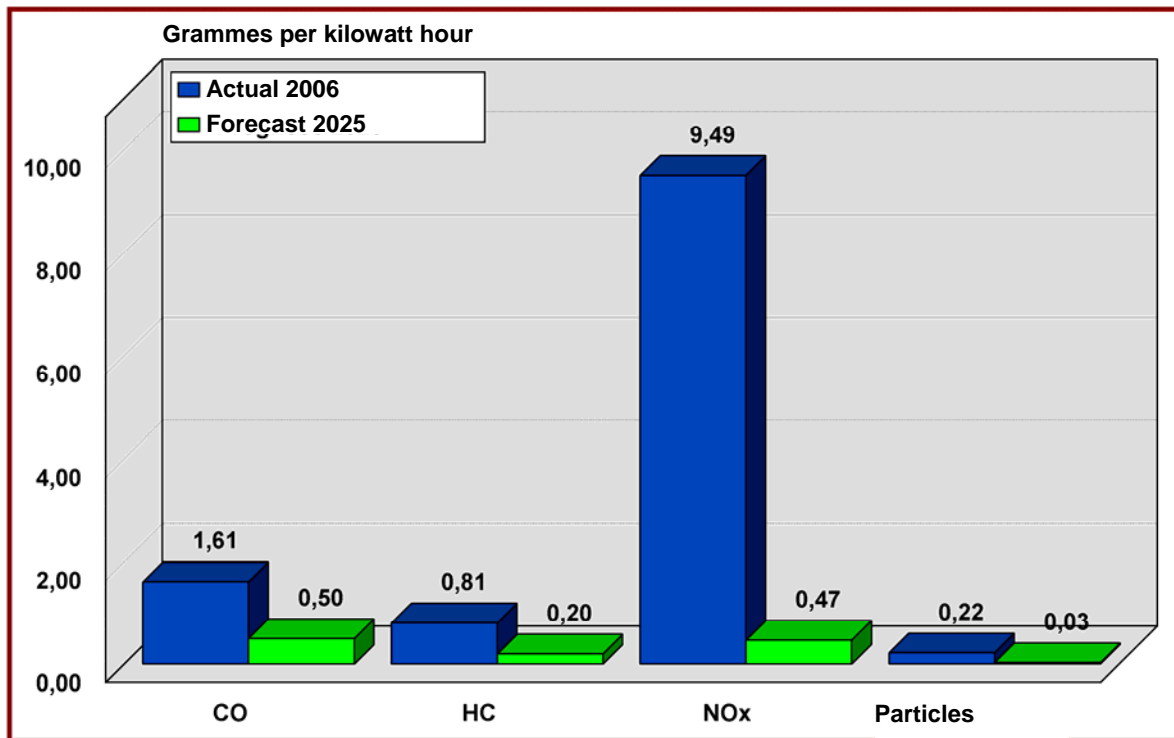
Exhaust emissions of electricity-powered railways depends on the structure of primary energy used for electricity generation. At the present stage, the consequences on railway emissions, of closing down atomic power plants cannot be estimated reliably.

Exhaust emissions from ship motors are limited by legal regulations. Since January 2003 new motors must respect maximum levels according to standard I as defined by the ZKR. Since July 2007 more strict levels according to ZKR standard II are valid, and the scope of validity of this standard was extended. Future more strict standards are under discussion. Assuming that the joint proposal of ZKR and of the German Ministry of Transport, Building and Urban Development becomes applicable, future changes will be as follows:

- ZKR standard III (expected for 2012):
 Reduction of thresholds of standard II
 by 30% for CO, 20% for HC and particles, and 30% for NOx
- ZKR standard IV (expected for 2016):
 Further reduction of thresholds of ZKR standard III
 by 75% for HC, by 90% for NOx and by 90% for particles.

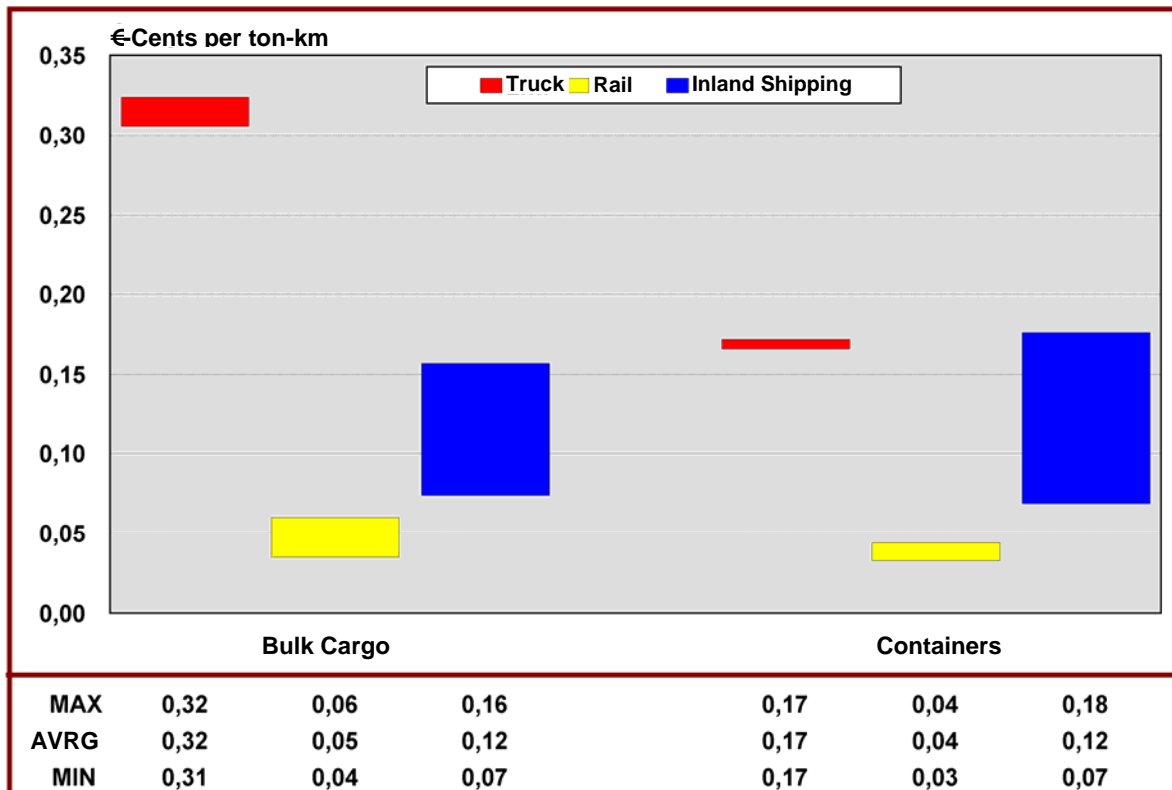
Hence, exhaust emissions by ship motors will decrease significantly. It must be considered that new regulations have only immediate effect on new motors. With an average lifetime of motors of 18 years, it will take time until more rigid emission restrictions will fully impact the total fleet. Even in view of this delay, expected emission reductions per kilowatt hour for the total fleet will be significant (see figure below).

Figure 10: Development of Exhaust Emission Factors in Inland Shipping with the Fleet Structures of 2006 resp. 2025



At present, electricity-powered railway transport causes clearly lower pollutive emissions (nitrogen oxide, sulphur dioxide, non-methane carbon hydrides, carbon monoxide and particles) than road and ship transport. Accordingly, on all selected transport routes the external costs of air pollution caused by railway transport are significantly lower than those of competing modes. When comparing inland shipping with road transport, there is a clear advantage for ship transport. The spread and average values of external costs of air pollution as calculated for selected OD pairs (routes) are shown in the figure below.

