International Transport Forum

Internalisation of External Effects in European Freight Corridors

10

Discussion Paper 2013 • 10

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Internalisation of external effects in European freight corridors

Discussion Paper No. 2013-10

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April 2013

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TABLE OF CONTENTS

PREFACE

This project was conducted and financed upon a request from the Swedish governmental Agency Trafikanalys (Transport Analysis), with a governmental assignment to annually report the rate of internalisation per mode for passenger and freight transport. In its 2013 report, the Agency wishes to show examples of how the marginal costs and the internalising taxes and fees vary within and between European countries. With this background, VTI was given the assignment to analyse ten freight routes in Europe within the Narvik (Norway)–Naples (Italy), and Oslo (Norway)–Rotterdam (the Netherlands) corridors. The corridors were stated in the assignment from Trafikanalys. During the project, two reference group meetings were held with the following participants: Kenneth Wåhlberg (Swedish Transport Administration), Stefan Back (TransportGruppen), Katarina Händel (Swedish Maritime Administration), Gunnar Eriksson (Trafikanalys), Rein Jüriado (Vinnova) and Anders Ljungberg (our Trafikanalys contact). Further, Glenn Håkansson (former truck driver) helped out with selecting the routes for the road transport. The authors would like to thank all participants for their helpful comments.

The report was reviewed by Jan-Erik Swärdh, Ph.D., on December 5, 2012 at a public seminar at VTI. The authors made alterations to the final manuscript of the report. Any remaining errors rest with the authors.

1. INTRODUCTION

External effects or externalities "consist of the costs and benefits felt beyond or 'external to' those causing the effect" (Anderson, 2006). In the case of transportation, the negative externalities (costs) can take the form of air pollution, noise and accidents. Since external effects do not have a market price, external effects are a form of market failure. Wear and tear of the infrastructure is external to individual drivers and operators, and thus also included in the analysis.

External costs can be internalised in various ways e.g. through regulatory measures, technological development or taxes and charges. Some forms of taxation are more effective than others in internalising costs. For example, fuel tax is effective in reducing CO_2 emissions as it will tend to promote technological change to reduce emissions per kilometre travelled as well as reducing the kilometres driven. A fixed, undifferentiated annual tax on owning a vehicle will, on the other hand, be ineffective in relation to reducing CO_2 emissions. While it will have some impact on reducing vehicle ownership (and thus indirectly vehicle use), it will not affect kilometres driven by individual vehicles. In this paper the focus is on the "rate of internalisation". This term is used to describe to what extent the marginal external costs, based on existing regulations and technology (e.g. the European Emission Trading Scheme and emissions classes for road vehicles), are compensated for through charges or taxes. Internalisation at a certain time is thus expressed as the ratio between average charges and taxes on the one hand, and marginal external costs on the other. In this case, a full rate of internalisation would imply that the transport companies are fully charged for the marginal negative effects caused by their transport. If the ratio is below 1, the taxes and charges levied are lower than the existing marginal external costs to society, i.e. there is an under-internalisation.

The aim of this project is to study the rate of internalisation of external effects through taxes and charges in two European freight corridors during 2012; for road, rail, and sea transport, respectively. The study is based on two presumed freight corridors, between Norway (Narvik) and Italy (Naples), and between Norway (Oslo) and the Netherlands (Rotterdam).

The analysis is further differentiated on a national level, where each country constitutes one segment of the transport.

1.2 Method and limitations

To address the issue of rate of internalisation, there are two important components, the negative external costs associated with transportation based on existing technology and regulations, and the existing charges and taxes levied in each country on the transportations companies/consumers. Our focus will be on links; consequently, neither external costs nor taxes and charges related to nodes will be considered (ports are seen as nodes in this study). The external costs that will be treated include air pollution[1], emissions of carbon dioxide (CO_2), noise, accidents, and the wear and tear of infrastructure. Due to its high level of uncertainty (see Section 1.7), congestion is only considered in our sensitivity analysis. Other external costs, such as the loss of landscape and soil and water pollution, will not be addressed here[2].

The starting point is that external costs related to a specific decision should be matched by a charge or tax of the same amount, in order to achieve maximum efficiency in any given activity. In this paper, we focus primarily on the decision to transport one extra kilometre; the marginal cost is, therefore, expressed as the cost per (extra) kilometre and the charge is basically the charge per (extra) kilometre.

The marginal costs are mainly based on data presented in the Handbook on estimation of external costs in the transport sector (CE Delft, 2008), commissioned by the EU, which hereafter will be referred to as IMPACT[3]. In some cases, other sources are used due to missing IMPACT data. The background of the IMPACT Handbook is a request by the European Parliament in the previous version of the so-called Eurovignette Directive for the Commission to present an analysis of external costs. The report was included in the "Greening Transport Package" issued during the summer of 2008 which also included an updated version of the Eurovignette Directive in which the values presented in the IMPACT Handbook was used.

The report is limited to the use of existing infrastructure with existing vehicles under existing regulations, while the potential externalities of the use of future infrastructure, with future technology and regulations will not be considered. Further, we base our analysis on current state-of-the-art knowledge; since there is more research and knowledge in the area of road traffic, that part of the analysis will be more thorough. It is important to note that only short-term marginal costs will be considered.

The taxes and charges taken into consideration in our analysis are those that are levied depending on the usage of the infrastructure or the vehicle/vessel, i.e. either per kilometre or by the number of passages (see section "Charges and taxes by mode"). The vehicle tax, which is an annual charge, for road transport is used to analyse the difference between domestic and international transport.

The study is limited to one vehicle or vessel type for each transport mode, and the transport is assumed to be unimodal. Whenever possible, we have selected the same, or similar, vehicle types as used by the OECD/International Transport Forum (ITF) in its study on fees and taxes for road and rail (ITF, 2008a and 2008b).

The routes selected within the corridors

In settling on the routes, the considerations obviously vary for the three transport modes represented. Whereas the sea route is quite straightforward, assuming that vessels will choose a fairly straight route from point A to point B, while rail and road traffic must

1 Based on the pollutants considered in CE Delft (2008), the relevant pollutants include particulate matter (PM), nitrogen oxides (NO_x) and sulphur dioxides (SO_2).

2 We will not consider positive external effects, such as the increased utility for consumers.

3 Internalisation Measures and Policies for All External Costs of Transport.

consider other factors such as the quality of road or track, which is not always in favour of the straightest route.

It is important to understand that the corridors are in some sense hypothetical, i.e. they are not chosen because these routes represent actual routes for each of the transport modes studied. This paper is an attempt to analyse the possible traffic flows along freight corridors, even though in reality, a vehicle only uses parts of the route in the freight corridor. The routes represent a selection of the main routes for Swedish goods.

Road

To specify the route for the road transport, several different tools have been used. SAMGODS is a tool for freight transport modelling, developed by the Swedish Transport Agencies (Vierth et. al., 2009). Since the Swedish segment contains a great number of details, this tool has been used to select the road routes for this segment. The Swedish routes have as far as possible been selected according to HVN-1 and HVN-2, i.e. the main freight routes as identified by the Swedish Transport Administration (Banverket et al, 2009). However, for roads in other European countries, other tools have been used, such as "Resa mellan" ("Travel in-between") (2012), Google maps and distance tables. These tools have also been used to calculate the share of motorways and non-motorways. In the north of Sweden, it is common with 2+1 roads, especially along the coast. These roads have a fatality risk similar to motorways (Carlsson, 2009), and might, therefore, be overestimated in the external cost calculations for accidents in instances where these routes have been classified as "other roads" for purposes of using the IMPACT values. On the other hand, if classified as motorways, since the parts that only constitute one lane indicate an increased wear and tear due to rutting (Lunds Universitet, 2013), the cost of wear and tear might be underestimated.

It has also been assumed that as far as possible, the routes follow the TEN-T[4] network, and discussions with a truck driver experienced in European driving have confirmed our choice of routes. For estimating the share of our routes that passes through urban and rural areas, the GIS tool developed in the ASSET (Assessing sensitiveness to transport) Project has been utilised (ASSET, 2012)[5]. These estimates are rather rough and are based on squares of 1km*1km, and might principally affect noise costs which depend on the population density (see Table 3).

Rail

There are currently several projects involving rail corridors in Europe. Some of these corridors already exist, while others represent future corridors (EC Mobility and Transport, 2012). In settling on freight routes, we have used some of the projects mentioned below as a reference for the track sections that are interesting from a corridor perspective. The distances have been calculated by mainly using the SAMGODS model. In cases of uncertainties, distances have been validated against other Swedish sources. The distances for all tracks outside Sweden have not been validated against other sources; hence, the uncertainties for these distances are greater.

4 Trans-European Network for Transport.

5 ASSET is an EU financed project from 2009 in which VTI has participated.

Within Europe, there are a number of different rail systems, which are hindering transnational rail traffic. The trains are sometimes forced to change locomotive and/or train driver at the borders. In order for rail not to lose market shares to other transport modes, EU has decided to institute measures to enable transnational rail traffic. The new system is called European Rail Traffic Management System (ERTMS) and is a standardized safety and train control system for European rail. The aim is to standardize all European railways through the ERTMS, but initially, focus will be on a few selected routes (Trafikverket, 2012b). Other projects involving European rail corridors include the TEN-T priority axes, RNE-corridors, CER, and TREND[6]. Comparing these different approaches has given us a fair idea of the prioritised and most important rail freight routes in Europe (EC Mobility and Transport, 2012).

We have chosen to follow the full extent of the ERTMS Corridor B through Denmark, Austria, Italy, and partly through Sweden and Germany. In Norway, the Netherlands, and partly in Germany, we chose the shortest route by studying rail maps. In Sweden, apart from following the ERTMS Corridor B route whenever possible, we also used common knowledge of the flows of rail freight traffic. In some cases, there were several alternative tracks between cities. In those cases, we consulted infrastructure managers in the relevant countries and studied local geographical characteristics in order to select the most likely route for our freight trains.

Sea

For sea routes, ships are assumed to take the shortest lanes and as far as possible follow the "Motorways of the Sea" routes without making any stops. Motorways of the sea is a concept developed as part of the transportation policy of the European Union to strengthen the network between Member States and to highlight the importance of sea transport. However, in some cases, it has been relevant to the analysis to add stops along the way. In these instances, the "sea-distance" web tool was used to calculate the distances (Sea distances, 2012).

Standardized vehicles, trains and ships

For road transport, the standardised vehicle is a 40 tonne, 18.75 metre long truck of the EURO Class IV, which is the EU standard for vehicle emissions. These assumptions are in line with the standardized HDV (heavy duty vehicle) featured in IMPACT and ITF (2008b). The fuel consumption is assumed to be 0.33 litres per vehicle kilometre for non-motorways and 0.26 l/vkm for motorways (HBEFA, 2012). These assumptions[7] are used to calculate the diesel tax per vehicle kilometre. The annual amount of kilometres driven for the vehicle is set at 125,000 (ASEK, 2012), and is used to recalculate the vehicle tax and the Eurovignette into a tax per vehicle kilometre.

Following Thompson (2008), we assume a freight train with a gross tonne weight of 960 tonnes. We also assume an electrical locomotive in our main analysis. There is no consensus on how to treat the emission from electric production in the contemporary transport sector. In this study, we have used the valuations and assumptions made in IMPACT; hence, a European mix of electric production is used. For the sensitivity analysis, a diesel locomotive will also be included.

6 RNE = RailNetEurope, CER= Community of European Railways, TREND = Test of Rolling Stock Electromagnetic Compatibility for Cross-Domain Interoperability.

7 However, these assumptions may differ from those used in the CE Delft Study (2008) on which the external cost valuations are based, since it is not transparent which fuel consumption has been assumed.

