IS INTERMODAL FREIGHT TRANSPORT MORE ENVIRONMENTALLY FRIENDLY THAN ALL-ROAD FREIGHT TRANSPORT? A REVIEW

Ekki Kreutzberger *, Cathy Macharis **, Laetitia Vereecken ** and Johan Woxenius ***

Key words: intermodal freight transport, environmental performance, external costs, internalisation

ABSTRACT

Intermodal transport, the combination and integration of several modes, with the use of loading units, has been said to be more environmentally friendly than unimodal road transport for the carriage of goods. The political and scientific interest in this transport market is largely due to this sustainability and ecological aspect of the intermodal transportation system. In this paper an overview is given of studies and papers that are tackling the issue of the external effects of both intermodal and unimodal transport. An overview is given of the types of external costs that were taken into account (emissions, security, noise,...) and the methodologies that were used to estimate the external effects and to value these effects in terms of costs. The results of the different studies are compared to each other and common conclusions are drawn.
1. INTRODUCTION

Intermodal transport, the combination and integration of several traffic modes with the use of loading units, has often been said to be more environmentally friendly than unimodal road transport for the carriage of goods. The political and scientific interest in this transport market is largely due to this sustainability and ecological aspect of the intermodal transportation system. Intermodal transport can also help to fight congestion on the roads.

For these reasons the White paper of the European Commission (2001) strongly supports the further stimulation of intermodal transport. Also in the scientific literature, the assumption of intermodal transport as a more environmental solution has been adopted.

Despite these powerful research and policy statements, there still is some discussion ongoing. A study for the International Road Community (IRU) and Bundesverband Güterkraftverkehr Logistik und Entsorgung (BGL) (IFEU and SGKV, 2002) has recently put the assumption of intermodal transport as being more environmentally friendly into question. In their study they found that combined road/rail transport require in some cases more primary energy. This study leads the IRU, for evident reasons, to recommend a transport policy which would not be based on a further promotion of intermodal transport. Also Transport en Logistiek Nederland (TLN) and the emission of CO₂, NOₓ and SO₂ is likely to be higher in intermodal transport than in unimodal road transport in many situations, partly because of increasing speeds and low loading degrees, and to a large extent because of pre- and post-haulage (PPH), and therefore more for continental flows than for maritime ones. TLN therefore advocates longer trucks instead of modal shift. The study, once again for obvious reasons, does not suggest longer trains.

Concluding, a first research question that arises is whether intermodal transport can be said to be more environmentally friendly than all-road freight transport, yes or no. There seem to be more yes than no to be found in research and policy documents. But the no ones require a check of the yes perception, including the certainty of results.

A further important point is that a clear goal of the European Commission in the future is to internalise the external costs in all modes of transport (European Commission, 1995 and 2001 and the reports of the High level group on transport Infrastructure Charging). The external costs, which are the monetisation of the external effects, need to be estimated very carefully and the effect on the competitive situation of the different modes has to be considered. The White Paper of the European Commission (2001) sees the internalisation of external transport costs as an important instrument of stimulation of intermodal transport: “The integration of external costs must encourage the use of modes of lesser environmental impact” (p. 18). This principle is elaborated in different legal frameworks. In article 5.3 of the European regulation, referred to as the Marco Polo Programme, adopted by the European Parliament in 2002, the financial assistance of the programme is announced to “take the form of an external cost savings award” (European Parliament, 2002/a). The European Commission (2001, p. 27) explains the intentions of this article: “Modal-shift actions receive financial assistance in accordance to the saved external costs they represent”. This is an independent and objective principle to determine the intensity of financial aid. “… a subsidy of €1 per shifted 500 tkm must compensate the non-covered external costs of road transport”. “The Commission will once in the while adjust the relation between the amount of shifted ton-kilometres and granted assistance of €1 ‘award’”. The same document indicates the size of external costs (see Table 1).

Table 1 says that external costs of long distance road haulage are twice as high as those of rail haulage, and 5 to 6 times that of barge and short-sea shipping. The largest external costs of road transport are local emissions (33%), congestion (23%) and accidents (22%). The largest one of rail transport are ...
local emissions (31%), noise (28%) and infrastructure (23%). For barge and short-sea transport the largest external cost is local emissions (60% and 50% respectively). Note that the non-road modalities values only refer to the main modality. External costs of PPH, terminals etc. are not included.

Table 1 Marginal external cost per transport modality, € per 1000 tkm

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Road/(highway)</th>
<th>Rail</th>
<th>Barge</th>
<th>Short-sea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents</td>
<td>5.4</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Noise</td>
<td>2.1</td>
<td>3.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Local Emissions (air pollutions)</td>
<td>7.9</td>
<td>3.8</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Climate change</td>
<td>0.8</td>
<td>0.5</td>
<td>Marginal</td>
<td>Marginal</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>2.5</td>
<td>2.9</td>
<td>1.0</td>
<td>Less than 1.0</td>
</tr>
<tr>
<td>Congestion</td>
<td>5.5</td>
<td>0.2</td>
<td>Marginal</td>
<td>Marginal</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>24.1</strong></td>
<td><strong>12.4</strong></td>
<td><strong>Maximal 5.0</strong></td>
<td><strong>Maximal 4.0</strong></td>
</tr>
</tbody>
</table>

Cost difference with road traffic

| Saved external costs not moved by unimodal road transport | 11.8 | Ca. 19 | Ca. 20 |

Saving of €1 by not transporting freight by unimodal road transport

| 85 tkm | 52 tkm | 50 tkm |


The size of external costs is substantial: unimodal road transport for 1050 km costs about € 1240-1540 per load unit\(^3\), if also the trip back has a load. Let the total PPH-distance be 2*25=50 km and the main modality distance be 1000 km, intermodal transport would then maximally be 840-1330 €/LU. This is, assuming a total train and LU-weight per load unit of averagely 30t, or 30-45 €/t for 1000km. Rail costs in reality are lower. Concluding, the range of maximal main modality (= rail) internal costs of 30-45 €/1000tkm can be related to the above mentioned external costs of 24 €/ton (road), 12 €/ton (rail) and 5 €/ton (barge).

The European Commission is cautious. Transport Commissioner Loyola de Palacio is, according to Simons (2002), aware of the fact that there still is some uncertainty on the area of external costs and that internalisation schemes can only be introduced gradually. Current initiatives of the EU emphasise the harmonisation dimension of transport systems in different parts of Europe with the same external costs should have tax, charge and subsidy regimes which imply the same cost levels. The Commission has in mind to launch an internalisation framework for road transport and aviation in the summer of 2003 and will have a public discussion on policy conclusions.

In the framework of this policy goal the discussion focuses on the coverage of external costs by taxes, charges and subsidies rather than on the level of the external costs itself. The cost coverage differs per modality and relation. The question is what the impact will be on the market share of intermodal transport by an internalisation of external costs. Even if the external costs are relatively large for road transport, this does not necessarily mean that - in case of internalisation - the competition between modes will change because only the external costs, which are not already covered by taxes/charges, will be added.

Finally, there is the policy issue of fair and efficient pricing. This means that all transport costs are paid by the users of transport services. In theory the sum of internal and external costs represents fair prices. But in practice transport prices differ. The European research project RECORDIT (2001) has analysed internal and external costs of intermodal freight transport, the cost coverage and the coverage by prices for three European relations. Obviously the prices of all-road transport are far below the level of internal and external costs, even though the cost coverage of external costs is – roughly speaking – rather high. Apparently the generation of internal costs is biased by the way operations are run.

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\(^3\) On the basis of the cost model ROCOM (Konings and Kreutzberger, 2002). A load unit in this comparison is defined as 1.5 TEU.
This paper is a response to the problems and challenges outlined in this introduction. It reviews different studies and papers that are tackling the issue of the external effects of both intermodal and unimodal freight transport and evaluate the results in the light of the followed approaches (section 3). The aim of the review is to contribute to the clarification of what the internalisation of external costs means for the modal competition; clarify for what is possible with the knowledge of applied sciences. The paper does hardly or not at all move into the specialised field of calculating effects and impacts of transport. The review is structured by analysing the aspects, which are enlisted in the theoretical framework of section 2. Section 4 enlists the conclusions.