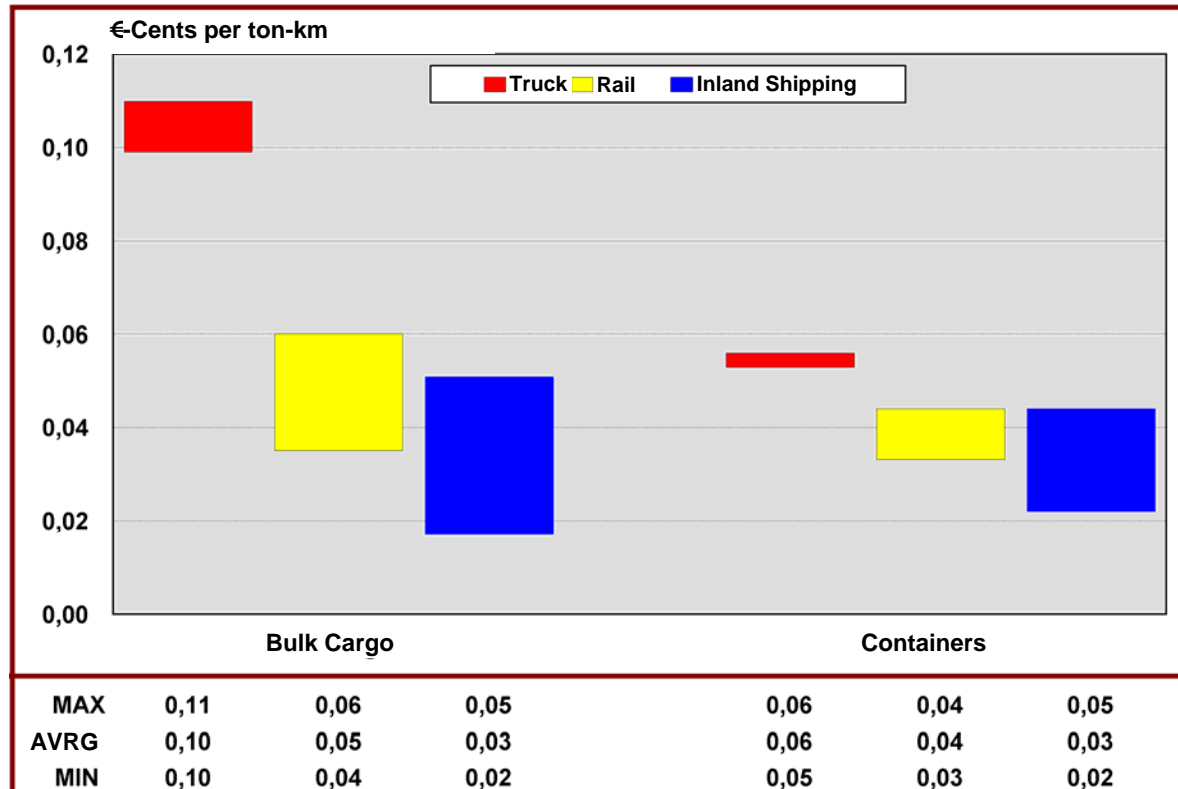
Figure 11: Spread and Average Values of External Costs of Air Pollution (NOx, NMHC, particles, CO, SO₂) for Selected Routes (OD pairs) in 2006



As explained above, exhaust emissions from inland shipping will decrease significantly due to the introduction of more strict regulations. This is also valid for road freight (transition to vehicles of emission class EURO 5). As regards electricity for railway transport the development largely depends on the future structure of primary energy used by power plants. Both further improvements or deterioration are possible. Therefore, unchanged emission factors will be assumed here. This leads to a significant improvement of the competitive position of competing modes till 2025.

Even then, railway transport remains better than road transport. But the difference will be largely reduced. Compared to inland shipping, railway transport will lose its advantage on all analysed transport routes. On the average for all bulk freight routes, the external pollution costs of inland shipping will be €-Cents 0.03 per ton-km compared to 0.05 for railway transport. For container routes, corresponding figures are 0.03 for inland shipping as opposed to 0.04 for railways.

Figure 12: Spread and Average Values of External Costs of Air Pollution (NO_x, NMHC, Particles, CO, SO₂) for Selected Routes in 2025



6.5 Landscape Dissection and Area Consumption

The term ‘landscape dissection’ refers to the disruption of natural ecological linkages, separating landscape areas from each other. Such disruption and fragmentation of landscapes and of water bodies is seen as a major cause for a decreasing number of faunistic and floristic species thus compromising biodiversity. Landscape dissection by transport infrastructure also reduces the recreation possibilities for people due to lessened undisturbed landscape experience.

The intensity of negative impacts from infrastructure clearly differs among transport modes. The road network, due to its high density (0.64 km/ km²) and heavy traffic load has by far the highest dissection effects on terrestrial biological life and on human recreation. Railway lines are normally less heavy barriers for migrating animals, though some species experience significant losses due to collisions and accidents with overhead electricity cables (birds of prey, owls). Adjacent recreation and settlement areas are affected by noise emissions. With regard to waterways, only canals can be considered as additional dissection axes. As the density of canals (0.005 km/km²) is far lower than for other modes, the dissection impacts are negligible. For natural river courses, barrages are an important barrier for migrating fish such as salmon or eel. Impacts on recreation landscapes are only minor or even positive (e.g. hiking and cycling on maintenance paths along canals).

The construction of new transport infrastructure uses space, normally on naturally developed soils. This can lead to considerable changes in land use.

The three transport modes road, railways, waterways differ in the magnitude of required areas as well as in their quality impacts. The waterway network of 6,700 km (of which 1,742 km canals) is much shorter than the railway network (34,200 km) or the road network (231,600 km). While roads and railways directly consume areas, waterways, being largely natural water courses, have only an indirect impact on landscape consumption.

The width of infrastructure lines can only be compared by giving a few examples. A two-lane railway line has a width of 14m; a 6-lane highway needs 35m. Waterways have a width of between 40m for many canals and rivers, and up to 150m for the Rhine.

While roads and railways serve exclusively transport purposes, almost fully sealing soils, waterways remain habitats for aquatic fauna – though sometimes minor sealing of waterway beds and shoulders is required. These habitats can have a highly positive ecological value. Waterways also serve other purposes than transport (e.g. water sports, energy generation, fishery). These qualitative aspects show a clear advantage of waterways against other modes.

Generally it is difficult to translate the described negative effects of transport on nature and landscapes into monetary terms. No direct valuation rates, e.g. from willingness-to-pay analyses, exist. Therefore, present studies are using avoidance costs as a proxy. The approach is to identify sealed and otherwise damaged areas along infrastructure alignments and to estimate the cost for de-sealing resp. for renaturation (repair cost approach). Significant uncertainties exist for the demarcation of negatively affected areas. Therefore, varying assumptions on the relevant length of relevant railway networks and on the degree of sealing lead to widely different evaluation results.

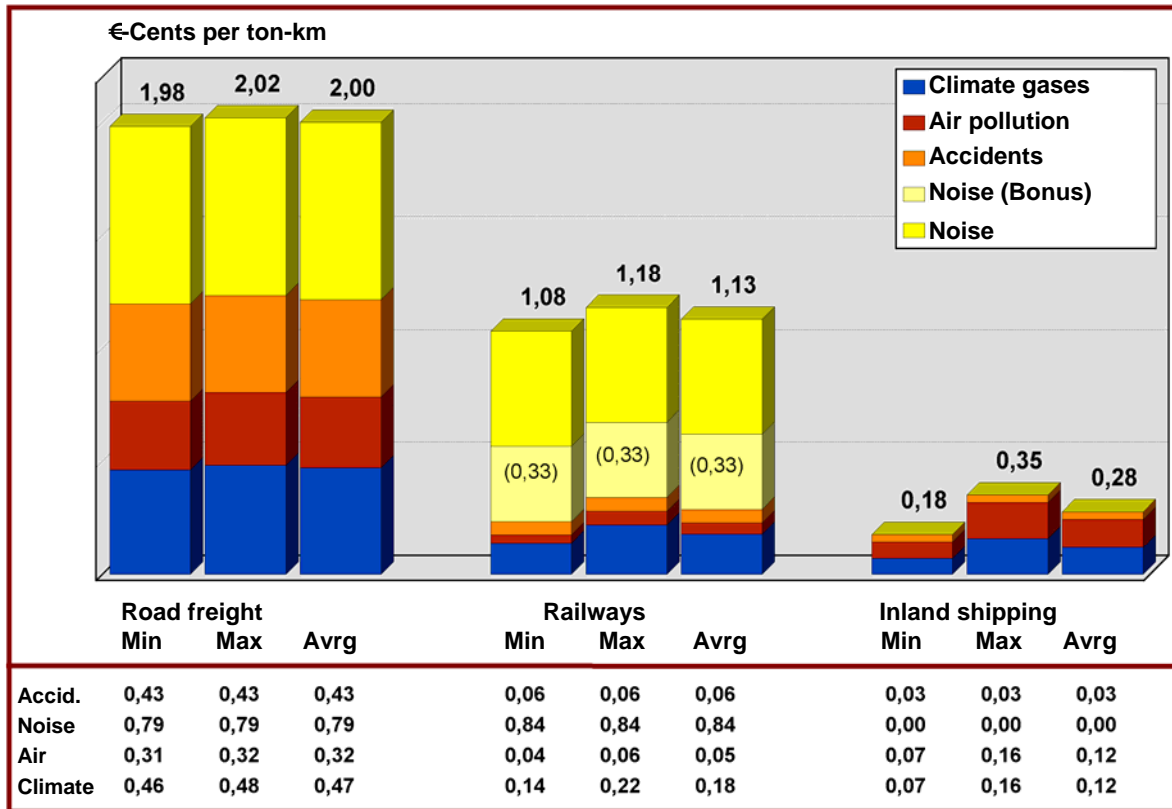
Considering these difficulties to assess the areas disturbed by transport infrastructures, this study abstains from the monetarisation of impacts. But it may be stated that the highest negative effects on nature and landscapes result from road traffic. No conclusion can be drawn as regards the relative impact intensity of railways versus waterways.