For sea transport, container feeders have been selected. Since the container can be handled by all modes, a container feeder is a common vessel in short sea shipping that is often used in comparative studies[8]. The size has been chosen based on two criteria, the most common ship sizes calling on both the ports of Norway and Italy (the Narvik-Naples corridor) as well as Norway, Sweden and the Netherlands (the Oslo–Rotterdam corridor) (Eurostat, 2012), as well as the common ships used in previous studies (e.g. Naturvårdsverket, 2010; Hjelle & Fridell, 2012). The characteristics of the container feeder selected are: 1000 TEU[9] with a gross tonnage (GT[10]) of 13 000 and an assumed load factor of 70 %[11]. Heavy fuel oil (HFO) containing 2.7 % sulphur is assumed to be used at 80 % and 20 % HFO with a 1 % sulphur content for the Narvik to Naples route, meanwhile for the Oslo–Rotterdam route, only HFO with a 1 % sulphur is assumed to be used (due to ECA regulations on sulphur content, see Section 5.1.3). Tier 1[12] is assumed for the emissions of nitrogen oxides (NO_x) from the vessel for both routes.

For the road routes, there is also a ferry connection in both corridors. For these routes, we assume the use of a RoRo ferry, based on available ships in the NTM[13] database similar to those used by the ferry companies operating along these routes, i.e. Trelleborg-Travemünde and Trelleborg–Rostock (TT Line, 2012). The same type of ferry is assumed to operate the Rödby–Puttgarden link. The characteristics of the ferry are the following: 2,200 lane metre, 6,080 deadweight tonnes (dwt) with an assumed load factor of 44 %. HFO with a 1 % sulphur content is assumed, and Tier 1 for NO_x emissions.

Sensitivity analysis

We also include sensitivity analyses to test the robustness of our analysis and to deal with such complex issues as congestion.

The following alternatives have been analysed for road and rail transport: Noise cost has been assumed for either all day or all night transport, compared to the main analysis for which an average of the cost valuation for day and night has been assumed.

Due to the specific topographical and meteorological conditions, correction factors for Alpine areas from Lindberg (2006) have been used for the total segment in Austria and 25 % of the Italian segment.

Further, for roads, the Swedish values on wear and tear from IMPACT have been analysed and compared to those for EUR27 used in the main analysis due to the fact that

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8 Note that the environmental impact of short sea shipping is strongly dependent on ship type and size. For cases when small RoRo and container vessels are among those with the worst environmental performance, see Hjelle & Fridell (2012).

9 Twenty-foot Equivalent Unit is a measurement which is equal to the size of one twenty foot container.

10 Gross tonnage= the total of all enclosed spaces within a ship expressed in tonnes, each of which is equivalent to 100 cubic feet.

11 Conversion factor from TEU to GT is based on Chiffi et al (2007).

12 Part of the MARPOL convention and regulates the allowed levels of NOx emissions from marine engines. Tier 2 was introduces in 2011, and Tier 3 will be introduced 2016 (IMO, 2008).

13 The Network for Transport and Environment (NTM) is a non-profit organisation, initiated in 1993, aiming at establishing a common base of values on how to calculate the environmental performance for various modes of transport, http://www.ntmcalc.org/index.html.

IMPACT values assume that variable average costs are a good approximation of the marginal cost. However, this is not the case for countries with low traffic volumes such as Sweden (a further explanation is found in Section 3.1). Also, the lowest fuel tax for each road route has been calculated; with the rough assumption that one tank would be sufficient for the entire trip[14]. For sea transportation, no sensitivity analysis has been conducted.
Finally, we have addressed the issue of congestion by using different approaches for road and rail. Because congestion is a function of transport demand relative to fixed supply (i.e. traffic volumes in relation to capacity) where demand varies considerably depending on the time of the day, congestion on the roads and the scarcity of track availability is quite specific to location and time. It is common to distinguish between two congestion peaks during the day, i.e. morning and afternoon commuting. Although the peaks vary for different environments, we assume that for road traffic, they are occurring at 7-9 am and 6-8 pm (Christidis and Brons, 2010). Where peaks occur is dependent on the demand in different locations (e.g. commuter traffic in large cities) in relation to capacity (e.g. motorways). It is not obvious that highways would have less congestion than other roads and there is often a correlation between demand and capacity.

The external cost of congestion is the difference between the average time cost of road users and the marginal cost, i.e. since this road user generates delays for all the others (Button, 1993), the external cost of congestion for the last road user consists of the sum of all others. It is also valid to note that there is a congestion cost without pricing and a congestion cost incurred after implementing pricing, i.e. while drivers adjust to new prices, a lower cost relevant to the congestion cost appears. IMPACT assumes a price elasticity of 0.3 when assessing the cost of congestion that arises after a congestion price has been introduced.

To exemplify the cost of road congestion in a corridor analysis, we imagine three methods. We have chosen the first method; the other two are potential developments for future analyses:

1. We assume that a transport starts at a certain hour and after taking into account driving and rest times, it will pass through peaks in the various segments (i.e. the location is not addressed more specifically than by country) before reaching the final destination, an example of a type of transportation that takes into account the time-specific characteristic.

2. The starting hour of the vehicle can be set for several different times of a day (e.g. 06.00 - 24.00), thus making congestion arise on various routes along the corridor. By adopting a distribution of departure times by using the Monte Carlo simulation model, we can study how congestion costs occur at different points along the corridor and then calculate an average congestion cost (e.g. in a study by Christidis and Brons, 2010).

3. The third method is to co-operate with a firm using route guidance systems. Their large databases make it possible to obtain real-time, or at least decent, estimates of the exact location and time for congestion in the road network.

Similar to road congestion, rail congestion is time and location specific. It is, however, hard to find a general rule applicable to all countries. First, data are lacking on the congestion/scarcity on the European railway network. In some countries, congestion

[14] This is probably not likely for the Narvik – Naples route.

seems to be the heaviest around major cities, while in other countries, track sections between major nodes are more congested. In the sensitivity analysis for rail congestion, we have assumed a worst case scenario in which congestion occurs along the entire route. At some locations along the route, there are special passage fees for peak hours. We assume that trains pass all such locations and are, therefore, charged the maximum congestion charges.

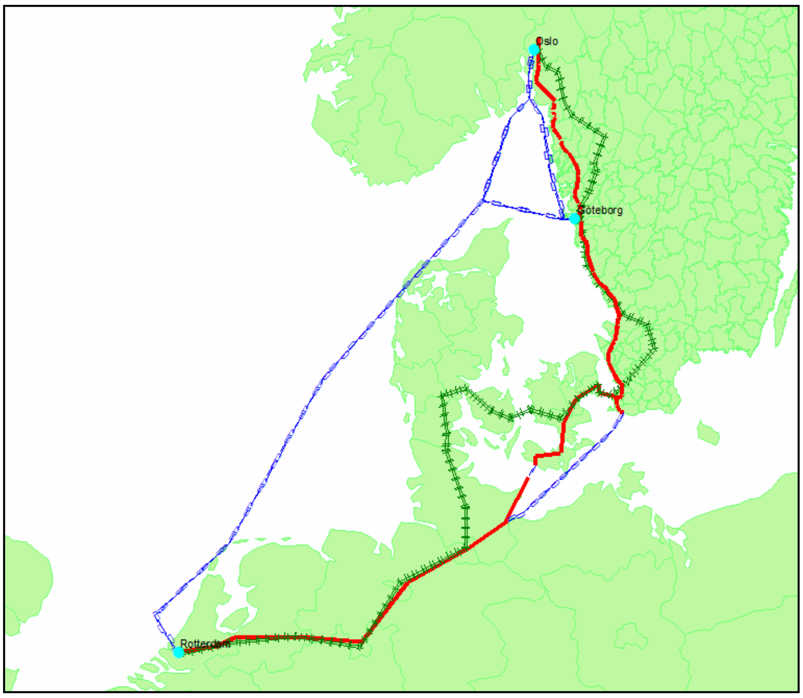
2. DESCRIPTION OF THE CORRIDORS

In this chapter, the two corridors will be presented, as well as the specific routes for each mode of transportation. The term corridor is used in a wider definition which includes the different routes selected for analysis in this study.

2.1. Oslo–Rotterdam

Figure 1 shows the sea, road and rail routes for the Oslo-Rotterdam corridor. The blue line represents the sea route, both for Oslo-Rotterdam and for Oslo-Gothenburg-Rotterdam. The red line represents the route by road, with the ferry connection between Trelleborg and Travemünde, as well as Rödby-Puttgarden, shown as a blue line. The green line represents the rail route, which in large parts is similar to the road route.

Figure 1. **The corridor between Oslo and Rotterdam, via Gothenburg**



Source: Authors editing from the SAMGODS model.

Road

The road corridor starting in Oslo, Norway passes through Gothenburg, Sweden and then runs via either Germany alone or Denmark and Germany before reaching Rotterdam in the Netherlands. The corridor is shown in Figure 1 and is specified in Table 1. For this corridor, we have assumed two different routes. The first route is via the ferry connection between Trelleborg and Travemünde, selected because it is one of the most frequently used freight routes to and from Sweden, and because it provides some resting time for the driver. The second route via the Rödby – Puttgarden ferry link is chosen because it constitutes an interesting example for future analysis when the Fehmarn Belt Fixed Link will have been built.

Table 1. **Oslo–Gothenburg–Rotterdam by road**

Country	Destination	Route
Norway	Oslo-Svinesund	E6
Alternative 1		
Sweden	Svinesund-Gothenburg	E6
	Gothenburg-Trelleborg	E6/E20/E22
	Trelleborg-Travemünde	Ferry
Germany	Travemünde-Lübeck	B75/A226
	Lübeck-Hamburg	A1/E22
	Hamburg-Hengelo	E22/E37/E30
Alternative 2		
Sweden	Svinesund-Gothenburg	E6
	Gothenburg-Malmö	E6/E20
	Öresund Bridge	Bridge
Denmark	Malmö–Rödbyhavn	
	Rödbyhavn-Puttgarden	Ferry
Germany	Puttgarden-Hengelo	E47/E22/E37/E30
The Netherlands	Hengelo-Rotterdam	E30/E25

Rail

The rail route between Oslo and Rotterdam starts along the Østfoldbanen between Oslo and the Swedish border at Kornsjö. At one point, the route has two alternative tracks. We have chosen the Eastern, and shortest, alternative. In Sweden, the train passes Gothenburg and follows the West Coast Line (Västkustbanan) to Halmstad, where the route makes a detour in order to avoid the congestion along the line further south. From Hässleholm, the route follows the Southern Main Line to Malmö, and across the Öresund Bridge to Denmark.

The route through Denmark runs through Copenhagen, then across the Danish mainland via the Great Belt Bridge, through the cities of Odense and Kolding to Padborg by the Danish/German border.[15]

In Germany, the route runs from Padborg/Flensburg, via Hamburg, and turns west, continuing towards Bremen and further to Osnabrück and Bad Bentheim. The great rail terminal in Duisburg was not included since it would constitute a large detour for trains running from Scandinavia towards Rotterdam.

In the Netherlands, the route runs through Hengelo, Almelo,Gouda to finally arrive in Rotterdam. The dedicated freight route, the Betuwe Line, starting from the port of Rotterdam to Germany, was excluded for the same reasons as discussed above regarding Duisburg. Even though a large part of the train freight from the Netherlands to Germany uses the Betuwe Line, it would have meant a large detour in this case.