2. THEORETICAL NOTIONS ON EXTERNAL COSTS

The policy field of external transport costs is rather complex. Research results and internalisation effects are highly method dependent. Many aspects must be distinguished:

1) The focus of the study;
2) The economic approach;
3) The transport system aggregation level;
4) The system chain;
5) The range of external effects;
6) The external cost strategy;
7) The methods of effect and impact estimation;
8) The methods of impact valuation;
9) The instruments to realise the internalisation;
10) The modality analysed.

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**Figure 1** External costs are substantial

<table>
<thead>
<tr>
<th>External costs for 1000km:</th>
</tr>
</thead>
<tbody>
<tr>
<td>barge: 5 euro/ton</td>
</tr>
<tr>
<td>rail: 12 euro/ton</td>
</tr>
<tr>
<td>road: 24 euro/ton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source: Kreutzberger, 2002.</th>
</tr>
</thead>
</table>

External costs for 1000km:
- barge: 5 euro/ton
- rail: 12 euro/ton
- road: 24 euro/ton

PPH + BE = 5% - 25%
or more at one side of the chain

| RESULT: highest maximum rail costs = 45 euro/ton |
| RESULT: lowest maximum rail costs = 30 euro/ton |

Distance

Cost

PPH min PPH max

Terminal min Terminal max

PPH + BE = 5% - 25%
or more at one side of the chain

1050 km unimodal truck operation

25 km PPH 1000 km train or barge operation 25 km PPH
Ad 1) The focus of the study

The focus describes what the main subject of a study is, namely the size of external effects, possibly also their valuation to costs and benefits, possibly also the cost coverage of social costs by taxes, charges and subsidies or even the relation between real and fair/efficient prices. Another interest could be the comparison of the transport sector with other economic sectors. The focus is of influence for the choice of economic approach (point 2).

Ad 2) The economic approach

Efficient prices according to welfare theory are prices based on marginal internal and external\(^4\) costs. Marginal external costs focus on the costs of the last additional unit of transport (vehicle, vehicle-km, ton, ton-km, load unit, load unit-km; absolute or percentage etc.). This is different than the average of all units. A distinction in the studies has to be made between internal and external costs that are based on a marginal cost basis or an average one. Another distinction is that of short run and long run external costs. Short run analyses consider the infrastructure to be given; therefore the depreciation and capital costs of infrastructure are excluded. Optimal price levels refer to a situation, which is fixed by the existing infrastructure. The question, whether better results could be achieved with more infrastructure of one kind and less of another, is excluded. Long run analyses are interested in optimal results, given the freedom of choice both on the operational cost level and on the infrastructure investment level. Short run marginal external costs only take account of tear and ware costs of infrastructure.

Marginal data are derived by bottom-up research. They take account of the specific situation (including the technology and the site). Average data emerge from top-down analysis procedures. Not all information can be provided in the bottom-up fashion. Infrastructure classically is considered to be a resource whose cost is known as total. In a top-down procedure the infrastructure costs can be allocated to the micro-level of an external cost analysis.

A typical policy question, for which marginal cost analysis is appropriate, is the search for an efficient level of taxes, subsidies and charges. The comparison of internal and external costs of the transport sector with those of other sectors can typically be carried out by means of average costs. Transport pricing policies of the European Community focus on short run marginal social costs (and benefits).

Ad 3) The transport system aggregation level

The size of external costs depends on the envisaged transport system level. This can be the whole transport system or sub-categories, like freight and passenger transport. The external costs to the society which is no participant of the evaluated traffic/transport group is smaller than if also the effects to other system participants are included (e.g. health effects of freight transport to only non-participants (like residents) and all society (residents, drivers and passengers)). The European research projects UNITE (Sansom et al., 1999) and RECORDIT (Schmid et al., 2001; D4) look to all external costs. The British long tradition of comparing infrastructure-related costs with revenues for the road sector by means of a “fully allocated costs” model excludes external costs internal to the transport system (Sansom et al., 2001).

Own risks of a participant are no external costs, as the participant has decided to accept them, when entering the system. Certain costs to others, like accident damages, or no external costs as far as they are covered by insurances and therefore already internalised.

Ad 4) The system chain

The external effects can be analysed for the transport system only, or also for upstream and/or downstream events. Upstream events are external effects of producing something, which is used in the transport system, like gasoline or vehicles. Downstream events are external effects of things that have been used in the transport system, like destroying or recycling old vehicles.

\(^4\) The sum of internal and external costs are social costs. The sum of marginal internal and marginal external costs are marginal social costs. The sum of average (or total) internal and external costs are average (or total) social costs.
Ad 5) The range of external effects

The following list of typical external cost components is not complete, but nevertheless often only partly the subject of research projects:

- accidents;
- noise;
- air pollution;
- climate change;
- infrastructure;
- congestion;
- water pollution;
- damage to certain ecological systems;
- space occupation;
- visual intrusion.

Some of these components are of interest primarily to other system participant groups (like congestion), others primarily to non-participants (like land occupation).

Infrastructure costs refer to maintenance costs only in a short run marginal cost approach. Otherwise also depreciation will be included. One or both may not be covered by users, making (parts of) infrastructure costs external ones. And if they are covered, the coverage may not reflect the cost generation (e.g., trucks causing much more damage to roads than cars; in this case freight road transport generates external costs to passenger road transport).

The last three components are normally not included in analyses, as their estimation is quite uncertain, despite of their policy relevance in densely populated European regions and often stop infrastructure projects. If it is true that space occupation of unimodal road transport per freight unit is significantly higher than that of intermodal transport (also this is doubted by some authors, as we will see below), then this should be expressed in pricing schemes or by other types of political decisions.

The tension between policy relevance and research exclusion of spatial occupation justifies a brief elaboration of this point. Ground costs are part of the investments and therefore internal (depreciation) costs. Their size is not shown in marginal short run costs, which exclude depreciation. External damage to users and owners of grounds along transport infrastructure will often be incorporated in noise cost estimations, possibly also in local emission cost estimations. The observed or expected decrease of real estate prices is due to such features. But then there is also the increase of real estate prices outside the noise and emission influence zones of infrastructure, due to the growth of influence zones by more traffic or more infrastructure, which are normally not included.

Such land developments may be observed in urban regions with a high network density, where the occupation is likely to significantly contribute to spatial scarcity. According to Ricardo’s law of diminishing returns (Ricardo, 1891), the value of a piece of property rises when less attractive land is being used. The theory was developed based on fertility of soil, but today the value of real estate more relates to building permits. Typically, the value of land used for infrastructure is underestimated by governments, who issue building permits. In investment calculations they tend to use a value without a building permit and not a proper market price for land that could be used for housing, shopping malls or factories as an alternative for infrastructure.

Ad 6) The external cost strategy

Internalisation policies can be based on three strategies, the prevention strategy, the damage compensation strategy and the damage recovery strategy. The first is directed towards (ex-ante) avoiding damage, the second towards compensating for realised damage, the last towards (ex-post) making damage undone. The size of the costs and of the relation between costs and measures may differ per strategy (Boneschansker and ’T Hoen, 1993).
Ad 7) The methods of effect and impact estimation

The calculation of effects is the starting point of modelling the pathway from effects to impact and costs/benefits. A series of projects has been executed like this in order to calculate different kinds of external costs for the European Commission. The “Impact Pathway Approach” was developed and applied the first time by the ExternE project (Friedrich and Bickel, 2001), later also adopted by UNITE and RECORDIT.