6.6 Summary of External Costs

When summarising the external costs from traffic noise, accidents, climate gas and air pollution, a clear advantage of inland shipping becomes obvious for all selected routes, for bulk freight as well as for containers. This advantage remains valid even if a bonus is assigned to railways regarding noise pollution.

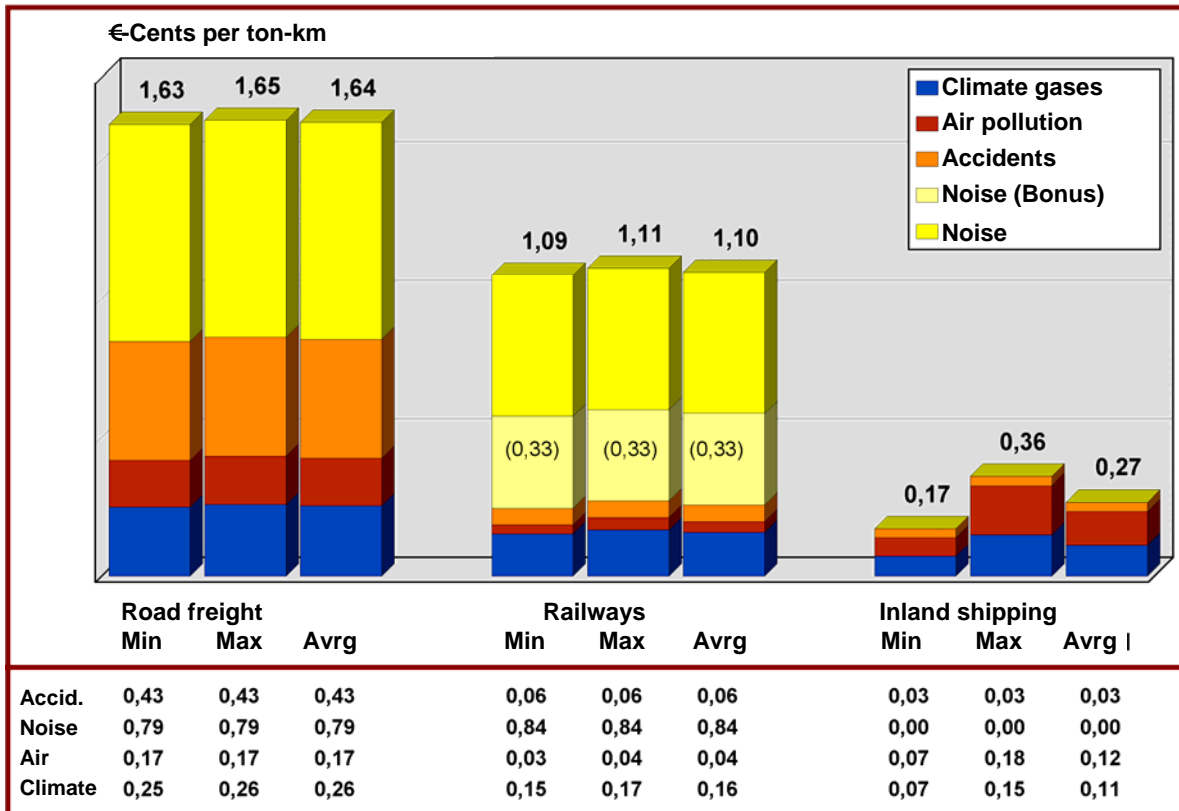
On bulk freight routes, the external costs of inland shipping are on the average by 83% lower than those of road transport, and by 70% lower than for railway transport. The spread of external costs, with minimum and maximum values, confirms this clear advantage of inland shipping.

Figure 13: Spread and Average Values of All External Costs (Noise, Accidents, Climate Gases, Air Pollution) for Bulk Freight on Selected Routes



A similar picture results for container transport. Here, average total external costs of inland shipping are by 78% below those of road and by 68% below those of railway transport.

Figure 14: Spread and Average Values of All External Costs (Noise, Accidents, Climate Gases, Air Pollution) for Container Freight on Selected Routes



7 Transport Costs

Transport costs are an essential aspect of comparing different transport modes. This study has performed cost comparisons under two perspectives:

- **Economies of scale**
The level of transport costs on inland waterways depends heavily on the size of vessels resp. of vessel combinations, and on the volume of cargo carried. Both parameters are influenced by the physical characteristics of the waterway sailed. Comparative cost calculations per ton-km reflect the cost degression according to typical vessels and effective vessel draft. Corresponding calculations have been carried out for railway and road transport.
- **Differentiation by transport routes**
For all three considered modes, the level of transport costs depends on various route-specific parameters. Therefore, considerations based on general averages have only a limited value. In order to arrive at more meaningful conclusions, comparative calculations have been made for 13 selected transport routes.

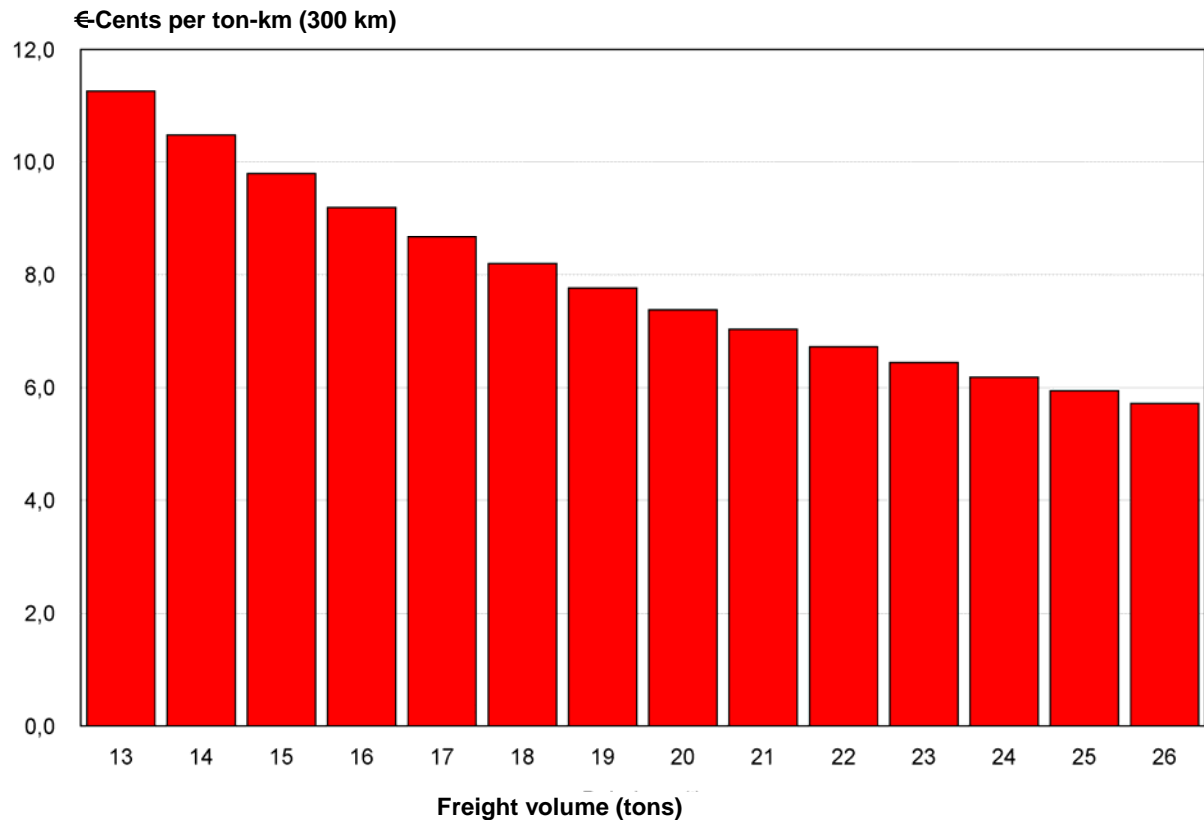
7.1 Economies of Scale

For all three transport modes, the cost of allocating the required vehicle for a given transport task and the cost of loading and unloading are largely independent of the transport distance. Hence, the cost per ton-km decreases with the distance. For a given transport distance, the unit cost depends on the loading capacity and on the capacity utilisation of vehicles employed. The cost per ton-km of loaded vehicles will be lower for higher freight volumes and the cost per ton-km for a roundtrip will be lower with a lower share of empty voyages.

For **road freight**, the average financial transport cost by trucks or truck-trailers over 200 km and with an average net load of 12.3 tons amounts to €Cent 14.3. For a distance of 1,000 km, this unit cost is reduced to €Cent 8.8 (-38%). This cost reduction has a degressive form. While the unit cost decreases by 16% for a distance of 300 km as compared to 200 km, the reduction is only 2% if the distance rises from 900 to 1,000 km.