Sea

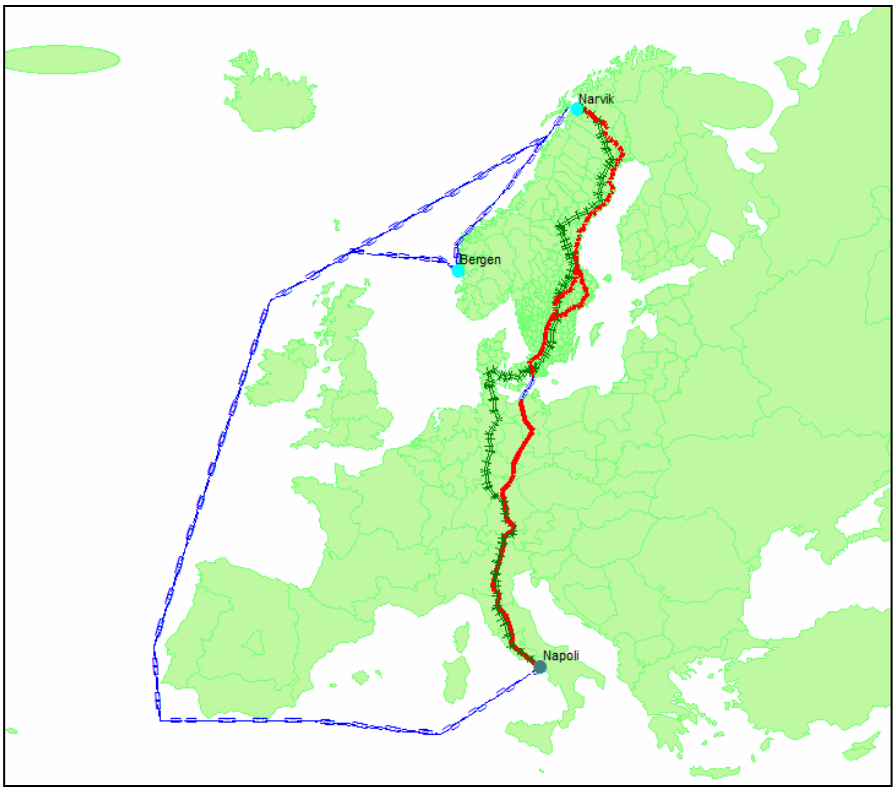
For the sea corridor, we have decided to illustrate two routes, one from the port of Oslo directly to Rotterdam and one from Oslo via Gothenburg to Rotterdam. As stated in the corridor specification, because container feeder traffic between Gothenburg and Rotterdam is common, the second route includes Gothenburg. The main maritime traffic flows to and from Sweden and the South of Norway can be seen on Swedish Maritime Administration maps based on AIS-data (SMA, 2012a). These maps show that the main traffic flows pass North of Denmark rather than through the Kiel Canal.

2.2 Narvik-Naples

Figure 2 below illustrates the routes in the Narvik-Naples corridor. The blue line represents the sea route. The red line shows the road route, with two possible routes through Sweden, either via Västerås or via Stockholm, with a ferry connection between Trelleborg and Rostock. The rail route is represented by a green line. Again, even though the rail line features more "detours" than the road, the rail and road routes are fairly similar.

15 An alternative trail would be possible in the future using the Fehmarn Belt Fixed Link. This alternative is, however, not relevant in this study since the majority of current flows of rail traffic runs across the Danish mainland.

Figure 2. **The corridor Narvik-Naples**



Road

In order to have all main routes of the freight flows represented, the road corridor from Narvik includes both the route via Västerås and Stockholm. However, there are mainly inbound and outbound transport to Stockholm, i.e. not a great deal of transit transportation. The Swedish routes have as far as possible been selected according to HVN-1 and HVN-2, i.e. the main freight routes identified by the Swedish Transport Administration (Banverket et al, 2009). For routes outside Sweden, the TEN-T has offered guidance. Table 2 summarizes the road routes in the Narvik – Naples corridor.

Table 2. **Route Narvik-Naples by road.**

Country	Destination	Road
Norway	Narvik-Riksgränsen	E6
Sweden	Riksgränsen-Luleå	E10
	Luleå-Gävle	E4
Alternative 1	Gävle-Västerås	Rv56
Via Västerås	Västerås-Örebro	E18
	Örebro-Ödeshög	Rv50
Alternative 2	Gävle – Stockholm	E4
Via Stockholm	Stockholm –Ödeshög	E4
	Ödeshög- Helsingborg	E4
	Helsingborg-Trelleborg	E20/E22
	Trelleborg-Rostock	Ferry
Germany	Rostock-Berlin	E55/E5
	Berlin-Leipzig-Nürnberg-Munich	E51/E45
	Munich-Innsbruck	E45
Austria	Brenner Pass (Innsbruck-Verona)	E45 (A13/12)
Italy	Verona – Naples	E45

Rail

The Narvik-Naples rail corridor starts off at the iron ore track between Narvik, Norway and Luleå, Sweden. It then runs from the North to South through the freight route via Vännäs, Avesta, Hallsberg and Mjölby. From Mjölby, the route follows the heavily used Southern trunk line to Malmö, where the Öresund Bridge leads across to Copenhagen, Denmark.
In Denmark, the route follows the same path as for the Oslo-Rotterdam route, passing through Copenhagen, via the Great Belt Bridge to Odense, to Padborg by the Danish/German border.

In Germany, the route runs from Padborg/Flensburg, via Hamburg, Hannover and Munich. Along this route, there are several possible options which are all part of the ERTMS Corridor B. Between Hannover and Munich, after consultation with Deutsche Bahn, we select the route via Ingolstad.

The route through Austria is quite straightforward, with its starting point in Kufstein, passing through Innsbruck and the border town of Brennero.

From Brennero, the route continues through Italy, via Verona, Bologna, Rome and further to Naples. At several points, there are alternative routes. We have chosen routes that correspond to the ERTMS Corridor B. Furthermore, we have avoided tracks that are dedicated to high-speed passenger traffic. Whenever possible, tracks passing outside the larger cities have been chosen, rather than tracks passing through city centres. On the assumption that the rail operator strives to minimize transport costs, we have avoided routes that would result in large detours.

Sea

For sea routes, ships are assumed to follow as far as possible the “Motorways of the Sea” network on their way from Narvik to Naples. To capture the effects of the NO_x tax levied between Norwegian ports (described in 4.3), a stop in Bergen was built into the assumption.

3. EXTERNAL COSTS BY MODE

As mentioned in the introduction, external effects are costs and benefits that are external to the cost or benefit causing the effect. In this report, we focus on emissions of air pollutants and carbon dioxide, noise, accidents and wear and tear. Congestion is only taken into account in the sensitivity analysis (as mentioned in Section 1.1.6). Naturally, the levels of external effects vary between the three transport modes in focus. For sea transport, the only external costs in IMPACT are air pollution and carbon dioxide. For land based modes, all external costs are included.

As noted in the introduction, our main approach is to use the estimates from IMPACT as far as possible due to its pan-European status without implying that better estimates do not exist in other databases.

This section presents the external effects of the three transport modes. For rail, since some externalities are measured in relation to weight and others in relation to distance, it can be difficult to compare different systems against each other. It is also important to bear in mind that these transport modes are not comparable in terms of volumes of transported goods. The standardized vehicles used in this report are a 40 gross tonne truck, a 960 gross tonne train and a 13,000 gross tonnage vessel.

3.1 Road

The valuation of the external cost used for highway routes are presented in Table 3. The IMPACT value for wear and tear stated in the table for Sweden is used in the sensitivity analysis, while the average value for all EU27 states is used for the main analysis (i.e. EUR27 in Table 3) because the values suggested in IMPACT are based on the assumption that the average variable costs for wear and tear are a valid approximation of the marginal cost. The average variable costs are assumed to constitute 26 % of the total average cost for all Europeans countries which means that all variations in the total average cost directly influence the marginal cost. The high costs in Sweden are primarily attributable to low traffic volumes. IMPACT explains it as ”/…/ very high values appear for Sweden, where high price levels and climate-driven construction costs, in combination with low traffic densities, lead to extremely high average costs per vehicle kilometre. In contrast, classical transit countries like Germany and Austria with high traffic volumes show rather low average costs, and thus also low marginal cost per lorry kilometre” (CE Delft, 2008, p. 53). Further, this is also in line with other studies of wear and tear in Sweden suggesting an external cost for heavy goods vehicles of approximately 0.15 Euro/vkm[16] (Kågeson, 2011).

16 An average value for all roads.

Table 3. **External cost valuation, road, cost per vehicle kilometre**[17]

		Heavy goods vehicle >32T	
		Motorways	Others
Air pollution	Euro IV	0.045	0.051
CO_2	Euro IV	0.019	0.021
Noise		Suburban	Rural
	Day	0.011	0.0013
	Night	0.020	0.0023
Accidents		Motorways	Other
	NO	0.0028	0.0252
	SE	0.0019	0.0172
	DK	0.0032	0.0285
	DE	0.0029	0.0265
	NL	0.0023	0.0206
	AT	0.0041	0.0366
	IT	0.0034	0.0307
Congestion		Motorways	Other
	Rural area	0.35	0.13
	Urban area	0.88	
Wear&Tear		Motorways	Other
	AT	0.0557	0.0779
	DE	0.0744	0.1736
	IT	0.1013	0.6592
	SE	0.5179	0.3453
	EUR27	0.0963	0.2110

Source: CE Delft (2008). Costs in Euros (2000 price level).

3.2 Rail

The valuations of the external costs of rail transport are given in Table 4. Since there is less research on external costs in rail traffic, the values used are more general than those used for roads, and there is no country or track-specific values available. All values of external costs are taken from IMPACT, except the value for wear and tear.

Since IMPACT lacks a value for external costs of wear and tear on rail, this value is instead taken from the recommended values for external effects from the transport

17 The valuations presented here are from CE Delft (2008) and expressed in Euros at 2000 price levels. When used in our calculations, these values have been recalculated into the value of Euro at 2012 price levels by the Harmonized Consumer Price Index (HCPI).

sector in Sweden, ASEK, a group representing several governmental transport agencies in Sweden (Trafikverket, 2012a). The estimate for wear and tear is based on maintenance costs alone which means that other infrastructure costs, such as operation and renewals, are excluded from the analysis. Since the estimate for wear and tear on roads is much more comprehensive, this fact will be of great importance when comparing the rates of internalisation for road traffic.

Obviously, there is a great difference in emissions between electric and diesel driven locomotives. The difference in external costs for noise during the day and at night is also noteworthy. Since trains in our example travel long distances, they are likely to run both day and night. In the main analysis, we will, accordingly, use an average of the external costs for noise at daytime vs. night time. In the sensitivity analysis, we will, however, isolate the effects of noise during daytime vs. night time.

The external costs for congestion are a somewhat complex matter. Whereas other externalities, except noise, are more or less constant throughout the day, congestion is normally an issue at certain times of the day and at certain locations along the tracks. Since both external costs and fees for congestion are difficult to handle, congestion will be treated in the sensitivity analysis instead of in the main analysis.

Table 4. **External costs, rail, per train kilometre**

External cost	Metropolitan	Other urban	Non-urban
Air Pollution, Electric locomotive	0.137	0.137	0.137
Air Pollution, diesel locomotive	7.192	3.96	3.35
CO_2, Electric locomotive	0.307	0.307	0.307
CO_2, Diesel locomotive	0.346	0.346	0.346
Noise, day	0.4193	0.4006	0.05
Noise, night	1.17106	0.6771	0.0845
Accidents[18]	0.1200	0.1200	0.1200
Congestion	0.2000	0.2000	0.2000
Wear&tear (gross tonne km)	0.0009	0.0009	0.0009

Source: CE Delft (2008) and Trafikverket (2012a). Costs in Euros (2000 price level).

3.3 Sea

The values for vessel emissions from IMPACT are for maritime transport divided into different oceans heavily used for such transport, as seen in Table 5. These valuations have been used in combination with calculations of emissions emitted by our two assumed vessels, i.e. the container vessel for sea transport and the RoRo ferry used for road transport. The calculations have been conducted by means of the NTM tool NTMCalcFreight Professional 3.0, (see Table 6 and the description of NTM). These calculations have been compared to similar calculations by the Swedish Maritime Administration, as well as those presented by Hjelle and Fridell (2012). Some results do not vary a great deal (e.g. PM), while for NO_x, the emission level varies up to

[18] IMPACT uses a value of accidents in the range of € 0,08-€ 0,30 per train kilometre. For simplicity, an average of these numbers is used.

approximately 65 % partly due to different assumptions made for vessels, as well as different calculation methods.