The first step of the pathway calculates the effects (like emissions, noise, congestion) resulting from a transport activity. Special attention is paid to the fact that many external effects are interrelated in a complex way. Congestion, for instance, creates more emissions and higher probability of accidents, but perhaps the consequence of each accident is smaller due to the lower speed. The marginal cost is also contextual. The effects of an additional vehicle, for instance, depend on the existing traffic intensity and other traffic characteristics (as average speed, the traffic situation) and also on the characteristics of the infrastructure surrounding. The noise increase by an additional vehicle is larger if the level is low, and smaller if the level is high. For congestion the relation is the opposite. Naturally any effect of traffic is larger if the urban density around infrastructure is relatively high.

The second step is called “dispersion modelling”. Take regionally dispersed emissions. They are often transported over hundreds of kilometres before they finally cause damage to human health or to the environment. In this step concentrations of pollutants are calculated taking into account aspects such as wind speeds and wind directions.

In the third step, “quantification of physical impacts”, the levels of dispersed effects are translated into impacts, through the application of dose-response functions. Those functions relate changes in human health, material corrosion, crop losses, etc. to unit changes in ambient concentrations of pollutants.

Other methods exist, such as the damage pathway or the simple use of existing data. In this review a distinction will be made between studies using the Impact Pathway approach and others.

Ad 8) The methods of impact valuation

The last step in the Impact Pathway Approach is the monetary valuation of impacts. As far as possible market prices are utilised (e.g. for crop losses, material degradation). For quite a number of goods (for example human health) such prices do not exist. For the valuation of those goods alternative techniques have been developed, amongst which hedonic pricing, the travel cost method, contingent valuation and the human capital approach are the most known. Weinreich et al. (2000) explain the concept of willingness-to-pay (WTP) as substitute valuation method. WTP describes the amount of money that actors state to give to avoid damage or achieve benefits. The willingness to pay could also be derived from islands of market mechanisms, for instance the response to highway or city centre entrance charges, then representing observed WTP. WTP is an ex-ante concept. Its ex-post pendant is willingness-to-accept (WTA). The above mentioned real estate price changes due to changes in traffic (network) developments are an example of observed damages. Stated damages would be expectations (ex-ante or ex-post estimations) of such developments.

Ad 9) The instruments to realise the internalisation

The instruments to realise internalisation are rather independent from the estimation of the size of effects, impacts and monetary values. But it is useful to have the instruments in mind when thinking about estimation. The instruments differ per strategy (Ad 6). All three strategies can be realised by introducing monetary instruments such as taxes, charges, subsidies and/or financial compensation, which equalise the distribution of (dis)advantages between generators of traffic effects and persons who suffer/benefit of the impacts. The prevention strategy may also include non-monetary instruments such as the prohibition, the restriction or the enforcement of certain transport/traffic features. These instruments need legal frameworks, for instance a definition who is owner of a right or a problem. Only if the non-participant of the transport system (e.g., resident) is owner of the right of certain residential qualities, he or she can demand financial compensation from the causer of quality damages. The legal framework also needs to cover the geographical scale of the problem caused. Hence, noise and local emissions can be dealt with on a community level (e.g. bans on engines running for more
than three minutes at stand still), sulphur emissions on a European level, while CO₂ emissions must be negotiated globally.

All of these instruments can be qualified in terms of the focus or economic approach (Ads 1 and 2). For instance, ECMT (2000) distinguishes efficiency and welfare neutral or enhancing taxes for road freight transport.

Ad 10) The modality analysed

The modality analysed can go from unimodal road transport to road/rail transport or inland waterway transport to pure rail transport, air transport, etc.

All aspects

All of these aspects serve as check list, when reviewing the literature in the following section. The summary of section 4 contains a table which gives an overview of the aspect scores of all reviewed literature.

3. REVIEW OF PAPERS AND STUDIES

In this section the different studies, projects and articles are reviewed. The utilised methodologies are summarised and the main results given. An overview of the reviewed papers is given in the end of the section. Here the different aspects, as discussed in section 2, are given for each of the studies. The review covers 14 studies (A-N) and starts with some supplementary information on the two critical research reports, which were already presented in section 1.

A) The IRU/BGL study (IFEU and SGKV, 2002) focuses on the comparison between primary energy need and CO₂ emissions of pure road transport and of a combined road/rail transport. The study shows that 3 of 19 routes examined require higher primary energy need by combined road/rail transport (figure 2). Otherwise in eight cases the primary energy need of combined transport is up to 20% lower than that of road transport, in six cases it is 20-40% lower and in two cases it is lower by more than 40%. The best results were achieved by swap bodies and containers. If on the other hand CO₂ emissions are compared, the same study indicates that in two cases emissions generated by combined transport are higher than those generated by pure road transport. The rest of the study shows clearly that CO₂ emissions by combined transport are lower than those produced by pure road transport (for example: in four cases up to 20% lower, in seven cases 20-50% lower). The study analyses that the higher the nuclear power or hydropower proportion in the electricity generation mix of trains is and/or the higher the thermal efficiency of fossil power plants is, the lower the overall CO₂ emissions generated by the combined transport. This study leads the IRU, for evident reasons, to recommend a transport policy which would not be based on a further promotion of intermodal transport.

Such a conclusion represents a biased interpretation of an otherwise solid analysis. The study calculates only direct effects of only two entities, namely energy need and CO₂-emission. The dispersion of CO₂ and the impacts of energy need and CO₂-emission to society, and the valuation of impacts are no subject of the research. The differences of environmental performance are due to:

- the type of train. Rolling road trains hardly have energetically advantages, if any at all, opposite to trains with semi-trailers and containers;
- the length of train. Trains with 10 wagons (ca 200 m) have a higher specific energy need than road. Trains with 15 wagons (ca 300 m) already have lower values. Long trains (ca 700 m) have an energy need of about 60%.
- the amount of PPH. The study concludes that for PPH “perpendicular to the main route, the combined transport will be energetically disadvantageous when the total distance of ‘PPH’ is more than the half distance of the direct road transport”. And if the direction of PPH “is opposite to the main route (backwards) the combined transport is less favourable as soon as ¼ of the direct road transport distance is required for PPH” (IFEU and SGKV, 2002, pp. 34-35).
The three trains with negative environmental performances have cumulative negative input characteristics: very short main modality distances (2 of the 3 cases), longer PPH-distances than main modality distances (3 of the 3 cases), short train lengths (2 of the 3 cases) and Rolling Road trains (3 of the 3). This allows for drawing the conclusion that average intermodal trains will always have better environmental performances (in terms of energy and CO₂ emissions) than unimodal road transport.

The negative performance of PPH is mainly due to the higher fuel consumption of trucks in local transport (48 instead of 35 litres/100 km), which is very reasonable argumentation. Less reasonable may be the fact that local road performances in unimodal road transport are considered to be short. If local parts had a comparable proportion in the entire road distance as in intermodal chains, the environmental performance of unimodal road would decrease. This reflection in any case indicates the importance of location policies.

Another important observation for conclusions from the IRU/BGL study is that reference trucks are assumed to be loaded in both directions of a roundtrip. In practice this is often not the case, not only because of freight imbalances (which also bother other modalities), but also because of insufficiently informed and integrated operations. For instance, international intermodal freight road transport from and to Holland has loading degrees (in tons) of less than 55%, partly due to empty return trips. Incorporating empty return trips implies higher specific energy need of unimodal road transport.