The figure below exhibits the consequences of different freight volumes at a transport distance of 300 km.

Figure 15: Transport Cost by Road Depending on the Freight Volume

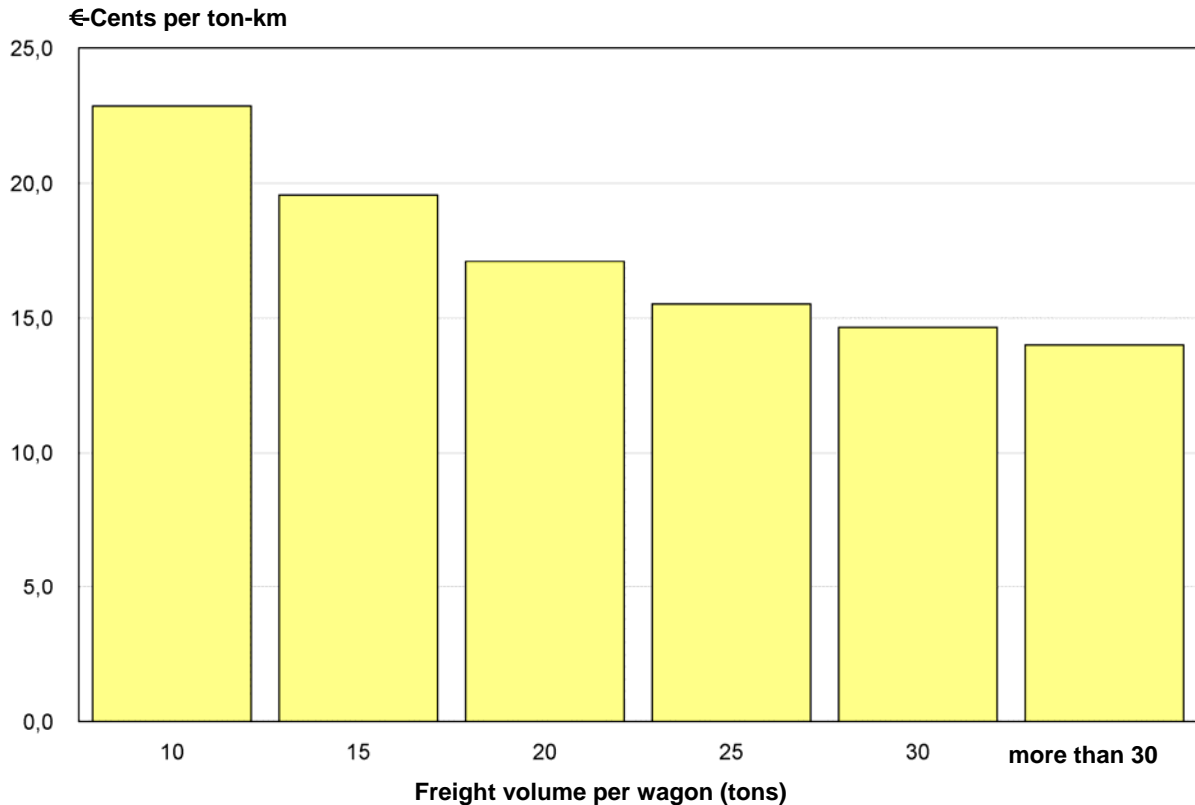


If the loading capacity of a truck of 26 tons is fully used for both the outward and the return journey, the cost per ton-km is €-Cent 5.72. If no freight is carried on the return journey (13 tons of freight as average per trip), the cost per ton-km increases by 97%, thus being almost reciprocally proportionate to the freight volume.

To calculate the dependency of unit costs from transport distance in **railway transport**, recent price information can be used. The values of the Railion AG per ton-km of wagonload clearly decrease with the distance. While the price is €-Cent 16.04 for a distance of 200 km, it is 55% less for 1,000 km (€-Cent 7.40).

The prices per wagon charged by Railion not only depend on the transport distance, but also on the freight weight per wagon. When applying average freight weight levels, the prices per ton-km are as shown in the figure below.

Figure 16: Transport Prices for Full Wagon Load of the Railion AG Depending on the Freight Weight

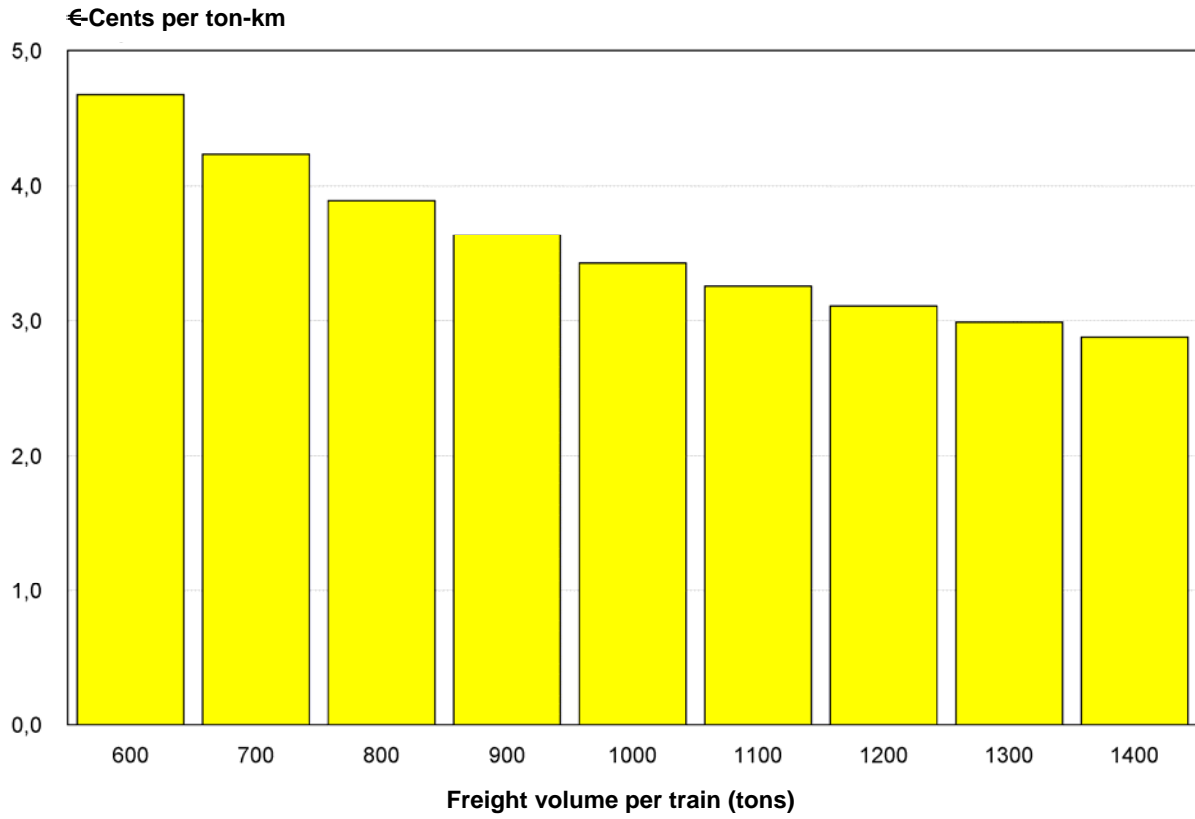


For consignments of less than 13.5 tons, the unit rate per ton-km is €-Cent 22.87. This rate is reduced to 19.56 for consignments of 15 tons (-14.5%), to 17.07 for 20 tons (-25.4%), to 15.52 for 25 tons (-32.1%) and to 14.65 for 30 tons (-36%). For consignments of 30 tons, the unit rate is €-Cent 14 (39% less than for 13.5 tons).

Prices charged by DB resp. Railion for block trains are not published. Some indications for the change of unit costs per ton-km for different freight volumes per train can be derived from a study prepared by the Fraunhofer Institute (2003). By applying unit rates from that study to different train configurations, the degression with growing freight volume per train has been calculated.

For a transport distance of 300 km, the full range of freight volumes per train of 600 to 1,400 tons was considered. While the unit rate per ton-km is €-Cent 4.68 for 600 tons, it is 3.89 for 800 tons (-17%) 3.42 for 1,000 tons (-27%), 3.11 for 1,200 tons (-33.5%) and 2.88 for 1,400 tons (-38.5%).