Table 5. **External cost, sea, cost per tonne emission**

External cost	EU 25	North Sea	North east Atlantic	Mediterranean	Baltic Sea
CO_2	25				
NO_x		5 100	1 600	500	2 600
SO_2		6 900	2 200	2 000	3 700
PM		28 000	4 800	5 600	12 000

Source: CE Delft (2008). Costs in Euros (2000 price level).

The NTM tool has been used for two reasons, first, to be able to specify the characteristics of the chosen vessels and second, to be able to use the same method for both the container vessel and the RoRo ferry.

Table 6. **Emissions, sea, in tonne per vessel kilometre**

	Container (Oslo – Rotterdam)	Container (Narvik – Naples)	RoRo[19]
CO_2	0.198	0.200	0.158
NO_x	0.005	0.005	0.003
SO_2	0.001	0.003	0.001
PM	0.0002	0.0004	0.0001

Source: NTMCalcFreight Professional 3.0 (NTM, 2012).

19 The RoRo ferry is assumed to operate across the ferry links included in the highway routes, i.e. Trelleborg – Travemünde, Trelleborg – Rostock andRödby – Puttgarden.

4. CHARGES AND TAXES BY MODE

All results, including fees and taxes, are given in Euros at 2012 price levels. For the valuations in IMPACT, the harmonized consumer price index (HCPI) from the European central bank (ECB) has been used to update the values (ECB, 2012).[20] The exchange rates have also been taken from ECB.[21]

4.1 Road

The information on charges and taxes for highways has been collected from the overview of fees (ACEA, 2012) published by the European Automobile Manufacturers' Association 2012), the update of ITF (2008b)[22] and from various websites for tolls in the relevant countries, i.e. Norway, Germany, Austria and Italy. However, no tolls are levied in Norway (on the selected roads in our study). There are charges to cross the Svinesund Bridge (between Norway and Sweden), as well as the Öresund Bridge (between Sweden and Denmark) which are taken into consideration (Transportstyrelsen, 2012; Öresundsbron, 2012).

Differences between national compared to international transport for respective country are studied by considering fees that only affect domestic transportation, i.e. the national vehicle tax. This tax is levied on an annual level but is recalculated per vehicle kilometre based on the assumption of an average mileage of 125,000 km per year. The same recalculations have been made for the Eurovignette, which is a time based fee. Although these fees do not constitute marginal taxes related to travel distance, they will affect the competition between haulers in the various member states.

The bridge passage fee is divided equally between the countries connected, i.e. the fee for the Svinesund Bridge is split between Norway and Sweden, and the fee for the Öresund Bridge is split between Sweden and Denmark. For the road tolls, the average rate per vehicle kilometre for a 40 tonne vehicle of Euro Class IV has been used for Germany and Italy based on the parallel update of the ITF Study from 2008 (ITF, 2008b) on road charges and taxes in Europe (Hylén, 2013). To calculate the total toll for this segment (ASFINAG, 2012)[23], the toll for Austria (an average value of the daytime and night time fee is assumed) is based on the web services.

The taxes and charges for road infrastructure are summarized in Table 7.

[20] August 2000: 89.85 and August 2012: 115.59

[21] 1 EUR=SEK 8.68; 1 EUR = NOK 7.4; 1 EUR=DKK 7.46 based on ECB exchange rates of October 12, 2012.

[22] Hylen, B. & Kauppila, J. & Chong, E. (2013).

[23] An average value of day and night fees along A13 and A12 assumed.

Table 7. **Taxes and charges, road**

	Vehicle tax (€/year)	Diesel tax (€/l)	Eurovignette (€/year)	Toll/Maut (€/vkm)	Toll total (€/segment)	Bridge (€/passage)
Norway	1591	0.50				6.6
Sweden	1093	0.51	1250			51.5
Germany	2054	0.47		0.183		
Austria	1752	0.40			107.5	
Italy	825	0.44		0.125		
The Netherlands	1152	0.43	1250			
Denmark	925.6	0.40	1250			44.9

Taxes and charges in Euros (2012 price level).

4.2 Rail

Information on charges for the use of the rail infrastructure has been collected from the network statements of each country. Additional information has been collected through contacts with infrastructure managers.

The access charges are designed differently in all seven countries along the two corridors in focus. However, all countries levy a charge for rail lines, also called an access or track charge. Track charges are levied according to the number of track kilometres driven. In some countries, the track charge is the sole charge that covers all costs including environmental issues, noise and wear and tear.

In other countries, like Sweden, the track charge is differentiated, which gives a high level of transparency into what the charges are actually meant to cover, e.g. there is an accident charge per train kilometre. Several countries have certain congestion charges which are commonly designed as passage charges for certain track sections during specific time periods.

Special charges are levied to cover the infrastructure costs by bridges and tunnels. In the case of the Öresund Bridge, the charge is divided equally between the countries that are linked by the bridge.

The Italian rail infrastructure charges diverge from those of other countries and are based on the use of nodes as well as lines.[24] It also includes a time aspect that varies from other European countries, since the speed of the train in relation to its scheduled speed, as well as the minutes spent in nodes, are a couple of factors affecting the charge. The track charges are based on an algorithm including a fixed access charge, the number of kilometres travelled, speed, level of congestion(density), wear (based on speed and weight), and the classification of the network. The train travelling from Brennero to Naples will pass three nodes, Bologna, Florence and Rome. Since the Italian track charge system is more complex than those of other countries, some assumptions

[24] Nodes are generally not treated in this report. In this case, however, it is necessary to include these node fees since they are a part of the track charge system and can be compared to the passage fees used in Sweden and Denmark.

need to be made regarding the speed of the train and levels of congestion along the tracks. In this report, passing a node is assumed to take 30 minutes, with the train assumed to pass the nodes between 9 am and 10 pm. Furthermore, the tracks between Brennero and Naples are assumed to be densely used, and the train is assumed to keep a steady pace of 70 kilometres per hour with some small deviations from the planned timetable.

Table 8 shows charges in the various countries. Please note that charges are not necessarily higher in a country featuring a high degree of charge differentiation, such as Sweden, which has a low infrastructure charge.

Table 8. **Taxes and charges, rail**

	Train path, minimum access charge	**Congestion charge**	**Environmental charge**	**Passage charge**	**Accident charge**
Norway	€ 0.0035/ gross tonnekm				
Sweden	Train path:€ 0.044-0.187/trainkm, and track charge:€ 0.000396 /gross tonnekm	€ 19.25 passage charge for trains passing Gothenburg and Malmö in peak hours	€ 0.0715-0.121/litre of diesel fuel	€ 154/passage Öresund bridge	€ 0.0891/ trainkm
Denmark	€ 0.2704/trainkm	€ 46, € 153.3, € 122.6 depending on time of day and train path	€ 0.00299/ gross tonnekm	€ 780/passage Great Bält Bridge + € 182 passage Öresund Bridge	
Germany	€ 3.11 /trainkm.				
The Netherlands	€ 2.28/trainkm				
Austria	€ 2.2331 /trainkm and € 0.00116/gross tonnekm				
Italy	€58 for access to main network. €24 for access to complementary network + a variable usage charge[25].			€ 53.26 for access to nodes + a variable usage charge[26].	

Source: Jernbaneverket (2011), Trafikverket (2011a), Trafikverket (2011b), Banedanmark (2012), DB Netze AG (2011a), DB Netze AG (2011b), ProRail (2011), ÖBB-Infrastruktur (2012), Rete Ferroviaria Italiana (2011). Taxes and charges in Euros (2012 price level).

4.3 Sea

Charges and taxes related to maritime traffic differs from those related to roads and rail infrastructure. The charges and taxes found relevant for ocean transportation include the Swedish fairway dues and the NO_x tax in Norway (see Table 9). There might be other infrastructure-related charges such as port dues in remaining countries, but as previously mentioned, nodes are excluded. The fees mentioned are both related to the usage of the vessels. The fairway dues are mandatory for marine vessels sailing within Swedish fairways. The dues consist of two parts: one part based on the amount of goods

25 The usage fee for the main network is calculated: €1,013*kilometres*(M_{speed} + $M_{density}$ + M_{wear})/3.

26 The usage charge is calculated: €1.013*minutes in the node*Φ*Ψ, where Φ represents time period, and Ψ assumes the value 4 if the train passes the main station and 1 if it passes a secondary station within the node.

loaded/unloaded in Swedish ports and a second part based on the gross tonnage of the ship. The latter part is environmentally differentiated to create incentives to reduce NO_x and SO_2 emissions. The fairway due is charged at a maximum level, based on the number of calls per month (i.e maximum charge is 24 per year for container vessels and 60 per year for the RoRo ferry)(SMA, 2012b). The NO_x tax is levied only for ships operating between Norwegian ports and for those with an installed engine power exceeding 750 kW. For each kilogram of emitted NO_x emission, a tax of 2.3 Euro is charged (Sjöfartsdirektoratet, 2012). Neither the fairway levy nor the NO_x tax are distance based.

Table 9. **Taxes and charges, sea**

	Fairway due (€/tonne good)	(€/GT)	NO_x-tax (€/kg NO_x)
Norway			2.3
Sweden	0.33	0.32 (0.28[27])	-

Source: SMA (2012b), Sjöfartsdirektoratet (2012) and author calculations.
Taxes and charges in Euros (2012 price level).

Pilotage charges are excluded since they are regarded as operational costs and are thus not aimed at covering externalities. There might be other infrastructure related charges included in the port dues that have not been investigated. This study does not take into consideration external costs or charges at nodes/terminals.

27 This charge is levied for the RoRo ferry.

5. RESULTS - RATE OF INTERNALISATION BY ROUTE

The results will be presented in the following sections for each route by transport mode and country. The tables for each route and mode, respectively, show the total external cost of the trip per segment (i.e. not per km), followed by a table presenting total taxes and charges and finally, the ratio of internalisation by segment.

5.1 Oslo-Rotterdam

Road

In the following tables (10-12), the results of the analysis for the highway transport along the Oslo to Rotterdam corridor are shown. Table 10 presents the external costs per country, not per vehicle kilometre, and indicates that wear and tear constitutes the main external cost followed by air pollution. In the sensitivity analysis, this result changes with the addition of congestion costs, which exceed the cost of air pollution but do not reach those of wear and tear. The method of calculating congestion contains uncertainties; it is nonetheless an important factor (both in the assumed low and high valuation scenarios). The results of the sensitivity analyses are presented in Table 12 and the Appendix.

Table 10. **External costs, Oslo-Rotterdam, road**

Segment	Country	Distance (km)	Air Pollution (€)	CO_2 (€)	Noise (average) (€)	Wear & tear (€)	Accidents (€)	Total (€)
Oslo-Svinesund	NO	113	6.6	2.8	0.5	15.2	0.6	25.7
Alternative 1								
Svinesund-Trelleborg	SE	478	27.8	11.7	2.0	62.3	1.6	105.4
Trelleborg-Travemünde	Ferry	215	31.8	9.6	-	-	-	41.4
Travemünde – Hengelo	DE	373	21.6	9.1	1.3	35.7	1.4	69.1
Alternative 2								
Svinesund-Malmö	SE	466	27.0	11.4	1.8	58.6	1.3	100.1
Malmö-Rödbyhavn	DK	179	10.4	4.4	0.7	22.3	0.8	38.6
Rödbyhavn-Puttgarden	Ferry	16	2.3	0.7	-	-	-	3.0
Puttgarden- Hengelo	DE	446	26.1	11.0	1.3	59.7	2.6	100.7
Hengelo - Rotterdam	NL	193	11.2	4.7	1.1	23.9	0.6	41.5
Total (Alt 1)		*1 372*	*99.0*	*38.0*	*4.9*	*137.1*	*4.2*	*283.2*
Total (Alt 2)		*1 413*	*83.5*	*34.9*	*5.3*	*179.7*	*5.8*	*309.2*

Costs in Euros (2012 price level).