B) Also the report of TLN is restricted to direct effects (no dispersion, impacts or valuation). The study focuses on energy need, emissions (local and CO₂) and land occupation of three modalities, unimodal road, intermodal rail and intermodal barge transport. The TLN cases refer to the following network and operational features: the main modality route length is 450 km, PPH rail maritime, rail continental, barge maritime, barge continental are 5%, 10%, 5% and 20% respectively. The trains have 21-28 wagons (maximal length then is approximately 400-550 m). The envisaged barges are the neo-

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**Figure 2** Primary energy consumption for every relation: Combined transport road/rail compared to road transport

<table>
<thead>
<tr>
<th>Relation</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kiskundoroszma-Wels (Istanbul-München, Road via Austria)</td>
<td>Rolling Road</td>
</tr>
<tr>
<td>Kiskundoroszma-Wels (Istanbul-München, Road via Praha)</td>
<td>Semi Trailer</td>
</tr>
<tr>
<td>Manching-Brennersee (Nürnberg-Verona)</td>
<td>Container &amp; Swap Body</td>
</tr>
<tr>
<td>Manching-Brennersee (München-Verona)</td>
<td></td>
</tr>
<tr>
<td>Lovosice-Dresden (Praha-Berlin)</td>
<td></td>
</tr>
<tr>
<td>Nürnberg-Verona</td>
<td></td>
</tr>
<tr>
<td>Stockholm-Basel (Road via Denmark)</td>
<td></td>
</tr>
<tr>
<td>Stockholm-Basel (Road via Ferry)</td>
<td></td>
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<tr>
<td>Lille-Avignon</td>
<td></td>
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<tr>
<td>Trier-Koblenz-Erfurt</td>
<td></td>
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<tr>
<td>Kiel - Hamburg-Billwerder</td>
<td></td>
</tr>
<tr>
<td>Köln-Busto(-Milano) (Road via Basel)</td>
<td></td>
</tr>
<tr>
<td>Köln-Busto(-Milano) (Road via Brennero)</td>
<td></td>
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<tr>
<td>London-Novara</td>
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<tr>
<td>Ludwigshafen-Tarragona</td>
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<tr>
<td>La Spezia-Milano</td>
<td></td>
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<tr>
<td>Hamburg-Budapest, Road via Praha</td>
<td></td>
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<tr>
<td>Hamburg-Budapest (Road via Passau)</td>
<td></td>
</tr>
<tr>
<td>Antwerpen-Busto(-Milano)</td>
<td></td>
</tr>
</tbody>
</table>

Source: SGKV, IFEU, 2001, page 43; Highlighting by authors.
kempenaar (32 TEU) and Europe barge (208 TEU). The report distinguishes maritime and continental flows and concludes that only the first have more favourable environmental performances. The main reason is that PPH distances are relative short or even zero. The report therefore advocates to stop the myths about the environmental effects of a modal shift.

Even though PPH – also according to other reports – deserves much attention, the TLN-report hardly contributes to a better understanding. Most results of modality comparisons are presented on the door-to-door level. The effects of PPH are not discussed separately. On this level the global direction of results is indicated in table 2.

### Table 2 Environmental performance of intermodal door-to-door transport in comparison with unimodal road transport

<table>
<thead>
<tr>
<th></th>
<th>Rail maritime</th>
<th>Rail continental</th>
<th>Barge maritime</th>
<th>Barge continental</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy need</strong></td>
<td>Favourable</td>
<td>Non favourable</td>
<td>Favourable</td>
<td>Non favourable</td>
</tr>
<tr>
<td><strong>CO₂</strong></td>
<td>Favourable</td>
<td>Non favourable</td>
<td>Favourable</td>
<td>Non favourable</td>
</tr>
<tr>
<td><strong>NOₓ</strong></td>
<td>Favourable</td>
<td>Slightly favourable</td>
<td>Favourable</td>
<td>Non favourable</td>
</tr>
<tr>
<td><strong>SO₂ and particles</strong></td>
<td>Non favourable</td>
<td>Non favourable</td>
<td>Non favourable</td>
<td>Non favourable</td>
</tr>
<tr>
<td><strong>Land occupation</strong></td>
<td>Non favourable</td>
<td>Non favourable</td>
<td>Non favourable</td>
<td>Non favourable</td>
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</tbody>
</table>

Some results of TLN are – as far as energy need and CO₂-emissions are concerned – quite deviating from the IRU/BGL study. The latter is more convincing in terms of methodology. The study assumes a very low fuel consumption of trucks, namely 29 litres/100 km (IRU/BGL: 34 litres/100 km). Train lengths are not varied. The reference truck is loaded in both directions of a roundtrip.

The conclusions about space occupation are contradictory. The study presents a figure which shows that space occupation of 30 truckloads on road or a track. The figure claims that road space occupation is lower if the collision avoidance system has blocks of more than 2 km. TLN concludes that “the space occupation of intermodal rail transport is a threefold of road transport (TLN, 1999, p. 16). This conclusion is a failure for different reasons. Dutch block lengths (2x1500 m for speeds of 130 to 140 km/hrs) would lead to much lower factors than 3, according to the TLN figure (page 17) itself. Longer trains (e.g., 50-70 load units instead of 21-28) would always have less space occupation. The figure does not take account of secondary infrastructure (e.g., nodes). And TLN does not discuss traffic space occupation by traffic other than by infrastructure. Distance zones because of security or utilisation restrictions due to noise and emissions are not incorporated.

Part of the TLN study is devoted to the coverage of environmental costs. This part of the study appears to be tendentious, cumulating in the conclusions that road covers 28%-179% of its costs, intermodal networks on the other would cover 0% (zero!) of their environmental costs (page 77).

C) An American article concerns the “Comparison of external costs of rail and truck freight transportation” (Forkenbrock, 2001). In this article the external costs (accidents, emissions and noise) are calculated for four (hypothetical) representative types of freight trains, differing substantially in terms of basic configuration, power, trailing tons of cargo, trip length and empty return rates. The resulting private and external costs are compared with those of freight trucking. The aim of the article is to find out if the full social cost pricing would exceed current operating costs faced by rail and trucking carriers.

The study concludes that on a ton-mile base, truck transport generates external costs that are more than three times higher than the four considered types of freight trains (also indicated by table 3). The last column of table 4 indicates that if all external costs were included in the costs faced by rail and truck freight providers, the costs of the freight shipment would increase by about 13 % for truck transport and by 9,3 to 22,6% for rail transport.
Table 3  External costs of truck and rail freight (in 1994 dollar-cents* per ton-mile)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Accidents</th>
<th>Air pollution</th>
<th>Greenhouse gases</th>
<th>Noise</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>General freight truck</td>
<td>0,59</td>
<td>0,08</td>
<td>0,15</td>
<td>0,04</td>
<td>0,86</td>
</tr>
<tr>
<td>Heavy unit train</td>
<td>0,17</td>
<td>0,01</td>
<td>0,02</td>
<td>0,04</td>
<td>0,24</td>
</tr>
<tr>
<td>Mixed freight train</td>
<td>0,17</td>
<td>0,01</td>
<td>0,02</td>
<td>0,04</td>
<td>0,24</td>
</tr>
<tr>
<td>Intermodal train</td>
<td>0,17</td>
<td>0,02</td>
<td>0,02</td>
<td>0,04</td>
<td>0,25</td>
</tr>
<tr>
<td>Double-stack train</td>
<td>0,17</td>
<td>0,01</td>
<td>0,02</td>
<td>0,04</td>
<td>0,24</td>
</tr>
</tbody>
</table>

Table 4  Private and external costs of truck and rail freight (in 1994 dollar-cents per ton-mile)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Private costs (1)</th>
<th>External costs (2)</th>
<th>User charge underpayment (3)</th>
<th>(2)+(3) as % of (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General freight truck</td>
<td>8,42</td>
<td>0,86</td>
<td>0,25*</td>
<td>13,2</td>
</tr>
<tr>
<td>Heavy unit train</td>
<td>1,19</td>
<td>0,24</td>
<td></td>
<td>20,2</td>
</tr>
<tr>
<td>Mixed freight train</td>
<td>1,2</td>
<td>0,24</td>
<td></td>
<td>20,2</td>
</tr>
<tr>
<td>Intermodal train</td>
<td>2,68</td>
<td>0,25</td>
<td></td>
<td>9,3</td>
</tr>
<tr>
<td>Double-stack train</td>
<td>1,06</td>
<td>0,24</td>
<td></td>
<td>22,6</td>
</tr>
</tbody>
</table>


D) The paper “Gecombineerd vervoer is milieuvriendelijk; fictie of werkelijkheid?” (Combined transport is environmentally friendly; fiction or reality?) from the authors De Leijer and Ruijgrok (1990) remarks that external effects of transport, such as emissions and energy need, should be compared on the basis of trip-characteristics instead of on ton-kilometres.