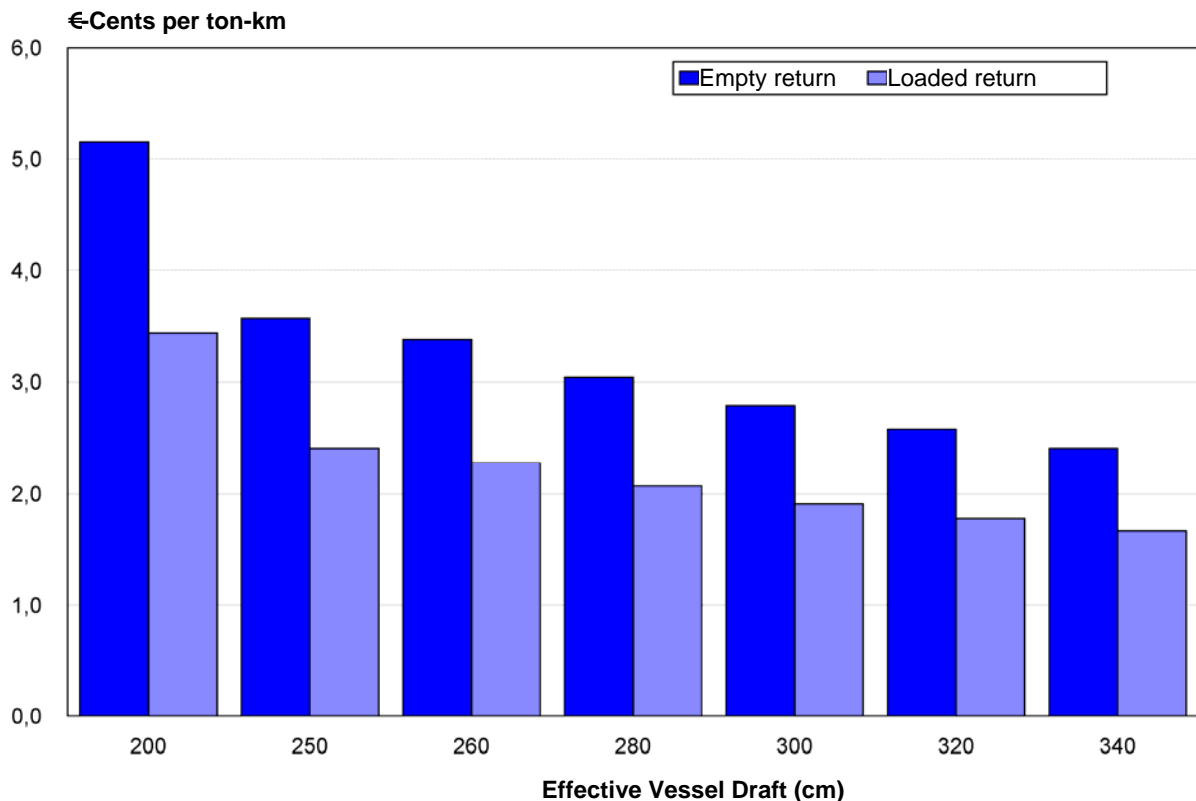
Figure 17: Unit Transport Cost per tonne-km on Railways of Block Trains as a Function of the Freight Volume per Train



As for road and railway transport, the unit cost per ton-km decreases in **inland shipping** for longer transport distances. Using the example of a fully loaded Big Motor Vessel (110 x 11,45 m) cruising on the river Rhine (assuming an empty return voyage), the cost per ton-km is €-Cent 2.73 for a distance of 200 km. This rate is 2.24 for a distance of 400 km, 2.08 for 600 km, 2.00 for 800 km and 1.95 for 1,000 km. The unit cost per ton-km for 1,000 km transport distance is by 28.5% lower than for 200 km.

The unit costs of inland shipping also depend on the usage of the potential vessel draft (construction draft). As an example, this is shown for a transport distance on the river Rhine river of 300 km. As the unit cost for a total roundtrip also depend on the freight volume on the return trip, the spread has been calculated for two cases: empty return voyage/ full capacity use also on the return trip. The figure below shows results for a big motor vessel (110 x 11,45 m).

Figure 18: Degression of Unit Costs per ton-km According to Effective Draft for a Big Motor Vessel



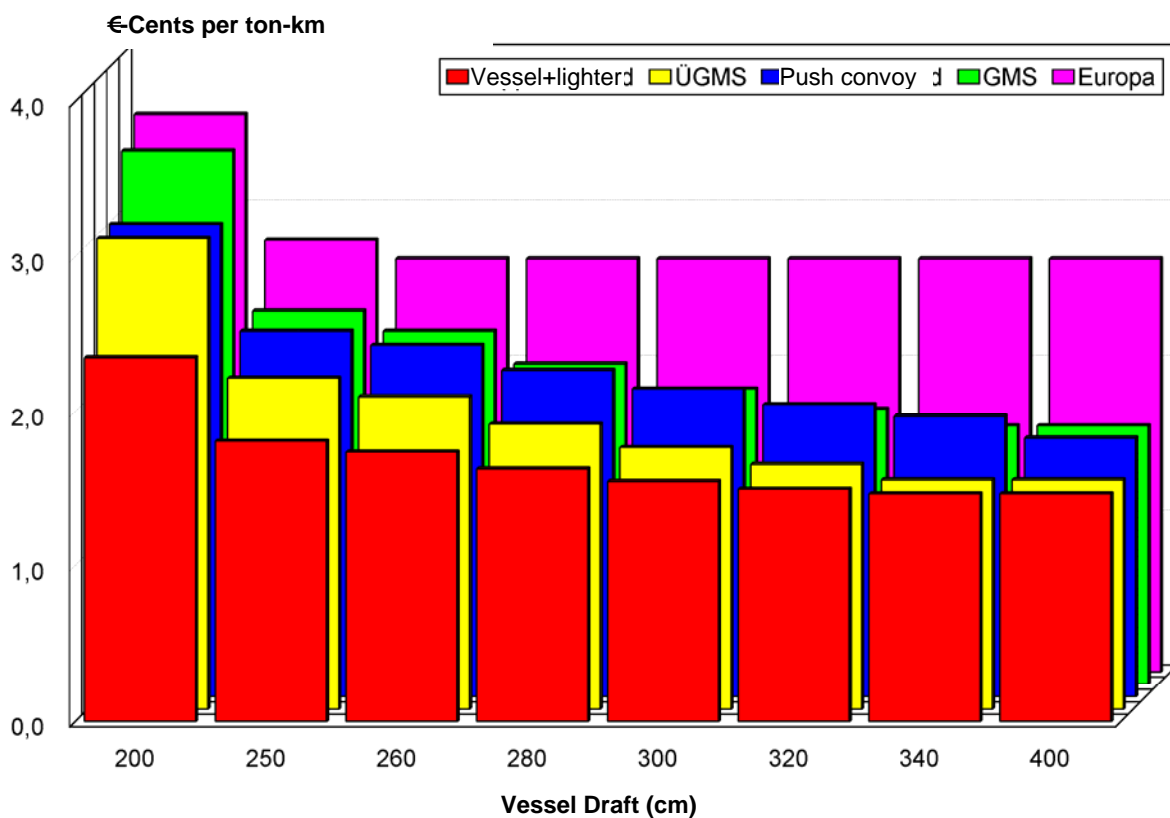
At a vessel draft of 2.0 m, the transport cost is €-Cent 5.15 per ton-km for an empty return voyage resp. 3.44 with a loaded return trip. If the maximum loading draft of 3.4 m can be used, the unit cost is only 2.41 (empty return) resp. 1.67 (loaded return). Compared to the use of a draft of only 2.0 m, the unit cost is reduced by 53.2% (empty return) resp. 51.5% (loaded return).

When comparing the unit costs of selected vessel types (single motor vessel, motorvessel-lighter combination, push convoy = pusher boat with 2 lighters) for varying use of potential vessel draft, results are as follows:

- For a draft of 2.0 m, the unit cost per ton-km of a vessel of 'Europe' type is €-Cent 3.60 – 5% higher than for a Big Motor Vessel GMS (3.44) and 18% higher than for the Extra Large Motor Vessel ÜGMS (3.04). Under the same assumptions, the cost rates for a push convoy corresponds to the ÜGMS, while the motorvessel-lighter combination has the lowest unit costs of 2.35 only.
- If the draft is raised to 2.6 m, then the cost disadvantage of the then fully loaded 'Europe' vessel is clearly increased. This cost of €-Cent 2.67 per ton-km exceeds the cost rate of the GMS (2.28) by 17%, resp. of the ÜGMS (2.02) by 32%. Push convoys and motorvessel-lighter combinations have rates of 2.27 resp. of 1.74 €-Cents per ton-km.

- Assuming an effective vessel draft of 3.4 m, all vessel types are using 100% of their capacity. Then the unit rates per ton-km are €-Cent 1.48 for the ÜGMS and 1.47 for the motorvessel-lighter combination. For the GMS they are 1.67, and 1.81 for the pusher-lighter combination. Under these conditions, the cost rates of the 'Europe' vessel exceed those of the GMS by 60%, and those of the ÜGMS and of the motorvessel-lighter combination by even 80%.
- If a vessel draft of 4.0 is permitted, then the unit cost of the push convoy is further decreased to €-Cent 1.67 – similar to the cost level of a GMS fully loaded on outbound and return voyage.