The external costs per vehicle kilometre are rather similar between the countries with the main difference due to the costs of wear and tear, which depend on the share of motorways as seen in the section “External costs by mode”. Some costs are also country-specific. For the ferry transport, external costs are based on the emissions from the RoRo ferry that can be allocated to our road vehicle.

Table 11 presents the taxes and charges for road transport between Oslo and Rotterdam summarized in Euros for each country, not per vehicle kilometre. The diesel tax represents the main fee followed by bridge passage charges and road tolls.

The diesel tax has been calculated according to fuel consumption and has been differentiated between motorways (0.33 l/vkm) and non-motorways (0.26 l/vkm). The passage fee for the Svinesund Bridge is equally divided between Norway and Sweden, and the same is the case for the Öresund Bridge between Sweden and Denmark. For the ferry between Trelleborg - Travmünde, only part of the fairway due (paid in Sweden) can be allocated to the vehicle. No charges or taxes are assumed for the ferry between Rödbyhavn – Puttgarden.

Table 11. **Taxes and charges, Oslo – Rotterdam, road.**

Segment	Country	Distance (km)	Vehicle tax (€)	Diesel tax (€)	Euro-vignette (€)	Road toll/ Maut (€)	Bridge/ Fairway due (€)	Total (excl. vehicle tax) (€)
Oslo-Svinesund	NO	113	1	15	-	7	7	29
Alternative 1								
Svinesund-Trelleborg	SE	478	4	64	5		7	76
Trelleborg-Travemünde	Ferry	215	-	-	-	-	17	17
Travemünde – Hengelo	DE	373	6	46	-	68		114
Alternative 2								
Svinesund-Malmö	SE	466	4	62	5	-	52	119
Malmö-Rödbyhavn	DK	179	1	19	2	-	45	66
Rödbyhavn-Puttgarden	Ferry	16	-	-	-	-	-	-
Puttgarden-Hengelo	DE	446	7	55	-	76		131
Hengelo – Rotterdam	NL	193	2	22	2	-	-	24
Total (Alt 1)		*1 372*	-	*147*	*7*	*75*	*31*	*260*
Total (Alt 2)		*1 413*	-	*173*	*9*	*83*	*104*	*369*

Taxes and charges in Euros (2012 price level).

The internalisation ratio, as described in the introduction, is calculated as a variable tax and charge divided by the marginal external cost. The vehicle tax and the Eurovignette are both paid based on time, e.g. annually, not per kilometre. However, as explained in the section Charges and taxes by mode, both of these charges are considered to be marginal taxes/charges and are recalculated into a cost per vehicle kilometre. For the total route from Oslo to Rotterdam, the internalisation ratio varies between 92 % and 119 %, dependent on the route (see Table 12). The Öresund Bridge fee is attributable to the over-internalisation of Alternative 2. However, for each segment, the rate of internalisation varies a great deal, e.g. an under- internalisation is observed in Sweden and the Netherlands, the countries that use the Eurovignette instead of road tolls. The Eurovignette generates a much lower fee per vehicle kilometre. The difference between the national and international internalisation ratio is the inclusion of the national vehicle tax. As seen in the table, the inclusion of the vehicle tax generates a slightly higher rate of internalisation (a rise of between 2 % and 8 %) for each segment.

Table 12. **Internalisation ratio, Oslo – Rotterdam, road.**

Segment	Country	Distance (km)	Total cost (€)	Total tax (€)	National (incl vehicle tax)	International
Oslo-Svinesund	NO	113	26	29	115%	109%
Alternative 1						
Svinesund-Trelleborg	SE	478	105	76	76%	72%
Trelleborg-Travemünde	Ferry	215	41	17		41%
Travemünde – Hengelo	DE	373	70	114	174%	165%
Alternative 2						
Svinesund-Malmö	SE	466	100	119	122%	118%
Malmö-Rödbyhavn	DK	179	39	66	173%	170%
Rödbyhavn-Puttgarden	Ferry	16	3	-		-
Puttgarden- Hengelo	DE	446	101	131	138%	131%
Hengelo – Rotterdam	NL	193	42	24	61%	57%
Total (Alt 1)		*1372*	*283*	*260*		*92%*
Total (Alt 2)		*1413*	*309*	*369*		*119%*

Further, sensitivity analyses have been conducted to test the robustness of the results. For wear and tear, the IMPACT cost for Sweden is higher than the cost used in our main analysis (i.e. the cost presented in the tables above). In the main analysis, we assumed the average value for EU27 to be similar to 0.096 Euro/vkm for motorways and 0.21 for trunk roads, instead of the suggested 0.52 and 0.35 for Sweden. When using the IMPACT values for Sweden, the internalisation ratio is approximately 70 % lower for the segment through Sweden. However, for the total route, the ratio changes from 45 % to 47 % (i.e. from 92 % to 49 % for Alternative 1, and from 119 % to 66 % for Alternative 2 (see Appendix).

The second key impact is the congestion cost. In the high congestion scenario, the internalisation ratio drops by 36 %, but only by 5 % in the low congestion scenario. However, due to high uncertainties, the congestion cost should be interpreted with caution, especially since we have not considered the location specific aspects in detail.

The third impact is the assumption of a changed diesel tax. By using fuel from the country with the lowest diesel tax, i.e. the Netherlands in Alternative 1, and Denmark in Alternative 2, the internalisation ratio drops by 6 – 7 %. The change of noise cost from an average valuation between day and night to a separate analysis of daytime and night time does not result in any significant impact on the internalisation ratio.

Rail

Table 13 shows the external costs for the rail route between Oslo and Rotterdam. Wear and tear is by far the largest cost along this route, and accidents represent the least costly externality. Since all cost calculations are based on distance, the externalities are higher in the countries through which the route is the longest.

Table 13. **External costs, Oslo-Rotterdam, rail.**

Segment	Country	Distance (km)	Air Pollution (€)	CO_2 (€)	Noise (€)	Wear & tear (€)	Accidents (€)	Total costs (€)
Oslo-Kornsjö	NO	140	25	55	28	144	17	269
Kornsjö-Öresund	SE	522	92	206	120	538	63	1 018
Öresund-Padborg	DK	340	60	134	62	350	41	647
Padborg-Bad Bentheim	DE	425	75	168	84	438	51	815
Bad Bentheim-Rotterdam	NL	169	30	67	70	174	20	361
Total		*1 595*	*281*	*630*	*365*	*1644*	*191*	*3 111*

Costs in Euros (2012 price levels).

The charges and taxes faced by a freight train travelling from Oslo to Rotterdam are presented in Table 14. As mentioned previously, all countries have a base charge for train lines. Denmark and Sweden feature a higher degree of charge differentiation, in addition to bridges charging passage fees. In our calculations, the passage fee for the Öresund Bridge connecting Sweden and Denmark is split equally between the two countries. The relatively high costs in Denmark are attributable to the high passage fees for the Öresund and Great Belt Bridges. Even though the distance travelled in Germany is shorter, the fees in Germany are more than twice as large as the fees in Sweden. Comparing the cost per kilometre with relative costs in excess of three Euros per kilometre, Norway, Denmark and Germany levy much higher track charges than Sweden, where the cost is less than one Euro per kilometre.

Table 14. **Taxes and charges, Oslo-Rotterdam, rail.**

Segment	Country	Distance (km)	Train path/ Access fee (€)	Passage fees (€)	Accident fee (€)	Total charges (€)
Oslo-Kornsjö	NO	140	492			492
Kornsjö-Öresund	SE	522	282	161	49	492
Öresund-Padborg	DK	340	96	972		1 067
Padborg-Bad Bentheim	DE	424	1 321			1 321
Bad Bentheim-Rotterdam	NL	169	385			385
Total		*1 595*	*2 575*	*1 133*	*49*	*3 757*

Taxes and charges in Euros (2012 price level).

The rates of internalisation are presented in Table 15. All countries, except Sweden, manage to reach a full internalisation ratio. Only half of the external costs in Sweden are internalised, while three of the other countries are far above the full internalisation ratio. The Netherlands is the country that comes closest to the full rate of internalisation. The high rate of internalisation in Denmark can partly be attributed to the inclusion of passage fees across the Öresund and Great Belt Bridges, which yields a high charge per train kilometre in Denmark.

Table 15. **Internalisation ratio, Oslo-Rotterdam, rail.**

Segment	Country	Distance (km)	Total costs (€)	Total charges (€)	Internalisation ratio
Oslo-Kornsjö	NO	140	269	492	183%
Kornsjö-Öresund	SE	522	1 018	492	48%
Öresund-Padborg	DK	340	647	1 067	165%
Padborg-Bad Bentheim	DE	425	815	1 321	162%
Bad Bentheim-Rotterdam	NL	169	361	385	107%
Total		*1 595*	*3 111*	*3 757*	*121%*

The sensitivity analysis shows that the different costs for daytime and night time noise only marginally affects the internalisation rate on this route. The inclusion of congestion costs yields somewhat lower internalisation rates, but the change is minor, and the basis of the congestion valuation is associated with uncertainties. The use of a diesel instead of an electrical locomotive lowers the rate of internalisation by 70 %. The difference in air pollution and greenhouse gases is large between electrical and diesel driven rail vehicles, which is clearly shown in this sensitivity analysis and was also presented in Table 4.

Sea

For sea transport, container vessels have been assumed, as mentioned in the introduction under the sea section. There are no fuel taxes for sea transportation, and since the focus is on links, port fees are not considered. Hence, the only charge included is the Swedish fairway due, which is levied when passing the port of Gothenburg. The results presented in Table 16 clearly show that the external costs by far exceed charges.

For sea transportation, it is relevant to comment on current and future increasingly stringent regulations for emissions of SO_2 and NO_x. These regulations will become more stringent in the Emission Control Areas (ECA), i.e. the North Sea, Baltic Sea and the English Channel, and stricter regulations compared with today will apply for all sea transport (Mellin, 2010). Hence, the regulation will address the external costs from shipping without being incorporated by means of taxes or charges. The regulation is rather expressed in higher prices for such items as cleaner fuels and cleaning techniques for operators.

Table 16. **Internalisation ratio, Oslo-Rotterdam, sea.**

Segment	Part of sea	Distance (km)	Air Pollution	CO_2	Total	Fairway due		Total	Internali-sation ratio
						(Good)	(GT)		
Oslo-Rotterdam	North sea	1 028	50 969	6 546	57 515				0%
Oslo-Gothenburg	North sea	302	13 904	1 923	15 827	1 637	1 485	3 121	20%
Oslo-Gothenburg – Rotterdam	North sea	1 230	56 629	7 833	64 461	1 637	1 485	3 121	5%

5.2 Narvik – Naples

Road

Table 17 presents the results of the road transport between Narvik and Naples. This segment contains two different routes through Sweden, one via Västerås and another via Stockholm. The main cost is wear and tear, followed by air pollution along the Oslo – Rotterdam corridor. The difference between the alternatives is mainly attributed to a higher share of motorways in Alternative 2, i.e. the Swedish segment, which generates a lower cost for wear and tear as well as accidents. In this corridor, the external costs per vehicle kilometre vary more greatly than in the Oslo – Rotterdam corridor, especially for the Northern parts i.e. Norway and Sweden. This result is mainly due to the high share of non-motorways in these segments.