Emissions are often expressed in ‘tonkm’, but the problem with using ‘ton-kilometres’ as unit of measurement is that it is not always an adequate basis for comparisons. For example, transporting 1000 ton over 10 kilometres would be regarded as the same as transporting 10 tons over 1000 kilometres, even though the choice of operations and vehicles is likely to be different in both cases. To circumvent this problem, emissions and energy need should be compared on the basis of aspects such as loading capacity, load factor, type of vehicle used, distance of PPH, geography of the trip, congestion on the road, etc.

A case study that compared the energy need of trips executed with semi-trailers on trains, swap bodies on trains, rolling road and trailers on barges, between Rotterdam on the one hand and Mannheim, Munich, Basel, Milan, Vienna and Montpellier on the other, allowed the authors to draw the next conclusion. The study showed that intermodal transport did not always have a positive impact on the environment in terms of energy need. But if aspects such as congestion on the roads, noise and safety matters are taken into account, intermodal transport could have a more positive impact (on the environment), than if the comparison was done only on the basis of energy need.

E) The article “Grondvervoer op rails, vergelijking emissies weg- en gecombineerd weg-railvervoer” (Transport by rail, comparison between the emissions of unimodal road transport and combined road-rail transport) (Van Binsbergen and Schoemaker, 1993) describes a study where the ACTS (Afzet Container Transport System), a kind of combined road/rail transport system, was used in the Netherlands to carry away polluted earth and provide clean earth instead. The aim was to analyse the magnitude of the realised emission reductions when using the ACTS compared to unimodal road transport. The calculations where made for the trip between Hengelo and Utrecht for the different combinations of loaden and unloaden return and depart trips. The results of the study are illustrated in the following table.
Table 5  Emissions of intermodal rail/road transport compared to unimodal road transport

<table>
<thead>
<tr>
<th></th>
<th>Loaden depart trip and loaden return trip</th>
<th>Loaden depart trip and unloaden return trip</th>
<th>Unloaden depart trip and loaden return</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx, aerosols, CxHy: up to 80% reduction</td>
<td>NOx, aerosols, CxHy: up to 81% reduction</td>
<td>NOx, aerosols, CxHy: up to 83% reduction</td>
<td></td>
</tr>
<tr>
<td>CO2, CO: reductions between 36% and 52%</td>
<td>CO2, CO: reductions between 38% and 53%</td>
<td>CO2, CO: reductions between 39% and 58%</td>
<td></td>
</tr>
<tr>
<td>SO2: increase of 52%</td>
<td>SO2: increase of 47%</td>
<td>SO2: increase of 46%</td>
<td></td>
</tr>
</tbody>
</table>

From the table it is clear that for the trip between Hengelo and Utrecht, only the emissions of SO2 seem to increase with the use of the intermodal ACTS, while all other pollutants can be reduced.

F) The paper “Emissies van gecombineerd vervoer” (Emissions of combined transport) (Walstra et al., 1995) concerns a case study carried out in the Dutch ‘Aagrunol Project’. The aim of the case study was to compare the emissions and the energy need associated with the transport of 200 000 tons of earth by unimodal road transport with that of combined transport. Furthermore the study comprises a theoretical analysis of the emissions and the energy need associated with road/rail transport. The methodology consisted of using existing information about emission factors and the energy need formula (of Rijkeboer) to calculate the emissions and the energy need.

The results in the Aagrunol project made it clear that combined transport, though its PPH produces quite some emissions, seems to be the most environmentally friendly option regarding emissions and energy need. Furthermore the differences in the emissions between the combined road/barge option and the combined road/rail option are very small. The emissions of CO2 are always lower with the barge option than the rail option, while the NOx, CO, CxHy and aerosol emissions are always higher.

G) When developing an “Energy logistics model for system calculations of transport- and energy supply systems”, Blinge (1995) compared transport of goods in a semi-trailer between Gothenburg and Stockholm by road and intermodal transport by use of electrically powered trains. The analysis includes PPH (50 kms), terminal handlings as well as main modality transport (distance = 448 kms). Three different location types of consigners/consignees were assumed (figure 3): in prolongation of the main modality route, perpendicular to the main modality route, and along the main modality route. These lead to different external unimodal road effects. Electricity can be generated in different ways, namely on the basis of fossil fuel, or on the basis of the Swedish or European power plant mix (rules 3, 4 and 5 respectively of table 6). Swedish electricity is generated by water and nuclear and thereby involving less emissions.

Table 6 shows that CO2 emissions are the lowest for the train, given Swedish energy. Other electricity sources imply that train CO2 emissions are lower than road (rows 11 and 12), unless the shippers are located along the track (row 13). SOx emissions of trains are lower in the combination “Swedish electricity” and “prolongation”. Otherwise road transport has better performances. For all other emissions, rail transport is more favourable.

In the Swedish practice the environmental performance of rail is more favourable than shown in table 6, because, the rail operator Rail Combi has an agreement with their power supplier that “their” electricity is “green”, i.e., water or wind generated with virtually zero emissions.
**Figure 3** Energy logistics model for system calculations of transport- and energy supply systems (visualisation of Blinge, 1995)

Intermodal rail transport is more favourable for:

- CO2
- SOx, if Swedish E.
- Other emissions
- CO2
- Other emissions
- CO2, if Swedish E.

**Table 6** Energy use and emissions including fuel generation for intermodal transport and road transport Gothenburg-Stockholm

<table>
<thead>
<tr>
<th>Part.</th>
<th>Energy use (MJ)</th>
<th>CO2 (kg)</th>
<th>SOx (g)</th>
<th>NOx (g)</th>
<th>CO (g)</th>
<th>HC (g)</th>
<th>CH4 (g)</th>
<th>Total (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermodal transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Functional unit: semi-trailer</td>
<td>1204</td>
<td>89</td>
<td>35.1</td>
<td>1322</td>
<td>369</td>
<td>104</td>
<td>27.6</td>
<td>32.9</td>
</tr>
<tr>
<td>2 Terminal handling</td>
<td>86</td>
<td>22</td>
<td>1.5</td>
<td>235</td>
<td>20.6</td>
<td>10</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>3 Rail transport 448 km Fossil fuel electricity</td>
<td>5850</td>
<td>457</td>
<td>2948</td>
<td>1453</td>
<td>316</td>
<td>27</td>
<td>n*</td>
<td>21</td>
</tr>
<tr>
<td>4 Swedish electricity</td>
<td>2861</td>
<td>84</td>
<td>211</td>
<td>168</td>
<td>126</td>
<td>105</td>
<td>n*</td>
<td>42</td>
</tr>
<tr>
<td>5 Western Europe electricity</td>
<td>4961</td>
<td>320</td>
<td>737</td>
<td>590</td>
<td>253</td>
<td>590</td>
<td>n*</td>
<td>105</td>
</tr>
<tr>
<td>6 Terminal handling</td>
<td>86</td>
<td>22</td>
<td>1.5</td>
<td>235</td>
<td>20.6</td>
<td>10</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>7 To consignee</td>
<td>1204</td>
<td>89</td>
<td>35</td>
<td>1322</td>
<td>369</td>
<td>104</td>
<td>28</td>
<td>33</td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 Fossil fuel electricity</td>
<td>8430</td>
<td>679</td>
<td>3021</td>
<td>4568</td>
<td>1095</td>
<td>504</td>
<td>56</td>
<td>87</td>
</tr>
<tr>
<td>9 Swedish electricity</td>
<td>5441</td>
<td>306</td>
<td>284</td>
<td>3283</td>
<td>905</td>
<td>335</td>
<td>56</td>
<td>108</td>
</tr>
<tr>
<td>10 Western Europe electricity</td>
<td>7541</td>
<td>542</td>
<td>810</td>
<td>3705</td>
<td>1032</td>
<td>820</td>
<td>56</td>
<td>171</td>
</tr>
<tr>
<td>Road transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Prolongation case</td>
<td>10321</td>
<td>763</td>
<td>310</td>
<td>11192</td>
<td>2579</td>
<td>950</td>
<td>237</td>
<td>308</td>
</tr>
<tr>
<td>12 Road transport 448 km</td>
<td>8146</td>
<td>602</td>
<td>238</td>
<td>8828</td>
<td>1962</td>
<td>756</td>
<td>187</td>
<td>246</td>
</tr>
<tr>
<td>13 Along route case</td>
<td>6611</td>
<td>489</td>
<td>193</td>
<td>7176</td>
<td>1658</td>
<td>600</td>
<td>152</td>
<td>197</td>
</tr>
</tbody>
</table>

Source: Blinge, 1995.; n* = negligible. Note: Total road (dependent on location shipper/consignee towards terminal) = 11 or 12 or 13. Total rail (dependent on electricity provision): 1+2+6+7+3= 8 or 1+2+6+7+4=9 or 1+2+6+7+5=10.