Figure 19: Transport Unit Costs for Selected Vessel Types at Different Levels of Effective Vessel Draft



Clearly, the reduction of unit cost rates is higher for larger vessels. Small vessels reach their maximum draft earlier and hence do not benefit from a permitted higher draft, thus not having the chance to reduce their unit costs by higher volume of payload.

7.2 Cost Comparisons for Selected Routes

Comparative calculations were prepared for 13 selected routes. Those routes were defined so as to reflect a sufficient variety of real-life transport tasks and to allow meaningful conclusions. Both container and bulk freight cases are included. For bulk freight both liquid and dry commodities are considered. For all chosen routes, these different commodities play a typical role. As concerns inland shipping, the chosen routes permit to include all relevant categories of waterways, from unrestricted natural rivers to canals. The table below provides an overview of the selected routes.

Table 3: Selected Routes for Comparative Analysis of Transport Costs

From	To	Commodity	Transport distance (km)		
			Road	Railway	Ship
Hamburg	Decin (Czech Rep.)	Foodstuff	558	532	635
Hamburg	Salzgitter	Coal	211	194	200
Rotterdam	Duisburg	Coal	243	267	227
Rotterdam	Großkrotzenburg (Main)	Coal	524	557	568
Rotterdam	Dillingen (Saar)	Iron Ore	457	515	671
Linz	Nürnberg	Iron and Steel	337	331	384
Hamburg	Hannover	Mineral oil products	145	176	259
Antwerp	Ludwigshafen	Chemicals	423	488	659
Rotterdam	Duisburg	Containers	243	268	229
Rotterdam	Basel	Containers	773	767	838
Hamburg	Berlin	Containers	314	284	357
Hamburg	Decin (Czech Rep.)	Containers	558	532	635
Rotterdam	Stuttgart	Containers	650	642	763

Cost calculations for road freight have been prepared for trucks or truck-trailer combinations. For bulk cargo empty return trips are assumed – 24 tons of cargo on one way, no cargo on the return tour. For the transport of containers, it is assumed that 2 TEUs are carried on both ways.

Financial costs also include the toll to be paid, since January 2005, by trucks using federal highways. The applied cost rate is €-Cent 12.4 per km corresponding to the average applicable for EURO 0-III motors. International transport routes and routes with a high share of urban and non-urban, but non-highway roads have a correspondingly lower share of road user costs and hence of variable costs.

Transport costs of railway freight relate, as for road and waterways, to the total roundtrip. Roundtrip times include the travel time as well as the time needed for formation and post-trip handling of trains, for changing direction, for waiting times, for loading and unloading at ports or elsewhere.

Based on planning data from the port of Duisburg, 750 net tons are assumed as the average freight volume for container trains. For these trains an identical load factor is applied for the return trip.

Block trains of German Railways carrying bulk cargo are usually arranged as shuttles with planned empty return trips. Due to the high degree of specialisation of wagons return freight can only exceptionally be found. Following assumptions have been made regarding train configuration and freight load:

- Trains carrying iron ore from Rotterdam to Dillingen: These are presently the most heavy trains of German Railways. With 40 wagons of a net carrying capacity of 87.5 tons each the total freight volume is 3,500 tons with a gross train weight of more than 5,000 tons.
- Trains carrying coal have different freight volumes, depending on the route: 2,000 tons for Hamburg – Salzgitter; 2,600 tons for Rotterdam – Duisburg; close to 2,900 tons for Rotterdam – Großkrotzenburg.
- For liquid bulk trains on the routes Hamburg – Hannover (mineral oil) and Antwerp – Ludwigshafen (chemicals) the maximum train length of 700m is assumed. Considering the number of tank wagons and their loading capacity, a total freight volume of more than 2,300 tonnes (Hamburg – Hannover) resp. 1,800 tons (Antwerp – Ludwigshafen) has been used.
- For the transport of animal feed (Hamburg – Decin) resp. of iron & steel (Linz – Nürnberg) a smaller number of wagons is assumed (20 resp. 15). Trains with a total length of 350 resp. 288 m reach net freight volumes of well above 1,000 tons (feed) resp. 1,500 tonnes (iron & steel), with gross train weights of 1,700 resp. 2,100 tons.

As for road and railways, transport cost calculations for inland shipping refer to a full roundtrip. This considers the degree to which on a specific route freight volumes are available on the way back (differentiated data are available from the Federal Office of Statistics). The cost rates include the cost of making ships available, staff cost, cost of energy and user charges on canals. For container transport the cost of collection resp. distribution by truck is also included. In contrast, for bulk freight it is assumed that such collection or distribution is not required.

Depending on the specific route, typical vessel types are considered whose measurements correspond to the respective regulations of water police. The following vessel types are assumed:

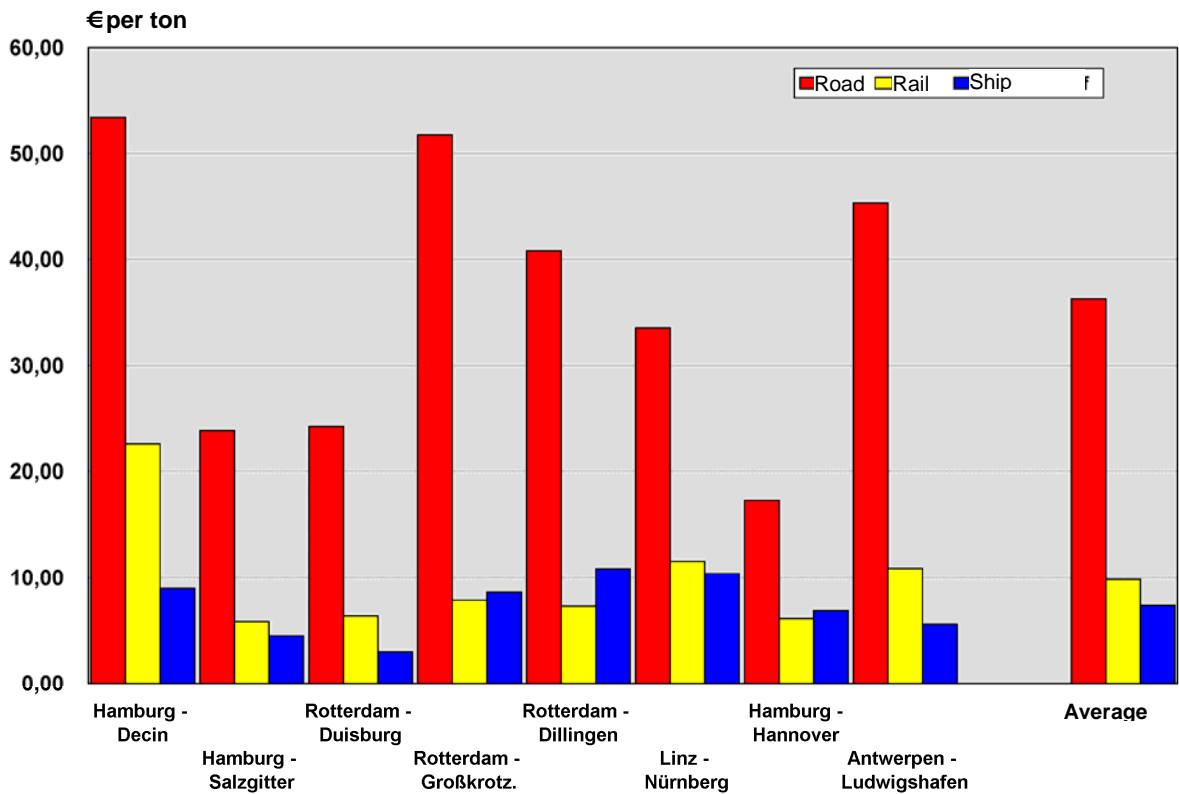
Table 4: Types of Vessels or Vessel Combinations and Return Freight Assumptions for Selected Shipping Routes

From	To	Commodity	Vessel Type	Return freight
Hamburg	Decin (Czech Rep.)	Foodstuff	Elbe pusher convoy	80%
Hamburg	Salzgitter	Coal	Motorvessel-Lighter combination	none
Rotterdam	Duisburg	Coal	Pusher with 6 lighters	none
Rotterdam	Großkrotzenburg (Main)	Coal	Motorvessel-Lighter combination	none
Rotterdam	Dillingen (Saar)	Iron ore	Motorvessel-Lighter combination	none
Linz	Nürnberg	Iron & steel	GMS 110 n	100%
Hamburg	Hannover	Mineral oil products	TMS 100 m (Tanker)	none
Antwerp	Ludwigshafen	Chemicals	ÜTMS 135 m (Tanker)	89%
Rotterdam	Duisburg	Containers	Jowi	91%
Rotterdam	Basel	Containers	Motorvessel-Lighter combination	96%
Hamburg	Berlin	Containers	Elbe pusher convoy	100%
Hamburg	Decin (Czech Rep.)	Containers	Elbe pusher convoy	100%
Rotterdam	Stuttgart	Containers	GMS 105 m	100%

The calculations show for all selected bulk routes the highest cost for road transport compared to railways and waterways. The average road cost rate of € 36.29 per ton exceeds those of railways resp. waterways by a factor of 3.7 resp. 4.9. Even if - unrealistically – 100% return freight would be assumed for trucks, this disadvantageous position would not be lost.