Table 17. **External costs, Narvik-Naples, road**

Segment	Country	Distance (km)	Air Pollution	CO_2	Noise (average)	Wear& Tear	Accidents	Total
Narvik-Riksgränsen	NO	48	3.1	1.3	0.2	13.0	1.6	19.2
Riksgränsen-Västerås-Trelleborg	SE	1 964	124.8	51.7	6.7	455.7	32.8	671.7
Riksgränsen - Stockholm – Trelleborg	SE	2 009	126.2	52.5	7.2	422.0	27.3	635.2
Trelleborg-Rostock	Ferry	154	22.0	6.7				28.7
Rostock- Kufstein	DE	869	50.2	21.2	2.6	83.0	3.2	160.2
Kufstein-Brennero	AU	109	6.3	2.7	0.4	7.8	0.6	17.8
Brennero-Naples	IT	922	53.4	22.5	3.1	123.0	4.2	206.2
Total (Via Västerås)		*4 066*	*259.8*	*106.1*	*13.0*	*682.5*	*42.4*	*1 103.8*
Total (Via Stockholm)		*4 111*	*261.2*	*106.9*	*13.5*	*648.8*	*36.9*	*1 067.3*

Costs in Euros, (2012 price level).

Table 18 summarizes the charges and taxes for the highway routes between Narvik and Naples. The highest tax is the diesel tax, followed by the road tolls in Germany, Austria and Italy. In a comparison of taxes and charges per vehicle kilometre between the segments, a great variation is shown. However, the costs levied are greater for the Southern parts of the corridor i.e. Germany, Austria and Italy. The extreme case of Austria generates a charge of over 1 Euro per vehicle kilometre.

Table 18. **Taxes and charges, Narvik-Naples, road**

Segment	Country	Distance (km)	Vehicle tax	Diesel tax	Euro-vignette	Toll/ Maut	Fairway due	Total (excl. Vehicle tax)
Narvik-Riksgränsen	NO	48	0.6	7.9	-	0	-	7.9
Riksgränsen-Västerås-Trelleborg	SE	1 964	17.2	311.8	19.6	-	-	331.4
Riksgränsen - Stockholm – Trelleborg	SE	2 009	17.6	309.9	20.1	-	-	330.0
Trelleborg-Rostock	Ferry	154	-	-	-	-	18.0	18.0
Rostock- Kufstein	DE	869	14.3	106.3	-	158.7	-	265.0
Kufstein-Brennero	AU	109	1.5	11.3	-	107.5	-	118.8
Brennero-Naples	IT	922	6.1	105.6	-	114.8	-	220.4
Total (Via Västerås)		*4 066*	*0*	*542.9*	*19.6*	*380.9*	*18.0*	*961.5*
Total (Via Stockholm)		*4 111*	*0*	*541.0*	*20.1*	*381.0*	*18.0*	*960.1*

Taxes and charges in Euros, (2012 price level).

Compared to the Oslo-Rotterdam routes, the internalisation ratio is in general slightly lower, which is primarily attributed to the higher share of non-motorways in Sweden, as well as the absence of bridge tolls.

The internalisation ratio for the Narvik to Naples route differs between 87 % and 90 %, i.e. there is an under-internalisation on these routes. However, for the Germany and Austria segments (see Table 19), there is a high over- internalisation. This over-internalisation is mainly attributed to the high costs of road tolls partly used to finance new infrastructure, e.g. a portion of the road toll in Austria has been raised since January 2012 to finance the Brennero Tunnel.

Table 19. **Internalisation ratio, Narvik-Naples, road**

Segment	Country	Distance (km)	Total Cost (€)	Total Tax (€)	National	International
Narvik-Riksgränsen	NO	48	19	7	44%	41%
Riksgränsen-Västerås-Trelleborg	SE	1 964	672	331	52%	49%
Riksgränsen - Stockholm – Trelleborg	SE	2 009	635	330	55%	52%
Trelleborg-Rostock	Ferry	154	29	18		63%
Rostock- Kufstein	DE	869	160	265	174%	165%
Kufstein-Brennero	AU	109	18	119	679%	670%
Brennero-Naples	IT	922	206	220	110%	107%
Total (Via Västerås)		*4 066*	*1 104*	*961*		*87%*
Total (Via Stockholm)		*4 111*	*1 067*	*960*		*90%*

The sensitivity analysis for this route follows the same pattern as the Oslo – Rotterdam corridor and indicates that wear and tear and the high valuation of congestion are the primary external costs. However, in this corridor, these changes are causing an equal impact on the internalisation ratio which is around 20 % lower compared to the main analysis. The cost of noise does not have a significant impact but the lowest diesel tax (i.e. the Austrian diesel tax) causes the internalisation ratio to drop by almost 10 %.

The introduction of the Alpine correction factors in Austria and parts of Italy lowers the over-internalisation, but a large over-internalisation is still observed in Austria. In Italy, the correction of wear and tear generates an internalisation ratio of 87 %, i.e. an under-internalisation.

Rail

The external costs along the rail route from Narvik to Naples follow the same patterns as the Oslo-Rotterdam route, as seen in Table 20. Costs for wear and tear are the highest, while costs for accidents are the lowest. The sensitivity analysis presented towards the end of this section will, however, consider the increased costs of the Alpine region.

Table 20. **External costs, Narvik-Naples, rail**

Segment	Country	Distance (km)	Air Pollution (€)	CO_2 (€)	Noise (€)	Wear & tear (€)	Accidents (€)	Total costs (€)
Narvik-Riksgränsen	NO	40	7	16	5	41	5	74
Riksgränsen-Öresund	SE	2 012	355	795	276	2 073	241	3 739
Öresund-Padborg	DK	340	60	134	62	350	41	647
Padborg-Kufstein	DE	875	154	346	170	902	105	1 677
Kufstein-Brennero	AU	106	19	42	12	109	13	193
Brennero-Naples	IT	760	134	300	127	783	91	1 435
Total		*4 133*	*728*	*1 632*	*652*	*4 258*	*496*	*7 766*

Costs in Euros, (2012 price level).

Table 21 shows the charges for trains travelling from Narvik to Naples. Since most charges are tied to distances actually travelled, the total sum of charges is generally higher along the longer segments, including Sweden, Germany and Italy. However, since each country sets its charges based on different criteria, it is not always clear that the longest segment produces the highest total fees. Comparing the cost per kilometre, the charges are significantly higher in Denmark, Norway and Austria than in Sweden. High costs in Denmark can be attributed to passages fees levied across the Öresund and Great Belt Bridges.

Table 21. **Taxes and charges, Narvik-Naples, rail**

Segment	Country	Distance (km)	Train path, access charge (€)	Passage fees (€)	Accident fee (€)	Total charges (€)
Narvik-Riksgränsen	NO	40	141			141
Riksgränsen-Öresund	SE	2 012	1 012	189	188	1 389
Öresund-Padborg	DK	340	96	1 000		1 095
Padborg-Kufstein	DE	875	1 821			1 821
Kufstein-Brennero	AU	106	353			353
Brennero-Naples	IT	760	1 454	251		1 705
Total		*4 133*	*4 876*	*1 440*	*188*	*6 504*

Taxes and charges in Euros, (2012 price levels).

The internalisation rate for trains on the Narvik-Naples route is presented in Table 22. Three of the countries feature fares above the full rate of internalisation. Germany has a nearly perfect rate of internalisation. As for the Oslo – Rotterdam corridor, Sweden has the lowest internalisation ratio.

Table 22. **Internalisation ratio, Narvik-Naples, rail**

Segment	Country	Distance (km)	Total costs (€)	Total charges (€)	Internalisation ratio
Narvik-Riksgränsen	NO	40	74	141	190%
Riksgränsen-Öresund	SE	2 012	3 739	1 389	37%
Öresund-Padborg	DK	340	647	1 095	169%
Padborg-Kufstein	DE	875	1 677	1 821	109%
Kufstein-Brennero	AU	106	193	353	183%
Brennero-Naples	IT	760	1 435	1 705	119%
Total		*4 133*	*7 766*	*6 504*	*84%*

A sensitivity analysis has been made to control for factors connected to the Alpine environment in Austria and Italy. The analysis shows that when considering the higher external costs assumed for the Alpine region, the internalisation ratios drop considerably for Italy and Austria. For the total route, the internalisation ratio drops by around 8 %.

The sensitivity analysis further shows that differentiating between daytime and night time noise costs affects the internalisation ratio. Night time traffic reduces the internalisation ratio by 9 %, while the scenario of daytime traffic alone raises the internalisation ratio by 4 %.

The inclusion of congestion in the analysis (see Appendix and the explanation in 1.1.6) lowers the internalisation ratio, but the congestion analysis is associated with large uncertainties. In our analysis, congestion lowers the internalisation ratio by 10 %.

Sea

For the sea route between Narvik and Naples, there is a clear under- internalisation for the Oslo – Rotterdam route. The route from Narvik via Bergen to Naples passes through the Northeastern Atlantic, the North Sea and the Mediterranean. The results are presented in Table 23.

Table 23. **Internalisation ratio, Narvik-Naples, sea**

Segment	Part of sea	Distance (km)	Air Pollution (€)	CO_2 (€)	Total (€)	NO_x tax (€)	Internalisation ratio
Narvik- Naples	Northeast Atlantic	6 273	133 312	40 349	173 660	0	0%
Narvik – Bergen	Northeast Atlantic	1 161	24 679	11 663	36 714	13 095	41%
Narvik-Bergen-Naples	Various	6 338	121 207	40 766	161 973	13 095	8%

5.3 Comparison between countries

As presented in the previous table, there is a large variation in the rate of internalisation between different countries. In this section, we will analyse this aspect in further depth.

The external costs for road transport differ between the countries, and the total cost per vehicle kilometre for the different segments varies between 0.16 and 0.40 Euro. This difference is also attributed to the share of motorways and urban areas. In terms of taxes and charges, the actual issue is whether a Eurovignette or road toll is levied since the countries with road tolls feature a higher internalisation ratio (i.e. Germany, Italy and Austria). The passage fees for bridges strongly impact the internalisation ratio, e.g. in Denmark, Sweden and Norway, for the routes between Oslo and Rotterdam.

The above-mentioned comparisons in the rate of internalisation between the countries are also evident in the various routes within the same country. An example is the rate of internalisation for Swedish highways which varies from 49 % in Alternative 1 (via Västerås) in the Narvik – Naples corridor to 118 % in the Oslo – Rotterdam corridor in Alternative 2 (via Denmark). The extremely high internalisation ratio in Austria is owing to the high road toll and low external cost of the all-motorway segment. When applying the Alpine correction factors, this ratio drops in the sensitivity analysis which allows for higher external cost, but there is still a substantial over-internalisation.

For rail, there are clear differences between the countries. Sweden is characterised by low internalisation, with rates of internalisation under 50 % for both routes. The most straightforward explanation is that the level of taxes and charges is not high enough to fully compensate for the negative externalities of rail traffic. Generally, wear and tear is the largest externality, representing over 50 % of the total external costs. For the infrastructure manager, this post would be the most interesting to further analyse and for which to develop an appropriate pricing schedule or index

Another observation is that the internalisation ratio is excessively high, with levels well above 100 % for several countries. In the case of Denmark, the high rate of internalisation can be partly explained by the high fees to cross the two bridges. Since the same methodological base to calculate the external costs in all countries was used, the differing internalisation rates are not so much a product of differing levels of externalities as much as different charging schemes and levels.

6. DISCUSSION AND CONCLUSIONS

External costs can, as mentioned in the introduction, be internalised in various ways, through regulatory measures (e.g. emission classes or sulphur limitation in marine fuel), technological development or taxes and charges. Our analysis focuses on the rate of internalisation at a certain time i.e. the ratio between charges and taxes on the one hand, and marginal external costs on the other.

The internalisation ratio varies considerably for different modes, countries and routes. Comparing the three transport modes, the internalisation ratio is highest for road and rail transport, and lowest for sea transport. For land based modes, the rates of internalisation are higher in the Oslo – Rotterdam corridor than in the Narvik – Naples corridor (see Summary in Table 24). For the road (Alternative 2) and rail routes, there is an over-internalisation for the Oslo- Rotterdam corridor, but the difference between individual countries is large.