**H)** In the report *The feasibility of a piggyback network for the British Isles*, MDS Transmodal and Servant Transport Consultants or the Piggyback Consortium (1994) investigates how different scenarios will impact the total external effects of transport domestically in the UK and between the UK and the Continent. Four scenarios with piggyback transport are compared with a business-as-usual sce-

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5 Piggyback is a term sometimes used for denoting intermodal transport based upon semi-trailers on rail.

6 UK road freight transport is dominated by semi-trailer transport but due to the limited loading profile on rail, they cannot be moved on rail without extending the infrastructure or investing in low-built rail wagons in combination with minor infrastructure adjustments.
nario. The total effects depend strongly on how much traffic is lifted from road to rail in the different scenarios. The scenario “central corridor with German routes” assumes an 8.7% market share of intermodal transport, while adding “halved track charges” to the scenario almost doubles the market share.

The results show that each scenario decreases energy need, CO₂, SOₓ, CO, HC and NOₓ emissions and accidents by 1-7% compared to the business-as-usual scenario. Congestion is vaguely said to decrease on some routes, while road maintenance is the only figure priced. A modal transfer is said to save £11 million annually, however without referring to a specific scenario. Noise and local disturbances around terminals are likely to increase marginally.

It should be noted though, that the calculations were part of a project promoting infrastructure and rolling stock investments for intermodal transport and as for the IRU-funded studies, there is a risk that the analysis is biased, but in this case favouring rail and intermodal transport.

I) Also Demker et al. (1994) line out scenarios in the report Environmental effects of traffic mode choice for freight transport and like the Piggyback consortium the calculations are based upon long term shifts between traffic modes. The risk of bias is here related to that shipping is favoured, and the authors largely take the approach that rail replaces shipping rather than road transport. The report has been criticised also for using non-favourable figures for electricity generation for rail.

One of the scenarios relates to a 25% increase in rail transport between 1991 and 2015. Twelve of the additional 14 million tons are expected to be referred to intermodal transport. Full transport chains are calculated and the results show just marginal changes (-2 to +3%) of all emissions and energy need compared to a basic scenario. Another scenario relates to an extensive transfer of goods from rail to road, however not stipulating the share of intermodal or wagonload transport. The results indicate increases for all emissions in the range of 12 to 21% and an increase of energy need by 4%.

J) In the early 1990’s, the Swedish transport industry realised that they were not considered as trustworthy by their customers, who were asking for environmental effects of logistics solutions. The assumptions, calculations and therefore results of different logistics service providers were simply too different. They then started Nätverket för Transporter och Miljön (NTM, the Network for Transport and the Environment). That is a non-profit association working for a common view and consensus on how the environmental issues of the transport sector are to be solved in order to attain a transport system that is sustainable in the long term. This means that NTM spreads knowledge on environmental issues, initiates research and development, and works for common bases of calculation of the environmental impact of transport (NTM, 2003). The basic attitude is that there is not one scientifically totally correct way of calculating environmental effects of transport activities, but an attempt must be made to do it in a consistent way across company and traffic mode borders. Their tool, NTM calc, is based upon Swedish emission data.

The Swedish intermodal operator Rail Combi published a comparison of environmental effects between Gothenburg and Stockholm in 2000 (Rail Combi, 2000), that is the same example used by Blinge. The calculation is very detailed concerning the transport chain, e.g. with real distances for different modes, including all terminal handling and marshalling operations and different locomotives. It is based upon an earlier version of NTM calc and the primary emissions are specified and translated into an Environmental cost. Since only emissions are dealt with and the train is powered by water-generated electricity, the environmental costs are virtually zero.

K) The European Commission has supported a number of studies in the field of environment and transport. The study “RECORDIT, deliverable 4; External cost calculation for selected corridors” (Schmid et al, 2001) and “RECORDIT, deliverable 6; Imbalances and inefficiencies of the current pricing system” (Weibel et al., 2001) calculates the external costs (global warming, noise, accidents, air pollution and congestion) of unimodal road transport and intermodal chains on three freight corridors: Genova-Manchester, Patras-Gothenburg, and Barcelona-Warsaw. RECORDIT covers the entire range of external cost calculations, from effects to dispersion, impacts and valuation, all systematically structured by applying the Impact Pathway Approach. External cost calculations include up- and downstream activities. The second report investigates the coverage of external costs by taxes, charges
and subsidies in all involved European countries and compares the social costs with real transport prices.

For the route Barcelona-Warsaw, where the involved modes are road and rail for the intermodal situation, the study concludes that intermodal transport generates about 38% of the external costs of all-road transport. For the route Patras-Gothenburg, where the intermodal chain is made up of road transport, short sea shipping and rail transport, intermodal transport’s external costs are 52% of the external costs of all-road transport. For the route Genova-Manchester, where the chain consists of rail, inland waterway, and short-sea shipping, the external costs of the intermodal chain are 42% of the external costs of all-road transport.

Table 7  Indication of some methodological features of external cost calculations and estimations of RECORDIT

<table>
<thead>
<tr>
<th>Component</th>
<th>Effects</th>
<th>Type of non-internalised impacts</th>
<th>Valuation and points of attention</th>
</tr>
</thead>
</table>
| Accidents       | Accident risks (mortality, light or severe morbidity) | a) Increase of WTP/WTA of others on other or same modality.  
b) Increase of WTP/WTA of friends of others  
c) Damage to rest of society | Road: evidence flow/risk is week.  
Ad a) No reliable country information (general)  
Ad b) Huge uncertainty  
Ad c) Fatalities: 10% of fatality risk value (Nellthorp, 2001)  
This is then to cover costs like production losses, administration costs, parts of medical costs.  
Not mentioned: loss of educational investments. |
| Air pollution   | Dispersion of local emissions (11 gases)     | Human health.  
Building materials.  
Crops.                                         | Missing impacts (paper authors):  
Rail downstream effects  
Road floodlight links and nodes;  
Rail shunting yards;  
Substitution materials in buildings.               |
| Climate change  | Dispersion of greenhouse gases, e.g. CO₂     | Global warming                                                       | Calculate prevention costs to realise targets (Kyoto)  
Problem: there is no Europe- and sector-wide strategy to realise Kyoto targets, at all or on the most efficient way.  
Stock character of CO₂ in sky implies that possibly the wrong measures are taken.  
Conclusion: uncertainty about measures, therefore also costs. |
| Noise           | Dispersion of noise                          | a) Medical costs paid by the health sector.  
b) Productivity loss of persons.  
c) Less enjoyment, more discomfort and fear.   | Ad a and b) “Cost of illness measure”, using market prices  
Ad c) WTP/WTA for loss of welfare. In addition WTP on the basis of house prices and surveys.  
Valuation: survey for (c) may suffer of unawareness, hence underestimation.  
Possibly high noise costs of rail recommend substitution of tread- by disc-brakes.  
Dispersion: noise dispersion only calculated for “directly hit houses”. |

Deliverable 6 gives an overview of so-called real costs, current costs and prices (figure 4). The real costs are social costs without indirect costs. As the internal costs in the real and current costs are the same, the requirement of internalisation of external costs will depend on the amount of coverage of external costs by the balance of taxes, charges and subsidies. For the three RECORDIT cases this is 89%-103% for the intermodal solutions and 90%-101% for the road solutions. The cost coverage is slightly better for road transport. This means that if cost coverage is the central criterion, and if the three cases were representative, internalisation would not improve the relative position of intermodal transport.
A comparison of current costs and prices shows, that the prices cover 96%-104% of the intermodal current costs, whereas in the road sector they only cover 60%-77%. Large deficits appear to be present in all-road solutions. RECORDIT suggests a certain amount of “non legal” actions as a cause.