When comparing railways and waterways transport, shipping has a, sometimes significant, cost advantage on 5 routes. For three routes railway transport is more advantageous, with a cost difference of 8.8% (for coal Rotterdam – Großkrotzenburg), of 10.9% (mineral oil products Hamburg – Hannover) and 32.8% (iron ore Rotterdam – Dillingen). On the average for all considered bulk freight routes the cost advantage of inland shipping compared to railway transport amounts to 25%.

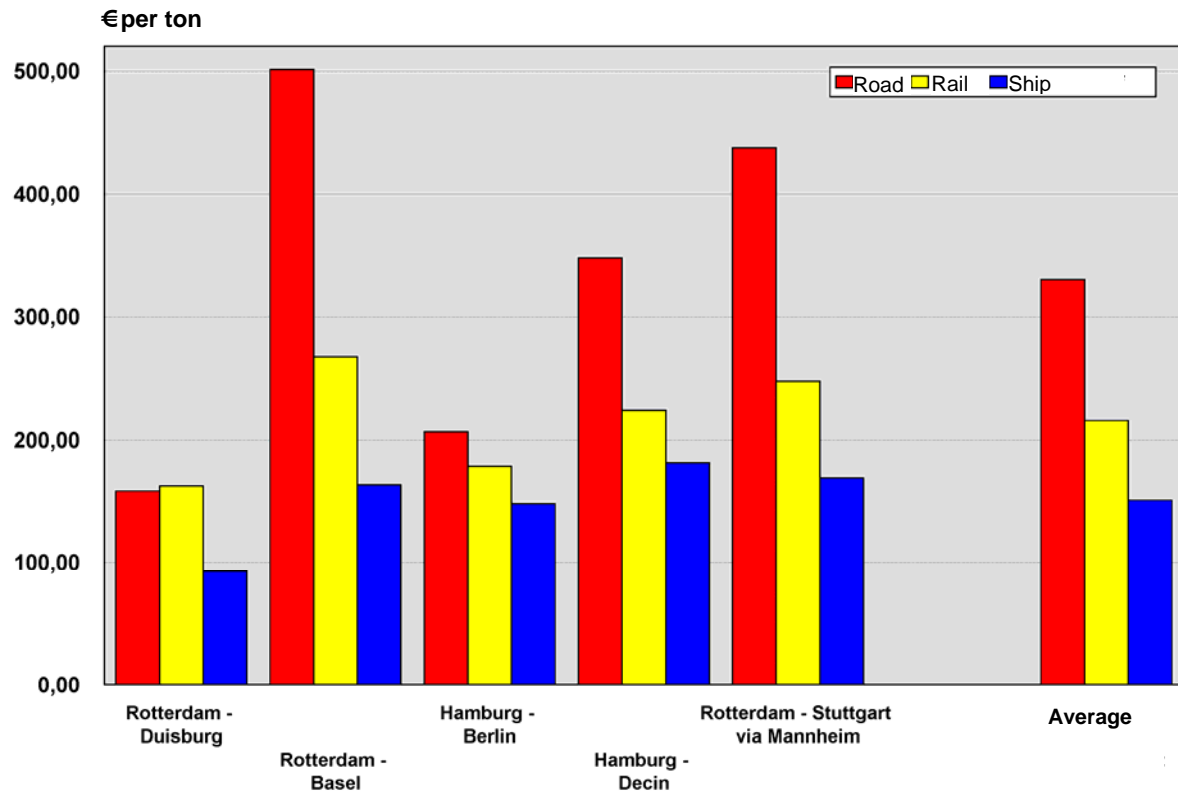
Figure 20: Financial Transport Cost of Transport Modes for Selected Bulk Freight Routes



In spite of the fact that calculated costs for railways and inland shipping include the cost of collection resp. distribution of containers by road, direct road transport is more expensive than for railway or waterway. With the exception of the route Rotterdam – Duisburg where the financial cost of direct road is slightly lower than for railways, the cost disadvantage of direct road is significant: more than +50% on the average as compared to railways and more than +100% compared to transport on waterway.

Results of the comparison of railways with waterways are even more expressed than for bulk freight routes. On all considered container routes, inland shipping is clearly less costly than railway transport. The cost advantage of inland shipping varies between around 17% (Hamburg – Berlin) and 43% (Rotterdam – Duisburg). On the average of all routes considered, the financial cost of inland ship transport of containers is 30% lower than that of railway transport.

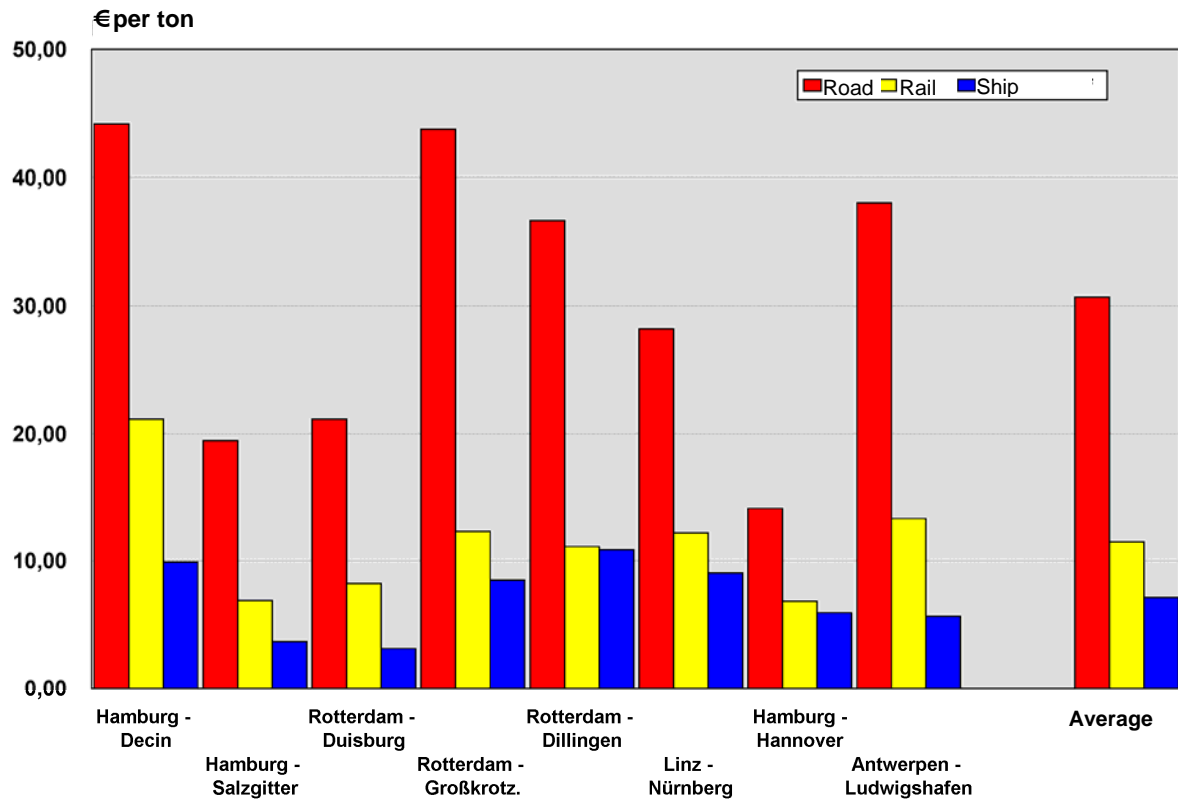
Figure 21: Financial Transport Cost for Selected Container Routes, by Modes of Transport



When comparing different transport modes, not only the financial costs are of interest but also the economic costs from the national economy perspective. In this study, the term economic cost comprises both the transport cost to the economy and the external costs due to noise, accidents, climate gas emissions and air pollution. The calculation of economic transport costs uses the same basic data as for financial costs. But now, these financial costs are converted into economic rates according to the methodology of the German Federal Transport Investment Plan (BVWP) 2003. Mineral oil taxes, road or railway or canal tolls are now excluded. The basics for evaluating external effects are explained in chapter 5.