Table 24. **Internalisation ratios, summary**

Corridor	Route	Road	Rail	Sea
Oslo - Rotterdam			121%	0%
	Alt 1	92%		
	Alt 2	119%		
	Via Gothenburg			5%
Narvik - Naples			84%	0%
	Alt 1	87%		
	Alt 2	90%		
	Via Bergen			8%

As mentioned in the introduction, the knowledge of external costs is more developed on the road side, which may explain the high internalisation ratios along the highway corridors, a fact that may also explain the observed variation in taxing and charging schemes. In comparison, sea transport are mainly regulated by setting maximum levels of allowed sulphur content in fuels, rather than by means of economic policy measures, such as taxes. When it comes to rail, it is clear that the shorter Oslo-Rotterdam route has a significantly higher rate of internalisation compared to the longer Narvik – Naples route. The explanation is mainly found in the country-specific charging systems, rather than in the length of the segment. The high rate of internalisation for the rail route, however, calls for further discussions.

A large part of the external costs along the rail corridors can be attributed to wear and tear. The capacity of each country to meet these external costs through the charging system will be crucial in order to be able to arrive at full rates of internalisation for rail traffic. The costs of wear and tear can be estimated by means of a variety of techniques; the technique applied in this analysis is based on maintenance costs alone, excluding the cost of operation and renewals. Thus, using an estimate of wear and tear that would include maintenance, operation and renewals would have produced considerably lower rates of internalisation along rail routes. For road traffic, the estimate for wear and tear in IMPACT includes, over and beyond maintenance, certain operational and renewal costs. It is, therefore, difficult to compare the internalisation of wear and tear costs for road versus rail transportation.

Similar to rail, the external costs related to wear and tear constitute a large part of the total sum of external costs for road traffic. This cost category by far exceeds other types of external costs (except for the high valuation of congestion on highway routes in our sensitivity analysis). Since the rate of internalisation varies considerably, in order to achieve full internalisation along these routes, it is necessary to further analyse the wear and tear of infrastructure, as well as the framework for infrastructure taxes and charges in each country.

For roads, the share of motorways is another important factor that affects the external costs along the routes analysed. In combination with road tolls and bridge fees, this share has a significant impact on the rate of internalisation.

The sensitivity analysis shows that other factors, such as noise, congestion and Alpine conditions, cause increased external costs. These factors vary as cost drivers in that the presence of a noise cost has a rather small impact, while Alpine conditions and congestion produce rather large impacts on the rate of internalisation. The high valuation scenario of road congestion is almost as important as wear and tear. Further, the sensitivity analysis shows that the use of diesel locomotives instead of electrically driven locomotives greatly impacts non-internalised external costs.

For road transport, the diesel tax level is also an important factor affecting the internalisation ratio. If a driver chooses to fill up the tank in the country with the lowest diesel tax, the internalisation ratio drops by up to 10 % (i.e. from 87 % to 79 % along the route through Västerås in the Narvik – Naples corridor).

Another way of looking at to what extent external effects are internalised is to calculate the non-internalised costs, i.e. the external cost subtracted by taxes and charges. In Table 25, the results of different routes are summarized. When reading the table, keep in mind that the various vehicles and vessels greatly differ in load capacity. The non-internalised cost per tonne is, therefore, presented, in brackets assuming a load of 12 tonnes for trucks, a load of 480 tonnes for trains and a load of 9100 tonnes for vessels.

Table 25. **Non-internalised external costs, cost per route (per tonne).**

Corridor	Route	Road	Rail	Sea
Oslo –Rotterdam			-674 (-1€/tonne)	57 515 (6€/tonne)
	Alt 1	24 (2€/tonne)		
	Alt 2	-58 (-5€/tonne)		
	Via Gothenburg			61 340 (7€/tonne)
Narvik - Naples			1 262 (3€/tonne)	173 660 (19 €/tonne)
	Alt 1	142 (12€/tonne)		
	Alt 2	107 (9€/tonne)		
	Via Bergen			148 878 (16 €/tonne)

Costs in Euros (2012 price level).

In conclusion, since the system for taxes and charges greatly differs between countries, international comparisons can sometimes be difficult. For example, Swedish rail fees are split into many components, while other countries merge a number of cost factors into one single track fee. It can, therefore, be difficult to arrive at a deeper understanding of how charging schemes are constructed. The development and knowledge of external costs vary a great deal both between countries and modes of transportation.

The uncertainties in the valuations of external costs call for a cautious interpretation of the results. Taking these uncertainties into account, we nevertheless believe that the results reflect the impact on internalisation by different transport policy decisions both by mode and by country.

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APPENDIX – SENSITIVITY ANALYSIS

In this Appendix, our sensitivity analyses are presented. The following changes have been analysed for road transport: noise cost has been assumed to be either all day transport (0.11 Euro/vkm for urban, 0.0013 Euro/vkm for non-urban) or all night transport (0.02 Euro/vkm for urban, 0.0023 Euro/vkm for non-urban). For the segment in Austria and 25 % of the route in Italy, the correction factors for Alpine areas from Lindberg (2006) have been used, i.e. 2.5 for air pollution, 1.2 for accidents, 1.5 for wear and tear, as well as 5 for noise. In Sweden, the values for IMPACT have been utilised for wear and tear in the amount of 0.52 Euro/vkm for motorway and 0.21 for non-motorways. Finally, the lowest fuel tax for each route has been calculated, assuming that one tank will be enough for the entire trip. For Oslo – Rotterdam, Alternative 1 through the Netherlands has the lowest tax; for Alternative 2, Denmark has the lowest tax. For the route between Narvik and Naples, Austria has the lowest fuel tax.

For rail, the Alpine correction factors are assumed for Austria and 25 % of Italy. The following factors are used: air pollution 3.5, wear and tear 1.4 and noise 4. Further, for noise either all day (0.54 Euro/trainkm for metropolitan area, 0.52 for urban, 0.06 for non-urban) or night transport (2.20 Euro/trainkm for metropolitan area, 0.87 for urban, 0.11 for non-urban) has been assumed and assuming a diesel instead of an electric locomotive. (Air pollution: 9.25 Euro/trainkm for metropolitan area, 5.09 for urban, 4.31 for non-urban. CO_2: 0.45 Euro/trainkm).

Congestion has been added to this analysis and for roads, it is assumed to occur during peak hours, i.e. 7-9 am and 6-8 pm. By settling on a driving schedule for road vehicles, these peak periods will occur in different countries. The share of peak hours that will occur in each country, i.e. each segment, has been used to calculate the congestion cost. The values used for roads are in the high scenario of 0.88 Euro/vkm for motorways in urban areas, 0.35 for motorways in rural areas, and 0.13 for non-motorways in urban areas. In the low scenario, 1/10 of these values have been used based on the EC (2008). For rail, we assume that congestion occurs along the entire route. The external cost of congestion for rail is 0.20 Euro/trainkm based on IMPACT. The assumption that congestion will occur along the entire route is improbable, but our aim has been to illustrate a worst case scenario. Since some of the countries have charges for passing certain locations at peak hours, the introduction of congestion affects both external costs and charges.

Oslo – Rotterdam

Road

Table 26 summarizes the results of the sensitivity analyses conducted for the external cost in the Oslo – Rotterdam corridor for road transport.
The difference in congestion cost in the Netherlands is due to the assumed driving schedule which generates a higher share of peak traffic in Alternative 2 as compared to Alternative 1.

Table 26. **External cost, Oslo – Rotterdam, sensitivity analysis, road**

Segment	Country	Distance (km)	Noise (Day)	Noise (Night)	Congestion (Low)	Congestion (High)	Wear&tear
Oslo-Svinesund	NO	113	0.4	0.7	0.0	0.0	15.2
Alternative 1							
Svinesund-Trelleborg	SE	478	1.4	2.5	7.9	79.2	310.2
Trelleborg-Travemünde	Ferry	215	-	-	-	-	-
Travemünde - Hengelo	DE	373	0.9	1.7	0.0	0.0	35.7
Alternative 2							
Svinesund - Malmö	SE	466	1.4	2.5	5.9	59.5	308.1
Malmö-Rödbyhavn	DK	179	0.6	1.0	3.1	31.3	22.3
Rödbyhavn - Puttgarden	Ferry	16	-	-	-	-	-
Puttgarden - Hengelo	DE	446	1.0	1.8	0.0	0.0	59.7
Hengelo - Rotterdam	NL	193	0.8	1.4	7.8 (8.6)	78.0 (86.4)	23.9
Total (Alt 1)		*1372*	*3.5*	*6.2*	*15.7*	*157.2*	*385.0*
Total (Alt 2)		*1413*	*4.1*	*7.4*	*17.7*	*177.2*	*429.2*

Costs in Euros (2012 price level).

For charges and taxes, the only analysis conducted for road transport is a varying diesel tax, i.e. assuming all routes are driven on fuel paid for in the country with the lowest tax within the segment. The varying taxes are illustrated in Table 27.

The difference between Alternatives 1 and 2 for the Norwegian and Dutch segments depends on the tax level. In Alternative 1, the Netherlands has the lowest diesel tax, but in Alternative 2, Denmark offers the lowest diesel tax.

Table 27. **Taxes and charges, Oslo – Rotterdam, sensitivity analysis, road**

Segment	Country	Distance (km)	Diesel tax
Oslo-Svinesund	NO	113	13 (12)
Alternative 1			
Svinesund-Trelleborg	SE	478	54
Trelleborg-Travemünde	Ferry	215	-
Travemünde – Hengelo	DE	373	42
Alternative 2			
Svinesund - Malmö	SE	466	49
Malmö-Rödbyhavn	DK	179	19
Rödbyhavn - Puttgarden	Ferry	16	-
Puttgarden - Hengelo	DE	446	48
Hengelo - Rotterdam	NL	193	22 (20)
Total (Alt 1)		*1 372*	*130*
Total (Alt 2)		*1 413*	*148*

Taxes and charges in Euros (2012 price level).

Table 28 presents the internalisation ratio for each sensitivity analysis performed for road routes between Oslo and Rotterdam. The main factor that affects the total internalisation ratio on the entire route is wear and tear, which generates an internalisation ratio of 49 % and 66 %, respectively, i.e. the internalisation ratio drops by 47 % and 45 %, respectively, compared to the main analysis. This is followed by introducing the congestion cost (high), which lowers the internalisation ratio by 36 % for both alternatives. The changed assumptions concerning noise do not generate a significant impact; however, the lowest diesel tax and low congestion cost generate a similar impact (a drop of 5 to 7 % of the internalisation ratios). On a country-specific level, the charge for wear and tear for Sweden has the biggest impact by lowering the internalisation ratio by 70 %.

Table 28. **Internalisation ratio, Oslo – Rotterdam, sensitivity analysis, road**

Segment	Distance (km)	Main Analysis	Noise (Day)	Noise (Night)	Wear & tear (SE)	Congestion (low)	Congestion (high)	Diesel tax (low)
Oslo-Svinesund (NO)	113	109%	110%	109%	109%	109%	109%	101%
Alternative 1								
Svinesund-Trelleborg (SE)	478	72%	72%	71%	21%	67%	41%	62%
Trelleborg-Travemünde (Ferry)	215	43%	43%	43%	43%	43%	43%	43%
Travemünde - Hengelo	373	165%	166%	164%	165%	165%	165%	159%
Alternative 2								
Svinesund-Malmö (SE)	466	118%	119%	117%	34%	112%	74%	105%
Malmö-Rödbyhavn (DK)	179	170%	171%	169%	170%	157%	94%	170%
Rödbyhavn-Puttgarden (Ferry)	16	0%	0%	0%	0%	0%	0%	0%
Puttgarden-Hengelo (DE)	446	131%	131%	130%	131%	131%	131%	123%
Hengelo – Rotterdam (NL)	193	57%	57%	56%	57%	48%	20%	57%
Total (Alt 1)	*1372*	*92%*	*92%*	*91%*	*49%*	*87%*	*59%*	*86%*
Total (Alt 2)	*1413*	*119%*	*119%*	*118%*	*66%*	*112%*	*75%*	*111%*

Rail

In the sensitivity analysis for rail, a number of parameters are tested to see how outcomes vary. Table 29 shows how external costs vary with the inclusion of different parameters.