Figure 4  The relation between “real costs”, “current costs” and “prices” in RECORDIT

![Diagram showing the relation between real costs, current costs, and prices in RECORDIT]


L) The QUITS project (QUality Indicators for Transport Systems), carried out by ISIS, ENEA, INISTENE, ZEW, ISI-Fraunhofer and WHO-ECEH (ISIS et al., 1998), calculates the environmental and health impacts of road and rail transport systems for the following routes: Frankfurt-Milan, Munich-Patras, Lille-London. The study calculates external costs of air pollutants, global warming, noise and accidents. The calculations are restricted to the use of transport infrastructure. Supply of infrastructure is not taken into account. Also down- and upstream effects are excluded. All calculations refer to a period of one year, which is 1995, or to a single trip.

The damage pathway approach has been followed, which is subdivided into four stages; the first stage calculates air and noise pollutants and counts accidents. The second stage is about the measurement of the concentration of noise and pollutants at different places (dispersion). The third stage quantifies the impacts by the use of exposure-response functions (which are linear functions between concentration changes and human health impacts). The fourth stage includes the monetary valuation of the impacts. To execute these four stages, an integrated model, which consists of three inter-linked models, was employed. For the route Frankfurt-Milan (>500km), the study concludes that air pollutants are the most important external cost for road transport; they constitute about 50% of the total external costs from road transport. For rail transport, the main externality is noise and constitutes more than 50% of the total external rail costs. In general each external cost (air pollutants, global warming, noise and accidents) of road transport is much higher than for rail transport. Over a period of time of 1 year (1 trip), the total external costs of road transport are about 12 times (11 times) higher than for rail transport. For both road and rail, CO₂ is the most emitted pollutant per trip, though the CO₂ emission of road transport is about 6 times higher than for rail transport.

For the route Lille-London (<500km), the study concludes that over a period of time of 1 year (1 trip) the noise nuisance is the highest external cost for both road and rail transport, though the monetary valuation of noise is about 12 times (1,15 times) higher for road transport than for rail transport. The external costs of noise constitute respectively 55% and 90% of the total external costs of road and rail transport. When all the external effects are considered over 1 year (over 1 trip), road transport seems to

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7 The three models involve the “Workbook on Emission Factors for Road Transport”, the “MLuS” and the “EcoSense”.

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have total external costs that are about 19 times (2 times) higher than rail transport. Regarding the emissions, it seems that CO₂ is the most emitted pollutant for road and rail transport. Per trip, road transport emits about 4.5 times more CO₂ than rail transport.

For the route Munich-Patras (>500km), the figures demonstrate that over a period of time of 1 year (and also in 1 trip), the air pollutants form the largest external costs for both rail and road transport. They make up respectively 42% and 50% of the total external costs of road and rail transport. The monetary valuation of air pollution generated by road transport over 1 year (per trip) is 114 times (6 times) larger compared to the air pollution caused by rail transport. The total external costs of road transport calculated over a period of time of 1 year (1 trip), are about 137 times (7.1 times) larger than for rail transport. Concerning the emission it appears that CO₂ is the largest pollutant for both transport modes. Road transport emits about 3 times more CO₂ than rail transport.

Summarising, the difference of external costs between road and rail is significantly higher than in other studies.

M) The European research project PETS (Pricing European Transport Systems; 1996-1999) had three main objectives. First, the study gives an overview of the current pricing situation of passenger and freight transport. Secondly, those prices are analysed to see whether they reflect the relevant internal and external costs. Finally, the consequences of moving to a more appropriate price level that takes into account external constraints and developments, are forecasted. As external costs of transport, PETS focused on accident costs, congestion, noise, air, pollution and global warming. Five corridors have been analysed in the study, but only 3 of them concern freight transport (the Cross-Channel Corridor, the Transalpine Corridor and the Finnish Corridor). Only the Transalpine Corridor deals with combined transport and rolling motorways.

PETS concluded that the appropriate level of charges is strongly dependent on the local context. Current charges can be too low in densely populated regions with a lot of traffic and too high in less busy areas. Another conclusion is that road freight vehicle taxation should be reformed and based on vehicle characteristics and distance travelled.

All reviewed literature

Table 10 gives a comprehensive overview of the ingredients of the reviewed studies. The structure of the table is derived from the contents discussed in section 2. The ensemble of reviewed literature represents a large range of freight transport fields, policy objectives and scientific approaches, at the same time rather the peak of an iceberg than a complete overview.

Only three studies cover and discuss the whole range from effects, dispersion, impacts, valuation, calculation of social costs and cost coverage, comparison of social costs and prices. Some studies present costs, a level which implies that the steps “dispersion”, “impacts” and “valuation” actually are incorporated. In the research or publications, however, they are not explicated. Finally there are numerous studies which focus on the effects only. Most envisaged effects or costs are average ones, including some which are dealing with cost coverage issues.
Table 8 Overview of ingredients of reviewed literature