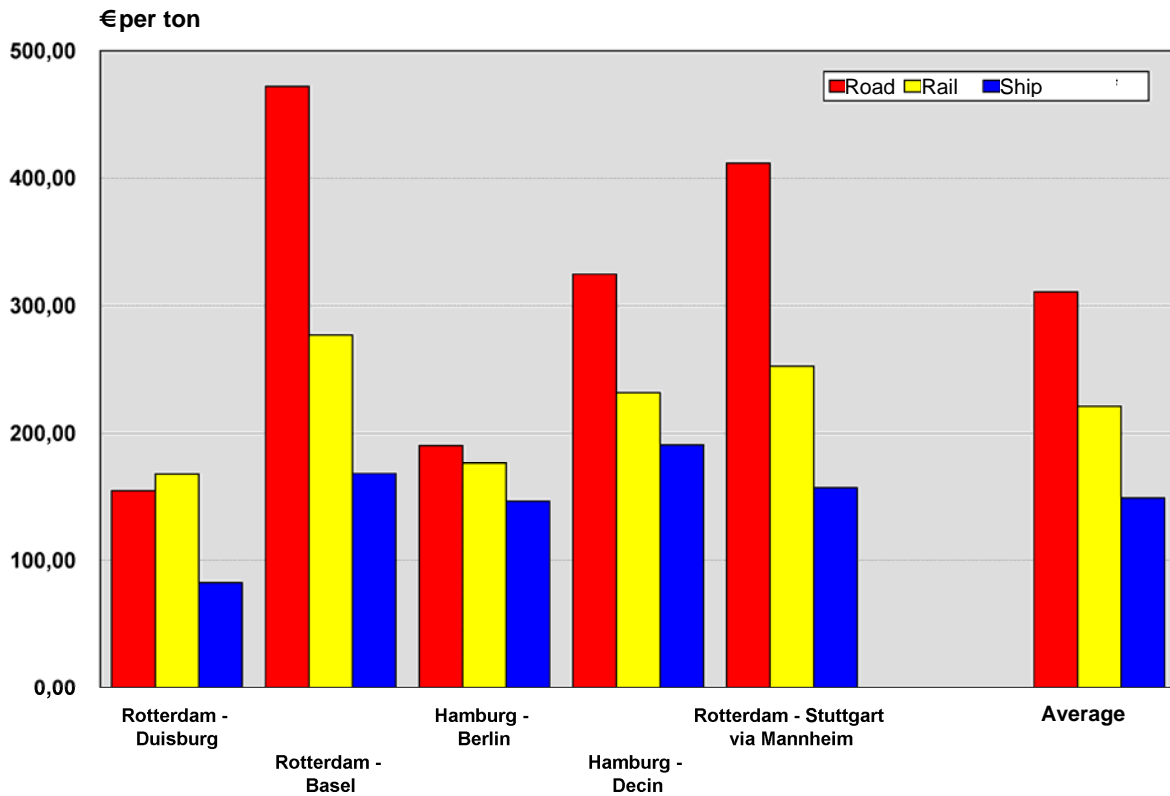
As for the financial costs, the economic cost of road transport exceeds the cost of railway resp. waterway transport for all analysed bulk freight routes (plus 167% resp. plus 334%). For all (eight) studied bulk freight routes inland ship transport causes lower economic costs than railway transport – for the financial cost this was the case for only 5 out of 8 routes. The economic cost disadvantage of railways compared to the cost of inland ship transport ranges from +2.2% (iron ore Rotterdam – Dillingen) to +161% (coal Rotterdam – Duisburg). On the average for all analysed bulk freight routes, the advantage of inland shipping amounts to 38.4%.

Figure 22: Economic Cost for Bulk Cargo Transport on Selected Routes, by Transport Modes (incl. external cost of noise, accidents, climate gas emission and air pollution)



For all considered container routes, too, inland shipping displays the lowest economic cost – 52.1 lower than road transport and 32.7% lower than railway transport. The highest cost advantage of waterways compared to road transport occurs on the long Rhine route from Rotterdam to Basel (-64.5%). Compared to railway transport, inland shipping has the highest cost advantage (-51.1%) on the route Rotterdam – Duisburg. On this route, even road transport has an economic cost advantage (-7.8%) vis-à-vis railways.

Figure 23: Economic Cost of Container Transport on Selected Routes, by Transport Modes (incl. external cost of noise, accidents, climate gas emission and air pollution)



To summarise, inland waterway transport has lower economic costs than the competing modes for all analysed routes, for bulk freight and for containers. Though having higher (external) costs of air pollution, this disadvantage is more than offset by lower other external costs. On three of the analysed routes, waterway transport while having lower economic costs displays higher financial costs.

8 Specific Aspects of Inland Shipping

8.1 Multiple Use of Waterways

The dominant use of waterways is for the transport of people or freight at low cost and without delay. While roads and railways have no important other functions, waterways also serve other purposes: flood abatement, potable water supply, wastewater disposal, irrigation, cooling water for power plants, fishery, support of ecological biotopes, recreation.

Biotope functions

In contrast to asphalt bands of roads or permanent ways of railways, waterways can be habitat of multiple and valuable natural life, depending on their level of technical sophistication. This applies for natural waterways, but can also be the case, with restrictions, for artificial waterways (canals). This is substantiated by the high number of waterside registered FFH and EU bird protection areas, as parts of the European protected areas system NATURA 2000, and by the dense network, along waterways, of nature or landscape protection areas. Different from roads and railway lines, waterways are among the last retreats for protected and endangered species.

Water Tourism, Water Sports, Recreation, Fishery

In the past, waterways played an important role for the development of industry, and hence of welfare, in many cities and regions. Still today waterways have a positive impact on regional development. This is also due to the manifold potentials of waterways to be used for waterbound tourism and recreation.

In view of growing domestic tourism (with a recent growth rate of 2%) and of an increasing tendency to activate port and other waterside areas for recreation purposes, water tourism (esp. boat tourism and passenger shipping) has become an important factor for regional development. Municipalities located along waterways develop diverse recreation opportunities with a view at improving their location attractiveness.

Waterways provide attractive opportunities for boat tourism, offering connections to European neighbour countries to the East and to the West, to the Mediterranean Sea and to the Black Sea. Several German regions offer waterway networks which are placed in beautiful landscapes and which offer excellent conditions for water sports and tourism.

The German Federal Association of the Water Sports Industry (Bundesverband Wassersportwirtschaft e.V. BWVS) estimates that in Germany around 7 million people practice active water sports. The estimated number of people in Germany to develop such interest, due to their stated sport preferences, is even close to 32 million. Therefore further growth of this sector can be expected. Water sports generate new opportunities for employment and income. For several regions, water sports and tourism have become an important factor in economic development.

Angling and sometimes also professional fishing occur on practically all federal waterways. A socio-economic study concluded that the economic benefits from angling in Germany

amount to € 6.4 billion per year. Approximately 52,000 jobs depend directly or indirectly on this activity.

Water Management

Water management deals with water supply and distribution, wastewater treatment, water quality control, construction and maintenance of water bodies, and flood protection of societies. Technical tasks comprise construction works and operation, while water management is based on natural and socio-economic sciences.

Federal waterways play an important role in the management of water basins. Households, industry, agriculture and other users are supplied annually with more than 17 billion m³ of water taken from waterways. Almost the same quantity - 16 billion m³ - are fed each year into the waterways. These figures do not include quantities supplied to small users. Therefore, real totals will be higher. Even so, the registered water quantity accounts for about half of total water intake and discharge in Germany.

8.2 Climate Change and Flood Protection

Rivers and river basins as well as coastal regions are the object of multiple and sometimes conflicting uses. The use of waterways by the shipping industry is only one of these. This use requires reliable conditions for a safe, smooth and economical operation of vessels. This includes fairways which are as stable as possible and which offer sufficient depth and width at only moderate currents.

Forecasts of regional climates and water flows indicate that climate change may lead to far reaching changes of hydrological and shipping conditions. This includes not only changes in water levels, but also in carried solid materials and temperature of river waters. Independent of how the probability of such scenarios and forecasts is assessed, there is a need for an early assessment of potential consequences. This is particularly necessary for federal waterways, because adaptive measures involve long-lived infrastructure requiring high investment volumes and therefore need early decisions.

Today, technical changes at rivers only get the acceptance by societies if considering the needs of different interest groups. They must be based on inter-disciplinary cooperation. Construction measures taken by the water and shipping administration aim at improving navigation possibilities with low to normal water levels. Generally, they are planned and executed so as to at least maintain the existing level of flood protection. The impact from any physical changes of waterways on hydraulic and morphological conditions for flood discharge is analysed scientifically in order to find solutions which maintain the level of flood protection. Where necessary, this includes compensation measures, e.g. by reactivating retention potentials (de-sealing, removing dikes further away from rivers) or by deepening the river bed.