Table 29. **External costs, Oslo-Rotterdam, sensitivity analysis, rail**

Segment	Country	Distance (km)	Air Pollution (Diesel locomotive)	CO_2 (Diesel locomotive)	Noise (Night)	Noise (Day)	Congestion
Oslo-Kornsjö	NO	140	651	62	40	28	36
Kornsjö-Öresund	SE	522	2458	232	167	73	134
Öresund-Padborg	DK	340	1558	151	89	36	87
Padborg-Bad Bentheim	DE	425	1984	189	124	44	109
Bad Bentheim-Rotterdam	NL	169	723	75	110	30	43
Total		*1595*	*7373*	*710*	*529*	*211*	*410*

Costs in Euros (2012 price level).

The result of the sensitivity analysis on the internalisation ratios is found in Table 30.

Table 30. **Internalisation ratio, sensitivity analysis, Oslo-Rotterdam, rail**

Segment	Country	Distance (km)	Main analysis	Diesel	Noise (day)	Noise (night)	Congestion
Oslo-Kornsjö	NO	140	183%	55%	183%	175%	161%
Kornsjö-Öresund	SE	522	48%	14%	51%	46%	46%
Öresund-Padborg	DK	340	165%	51%	176%	163%	195%
Padborg-Bad Bentheim	DE	425	162%	48%	170%	154%	143%
Bad Bentheim-Rotterdam	NL	169	107%	36%	122%	98%	97%
Totalt		*1595*	*121%*	*37%*	*128%*	*116%*	*118%*

The main analysis is based on the assumption that an electrical locomotive is used for the entire route. Diesel locomotives are, however, still in use; therefore, we analysed the effects of using a diesel locomotive for the entire route. The internalisation ratio drops by 73 % when using a diesel locomotive. The explanation is that diesel locomotives cause higher levels of emissions of air pollution and carbon dioxide, but most countries do not differentiate between diesel and electrical locomotives. Only Sweden levies an additional fee for the use of diesel fuel. Thus, external costs rise, while fees remain the same, causing a considerably lower rate of internalisation.

In the main analysis, there is also an assumption of trains running both day and night. The external costs for noise are higher at night than during the day. In the main analysis, these costs are divided equally, i.e. we assume 50 % night noise and 50 % day noise. In an attempt to isolate the effects of noise, we instead test a scenario when trains run only during the day or only during the night. Since the external costs for noise are higher at night, the rate of internalisation is generally somewhat lower at night, but the differences are small. The overall internalisation ratio drops by approximately 7 %. There is however little variation, and it is, therefore, reasonable to believe that the external costs of noise are of minor importance, compared to other costs.

The effects of congestion are also analysed. In the main analysis, congestion was excluded due to the complexity of congestion issues. In the main analysis, the external costs, as well as taxes and fees tied to congestion are assumed to be zero. In the sensitivity analyses, congestion is assumed to affect the entire route, and congestion fees, where such exist, are assumed to be maximised. When congestion is considered, the overall internalisation ratio drops by 14 %, and it is clear that congestion has a bigger effect than noise. The analysis of congestion should, however, be treated with some care since it is unlikely that a train running from Oslo to Rotterdam should encounter congestion at every single point along its track. Congestion is instead heavily tied to certain locations and points in time.

Narvik – Naples

Road

In the tables below (number 31-34) the sensitivity analyses for the highway routes in the Narvik – Naples corridor are presented in the same way as for Oslo – Rotterdam. A similar result is seen, i.e. congestion and wear and tear are the factors that generate the highest costs.

Table 31. **External cost, Narvik- Naples, sensitivity analysis, road**

Segment	Country	Noise (Day)	Noise (Night)	Wear& tear (SE)	Congs-tion (low)	Conges-tion (high)
Narvik-Riksgränsen	NO	0.1	0.2	13.0	0.0	0.0
Riksgränsen-Västerås-Trelleborg	SE	4.8	7.9	740.4	6.7	66.7
Riksgränsen - Stockholm – Trelleborg	SE	5.2	9.2	891.2	10.5	104.8
Trelleborg-Rostock	Ferry	-	-	-	-	-
Rostock-Kufstein	DE	1.8	3.3	83.0	7.7	76.6
Kufstein-Brennero	AU	0.3	0.5	7.8	0.0	0.0
Brennero-Naples	IT	2.2	3.9	123.0	12.1	121.0
Total (Via Västerås)		*9.2*	*15.8*	*967.2*	*26.5*	*264.3*
Total (Via Stockholm)		*9.6*	*17.1*	*1 118.0*	*30.2*	*302.4*

Costs in Euros (2012 price level).

The additional analysis in this corridor is the correction factor used for Alpine conditions (see Table 32). The assumption is that all of Austria is considered an Alpine region, while only 25 % of Italy is considered to be Alpine.

Table 32. **External cost, alpine regions, road**

Segment	Air Pollution	Noise (Average)	Wear & tear	Accidents
AU	15.8	1.9	11.7	0.7
IT	86.8	6.9	169.2	5.4

Costs in Euros (2012 price level).

As for the Oslo – Rotterdam case, the diesel tax has been modified. For these routes, the tax in Austria has been assumed since it is the lowest.

Table 33. **Taxes and charges, Narvik - Naples, sensitivity analysis, road**

Segment	Country	Distance (km)	Diesel tax
Narvik-Riksgränsen	NO	48	6
Riksgränsen-Västerås-Trelleborg	SE	1964	245
Riksgränsen - Stockholm - Trelleborg	SE	2009	234
Trelleborg-Rostock	Ferry	154	-
Rostock- Kufstein	DE	869	90
Kufstein-Brennero	AU	109	11
Brennero-Naples	IT	922	96
Total (Via Västerås)		*4066*	*449*
Total (Via Stockholm)		*4111*	*447*

Taxes and charges in Euros (2012 price level).

For the Narvik – Naples corridor, the main impacts on the internalisation ratios are congestion (high) and wear and tear, followed by the varying diesel tax and the correction factors for the Alpine areas (in Austria and parts of Italy). However, due to high uncertainties, the congestion cost should be interpreted with caution especially since the geographical aspect has not been taken into consideration. The analysis of noise cost by night or day only indicates a minor effect.

Table 34. **Internalisation ratio, Narvik - Naples, sensitivity analyses, road**

Segment	Main analysis	Noise (Day)	Noise (Night)	Wear & tear (SE)	Congestion (low)	Congestion (high)	Diesel tax (low)
Narvik-Riksgränsen	41%	41%	41%	41%	41%	41%	33%
Riksgränsen-Västerås-Trelleborg	49%	49%	49%	35%	49%	45%	39%
Riksgränsen - Stockholm - Trelleborg	52%	52%	52%	30%	51%	45%	41%
Trelleborg-Rostock	63%	63%	63%	63%	63%	63%	63%
Rostock- Kufstein	165%	166%	165%	165%	158%	112%	156%
Kufstein-Brennero	670%	525%	813%	670%	670%	670%	670%
Brennero-Naples	107%	107%	106%	107%	101%	67%	102%
Total (Via Västerås)	*87%*	*85%*	*89%*	*69%*	*85%*	*70%*	*79%*
Total (Via Stockholm)	*90%*	*88%*	*92%*	*73%*	*87%*	*70%*	*81%*

Due to changes in the valuation of air pollution, followed by wear and tear, the analysis of the Alpine correction factors indicates a major impact.

Table 35. **Internalisation ratio, Narvik - Naples, alpine factor, road**

Segment	Main analysis	Air Pollution	Noise (Average)	Wear & tear	Accidents
AU	670%	437%	618%	549%	666%
IT	107%	92%	105%	87%	106%

Rail

The sensitivity analysis for the Narvik-Naples rail route is similar to the Oslo-Rotterdam rail route. An addition is, however, made--an analysis for Alpine conditions, which affects the external costs in some countries along the route. Tables 36, 37 and 38 summarize the results of the sensitivity analysis.

Table 36. **External costs, Narvik - Naples, sensitivity analyses, rail**

Segment	Country	Distance (km)	Air Pollution-diesel locomotive	CO_2-diesel locomotive	Noise – (Night)	Noise-(Day)	Congestion
Narvik – Riksgränsen	NO	40	175	18	7	4	10
Riksgränsen – Öresund	SE	2012	8 876	896	361	190	518
Öresund – Padborg	DK	340	1558	151	89	36	87
Padborg-Kufstein	DE	875	4141	390	263	77	225
Kufstein – Brennero	AU	106	458	47	15	9	27
Brennero – Naples	IT	760	3476	338	183	70	196
Total		*4133*	*18685*	*1840*	*917*	*386*	*1063*

Costs in Euros (2012 price level).

The Narvik-Naples route passes through Alpine areas, which are to some extent subject to higher external costs. An Alpine correction factor has been applied to Austria and parts of Italy, which produces lower rates of internalisation for these countries.

Table 37. **External cost, alpine regions, rail**

Segment	Country	Distance (Km)	Air pollution	Noise	Wear & tear
Kufstein – Brennero	AU	106	65	46	152
Brennero – Naples	IT	760	251	253	1057

Costs in Euros (2012 price level).

The internalisation ratio drops greatly when switching to a diesel locomotive. Again, diesel locomotives have higher levels of emissions of air pollution and carbon dioxide, but for most countries, the access fees are the same for diesel and electrical locomotives. While fees remain at the same level, this situation causes higher external costs, resulting in a lower internalisation ratio.

Table 38. **Internalisation ratio, Sensitivity analysis, Narvik-Naples, rail**

Segment	Main analysis	Noise (Day)	Noise (Night)	Congestion	Diesel	Alpine area
Narvik-Riksgränsen	190%	193%	186%	166%	58%	190%
Riksgränsen-Öresund	37%	37%	36%	32%	11%	37%
Öresund-Padborg	169%	176%	163%	151%	51%	169%
Padborg-Kufstein	109%	115%	103%	96%	32%	109%
Kufstein-Brennero	183%	185%	180%	160%	55%	111%
Brennero-Naples	119%	124%	92%	106%	35%	87%
Total	*84%*	*86%*	*76%*	*74%*	*25%*	*77%*

When controlling for noise at day and night, there is some variation. If trains would only run during the day, avoiding the external costs of noise at night, the internalisation ratio would increase by only 2 %. Night time traffic tends to reduce the internalisation ratio by 10 %. In the case of Italy, the internalisation ratio drops by approximately 23 % for night time traffic due to the charging structure since Italian track charges are lower at night. The gain from running all day trains is not considerable, especially since the external costs from congestion would increase leading to the conclusion that increased night time traffic increases external costs

The sensitivity analysis further shows that when considering congestion, internalisation ratios fall somewhat by around 12 % overall. Three of the countries have explicit charges aimed at meeting the costs of congestion, but the others have probably included such fees in their access charges. Congestion also seems to have a greater impact on the internalisation ratio than noise. As discussed above, analysing congestion is not straightforward, and the figures should be interpreted as rough estimates.

IMPACT also includes costs that are specific to the Alpine regions. Correction factors are added to the noise, air pollution and wear and tear. For the Austrian segment, the Alpine correction factors are considered for the entire segment. In Italy, approximately 25 % of the segment runs in Alpine areas, which means that the correction factor is only applied to 25 % of the distance. The consideration of Alpine factors reduces the overall internalisation ratio by 8 %. Analysing only the Austrian and Italian segments, the difference is considerable, with the internalisation ratio dropping by 40 % and 27 % for each country, respectively.

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