<table>
<thead>
<tr>
<th>Score</th>
<th>Study</th>
<th>1) Focus of study</th>
<th>2) Economic approach</th>
<th>3) System aggregation</th>
<th>4) System chain</th>
<th>5) External effects</th>
<th>6) Strategy</th>
<th>7) Impacts</th>
<th>8) Valuation</th>
<th>9) Instruments</th>
<th>10) Modality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E = Effects</td>
<td>I = Impacts</td>
<td>V = Valuation costs and benefits</td>
<td>C = Coverage of costs</td>
<td>P = Pricing and social costs</td>
<td>5/5 = five of five effects</td>
<td>U = Upstream effects included D = Downstream effects included</td>
<td>P = Prevention DC = Damage compensation DR = Damage recovery</td>
<td>IPA = Impact pathway approach O = Other</td>
<td>SW = Stated willingness to pay DW = derived willingness to pay OD = Observed damage ED = Expected damage O = Otherwise</td>
</tr>
<tr>
<td></td>
<td></td>
<td>E = Marginal A = Average S = Short run L = Long run</td>
<td>External field consists of: NP = Non-participants of the transport system P = Participants of the transport system</td>
<td>U = Upstream effects included D = Downstream effects included</td>
<td>A = Accidents N = Noise E = Energy AP = Air pollution CC = Climate change I = Infrastructure C = Congestion W = Water pollution S = Space occupation O = Other entities 10/10 = ten of ten effects</td>
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<td>P = Prevention DC = Damage compensation DR = Damage recovery</td>
<td>IPA = Impact pathway approach O = Other</td>
<td>SW = Stated willingness to pay DW = derived willingness to pay OD = Observed damage ED = Expected damage O = Otherwise</td>
<td>T = Taxes Ch = Charges S = Subsidies C = Compensation L = Legal frameworks discussed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>E = Effects I = Impacts V = Valuation costs and benefits C = Coverage of costs P = Pricing and social costs 5/5 = five of five effects</td>
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<td>E = Effects I = Impacts V = Valuation costs and benefits C = Coverage of costs P = Pricing and social costs 5/5 = five of five effects</td>
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<td>E = Effects I = Impacts V = Valuation costs and benefits C = Coverage of costs P = Pricing and social costs 5/5 = five of five effects</td>
</tr>
<tr>
<td>A</td>
<td>iRU/BGL, 1999</td>
<td>E 1/5</td>
<td>A</td>
<td>N. e.</td>
<td>0/2</td>
<td>E, CC</td>
<td>2/10</td>
<td>N.a.b.1</td>
<td>N.a.b.1</td>
<td>N.a.b.1</td>
<td>0/5</td>
</tr>
<tr>
<td>B</td>
<td>TLN, 1999</td>
<td>E, V, C 3/5</td>
<td>A</td>
<td>N. e.</td>
<td>0/2</td>
<td>E, AP, CC, (C), S</td>
<td>5/10</td>
<td>N. e.</td>
<td>N. e.</td>
<td>T, Ch, 2/5</td>
<td>Ro, Ra, RaPi, Ba, PPH, I 6/6</td>
</tr>
<tr>
<td>C</td>
<td>Forckenbrock, 2001</td>
<td>E, V 2/5</td>
<td>A</td>
<td>NP, P</td>
<td>0/2</td>
<td>A, AP, CC</td>
<td>N 4/10</td>
<td>N. e.</td>
<td>O</td>
<td>O</td>
<td>0/5</td>
</tr>
<tr>
<td>D</td>
<td>De Leijer and Rui- grok, 1990</td>
<td>E, I, V 3/5</td>
<td>A</td>
<td>NP, P</td>
<td>0/2</td>
<td>(A, N, C) E</td>
<td>4/10</td>
<td>N. e.</td>
<td>O</td>
<td>O</td>
<td>0/5</td>
</tr>
<tr>
<td>E</td>
<td>Van Binsbergen and Schoemaker, 1993</td>
<td>E, 1/5</td>
<td>A</td>
<td>NP, P</td>
<td>0/2</td>
<td>(A, N, C) E</td>
<td>4/10</td>
<td>N. e.</td>
<td>O</td>
<td>O</td>
<td>0/5</td>
</tr>
<tr>
<td>F</td>
<td>Walstra et al., 1994</td>
<td>E, 1/5</td>
<td>A</td>
<td>NP, P</td>
<td>U*</td>
<td>1/2</td>
<td>AP, E,</td>
<td>2/10</td>
<td>N. e.</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>G</td>
<td>Blinking, 1995</td>
<td>E, 1/5</td>
<td>A</td>
<td>NP, P</td>
<td>0/2</td>
<td>E, AP, CC</td>
<td>3/10</td>
<td>N.a.b.1</td>
<td>N.a.b.1</td>
<td>J N.a.b.1</td>
<td>0/5</td>
</tr>
<tr>
<td>H</td>
<td>Piggyback consor tium, 1994</td>
<td>E, V, C, P 4/5</td>
<td>A</td>
<td>L</td>
<td>NP, P</td>
<td>0/2</td>
<td>A, N, E, AP, CC, I, C, O</td>
<td>P</td>
<td>O</td>
<td>ED (infrastruc ture maint.)</td>
<td>Ch</td>
</tr>
<tr>
<td>I</td>
<td>Demmer et al., 1994</td>
<td>E, 1/5</td>
<td>A</td>
<td>NP, P</td>
<td>0/2</td>
<td>E, AP, CC</td>
<td>3/10</td>
<td>N.a.b.1</td>
<td>N.a.b.1</td>
<td>J N.a.b.1</td>
<td>0/5</td>
</tr>
<tr>
<td>L</td>
<td>QUIDS, 1998</td>
<td>E, I 2/5</td>
<td>M, A</td>
<td>NP, P</td>
<td>0/2</td>
<td>A, N, AP, CC, I, C, O</td>
<td>5/10</td>
<td>N. e.</td>
<td>IPA</td>
<td>SW, DW,</td>
<td>0/5</td>
</tr>
<tr>
<td>M</td>
<td>PET, 1996-1999</td>
<td>E, I, V, C, P 5/5</td>
<td>M or A depending on the corridors</td>
<td>P</td>
<td>0/2</td>
<td>A, N, AP, CC, C</td>
<td>5/10</td>
<td>N. e.</td>
<td>O</td>
<td>ED</td>
<td>T, C</td>
</tr>
</tbody>
</table>

x/x=x of x effects for each column, N.a.b.1 = Not applicable because of 1; N. e. = Not explicated * for the electricity production in power plants. ** Coastal shipping
4. CONCLUSIONS

The overview clearly shows that intermodal transport has substantially better environmental performances than unimodal road transport:

- already, if only “energy use” and “CO₂ emission” are taken into consideration;
- but even more if local emissions (except SOₓ), accidents, congestion, and noise are incorporated in calculations;
- except for SOₓ in which intermodal rail transport will only have better performances in case of very favourable conditions;
- for different kinds of commodities, such as general cargo (higher value and lower density) and also some bulk commodities;
- unless different unfavourable conditions cumulate, like:
  - very long PPH distances;
  - shippers locations along the main modality route, implying a backwards move of PPH-vehicles;
  - electricity production from non energy-efficient fossil power plants;
- except for rolling road trains which has environmental performances comparable to unimodal road transport, but offers to move emissions from sensitive areas such as alpine valleys and tunnels.
- despite the fact that important effects are excluded from any study up to now, like water pollution and damage to ecological systems;
- despite the fact that spatial scarcity, an important entity in urban conglomerations of crowded Europe is only partly articulated in studies;
- and partly because of the fact that the environmental disadvantages of nuclear electricity production are excluded from all studies up to now.

Only some studies elaborate the performance differences into internalisation and pricing policy frameworks. Such elaboration is of interest for European transport, energy and sustainability policies, as these expect the internalisation to improve the competitiveness of intermodal transport. The methodology of estimating or calculating dispersion and impacts and valuating impacts to costs/benefits is complex. Results are quite method dependent, are characterised by certain amounts of uncertainty, and show larger ranges. The policy urgency would nevertheless justify careful internalisation trajectories.

A point which deserves attention is that the RECORDIT study does not confirm the expectation of the White paper that internalisation of external costs would improve the competitiveness of intermodal transport. The criterion hereby is not the height of external costs, but the coverage of external costs by the balance of taxes, charges and subsidies is the criterion for additional internalisation actions. The external costs of intermodal transport are significantly lower than those of unimodal road transport, despite any uncertainty of results. For the corridors, analysed in RECORDIT, however, the cost coverage is higher for unimodal road transport than for intermodal transport. The report also observed that the prices of unimodal transport are far below the expected social (= sum of internal and external) costs. In this case the control of operational rules (like driving times) would contribute more to the improvement of the competitiveness of intermodal transport than internalisation of external costs.

Lack of cost coverage could also be an incentive for intermodal transport to improve its quality. A good example is investment into the development and implementation of disc brakes for trains, which generate less noise.
PPH is a crucial part of the success of intermodal networks. Even though the majority of studies would oppose the conclusions of one study which claims that – more or less – only maritime networks perform environmentally competitive with unimodal road transport, the PPH for two reasons does deserve much more attention by transport policies than currently is the case. PPH is a burden for intermodal chains and networks on the level of both internal and external costs. Congestion and local environmental strains are most critical in urban areas and unwise use of intermodal transport often adds to the local problems, while total external effects are lowered (Holzapfel, 2003). Improving the resource, operational network efficiency of PPH would:

- increase the market competitiveness (direct and internalised costs) of intermodal transport;
- improve the cost coverage of external costs of intermodal transport, implying that internalisation is more likely to support intermodal transport; and
- improve the tolerance for local effects in urban areas.

Also for both reasons, internal and external costs, spatial and network policies are crucial. Short distances between terminals and shippers locations allow to restrict operational costs and reduce external costs of intermodal chains. The advantages of the main modalities are only to lower degrees absorbed by the disadvantages of PPH.

It would be of interest, from the policy point of view, to invest more into research about:

- long run marginal cost comparison, in order to derive more argumentation for the direction to extend infrastructure network development;
- short run marginal cost comparison in European conglomerations, in order to derive more arguments for innovative urban distribution operations;
- external costs for non-traffic participants separately, as sustainability in terms of residential quality attracts more and more attention.

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