EJTIR

Issue 19(1), 2019
pp. 60-76
ISSN: 1567-7141
http://tlo.tbm.tudelft.nl/ejtir

Evaluating the external costs of a modal shift from rail to sea: An application to Sweden's East coast container movements

Inge Vierth[1]
Swedish National Road and Transport Research Institute, Stockholm, Sweden

Victor Sowa[2]
Swedish National Road and Transport Research Institute, Stockholm, Sweden.

Kevin Cullinane[3]
University of Gothenburg, Gothenburg, Sweden.

This study analyzes the comparative level of social and external costs if an existing transport chain is replaced by one that includes a greater use of shipping. The main objective of the paper is to assess, on the basis of changes in social and external cost, the potential effectiveness of policies which aim to promote a modal shift to shipping. The social and external costs of both options are evaluated, therefore, using both Sweden's national guidelines for cost-benefit analysis and the European guidelines. A secondary objective of the paper is to evaluate the sensitivity of outcomes to the methodology applied and the input values employed, as well as to identify the relative strengths and weaknesses of these two CBA methodologies when applied to choices involving a shipping mode, The paper concludes that evaluation outcomes are highly sensitive to the choice of CBA methodology and the input values embedded therein. In addition, a number of shortcomings with the guidelines are identified, the most important of which are the need to: (1) have specific values for air pollution from ships; (2) incorporate a system for continuous updates of emission factors, given that vessel speeds vary over time and; (3) incorporate values for water pollution and its effects on the coast and sea bottom. For the Swedish guidelines specifically, there is a need to encompass a value for the scarcity of rail capacity.

Keywords: External costs, CBA, container, rail, shipping, transport chain, internalization

1. Introduction

A number of EU transport policies are aimed at incentivising a modal switch for long distance freight transport from road to both rail and sea (European Commission, 2011). However, as pointed out by Armstrong and Preston (2017), a number of rail systems suffer from capacity problems which limit the potential and desirability of modal switches from road to rail. Such is the case in Sweden, where the shortage of rail capacity has become so problematic that a policy objective has been set to move freight off both road and rail and on to water. Although the benefits of such a modal switch are not categorical in every case (Hjelle, 2014; Tzannatos et al., 2014), Styhre et al. (2014) identified the main general benefits of increased shipping compared to other modes of transport as being, among other things: lower costs for shippers, a greater

1 Malvinas Väg 6, 114 28 Stockholm, SWEDEN. T: +46 8 555 770 20, E: inge.vierth@vti.se
2 Malvinas Väg 6, 114 28 Stockholm, SWEDEN. T: +46 8 555 770 20, E: victor.sowa@vti.se
3 PO BOX 610, SE-405 30 Gothenburg, SWEDEN. T: +46 31 786 1490 E: kevin.cullinane@gu.se

availability of infrastructure, the potential for lower emissions, less accidents and less congestion or capacity problems.

The analysis presented in this paper identifies and compares the external costs of freight traffic brought about by a restructuring of an existing transport solution so that there is a greater use of shipping. Both the social costs (that are caused by the transport chain) and the external costs (that take into account the internalizing fees) are calculated for two alternative transport chains: a rail and shipping option and a direct shipping option. The results are presented in terms of social costs, (uninternalized) external cost and the internalization rate. The calculations are based on; (1) information from shippers and transport operators regarding the type of vehicles used, their capacity utilisation and the routes deployed (Vierth and Sowa, 2015); (2) the use of the NTM calculation tool regarding emission factors and; (3) the Swedish and European CBA guidelines, respectively, on the unit values of external costs.

Through the application of CBA, the primary objective of the study is to determine the conditions under which policies which are, or might be, implemented to promote a modal shift from rail to shipping are actually efficacious in terms of reducing social and external costs within the Swedish context. The comparative level of social and external costs provides not only an obvious and valuable input into mode/route choice decision-making, but also has the potential to inform transport policy with respect to relieving some of the intense demand on land infrastructure. This may be achieved by replacing long land-based routes by shorter land-based routes to the nearest port and then utilising the sea mode.

By applying the standard CBA guidelines of both Sweden and the EU, a secondary objective of the study is to identify the appropriateness of both sets of guidelines in applications which specifically involve a shipping mode. A detailed comparison of the outcomes associated with each set of guidelines also provides an opportunity for not only assessing the relative strengths and weaknesses of each set of guidelines when applied to this sort of context, but also the sensitivity of the decision outcomes to the set of assumptions and input values which underpin whatever CBA guidelines are applied.

Despite the focus within this study on a specific application to Sweden, similar circumstances often arise in many geographical contexts across the world. This is particularly so with the global proliferation of transport policies which seek to move cargoes off the land transport network and towards water-based transport. Thus, there is an obvious and significant potential for the generalizability of the approach, results and conclusions presented within this paper.

The specific case investigated herein is the movement of containers that originate from within the Mälardalen region on the East coast of Sweden. The containers are currently transported by rail, through ports and intermodal terminals on the East coast, to the port of Gothenburg on the west coast of Sweden, for onward sea transport to a continental hub and the final destination. Instead, this study hypothesizes an alternative routing where these containers are transported by vessel directly from a port in Mälardalen. In 2013, 120 000 TEUs[4] were transported by rail between Mälardalen and the port of Gothenburg (Vierth and Sowa, 2015). If this volume were to be transferred to local ports for accessing a longer sea leg for the freight movement, this would mean an expansion from 260 000 to 380 000 TEUs in the container throughput of the East Coast ports. The focus of this study is to calculate and compare the external costs of direct shipments from Stockholm (as a representative East Coast port) to Hamburg (as a representative continental port), to the external costs of the existing transport chain; where rail transport is used to

4 TEU = Twenty-foot equivalent unit, a standard measure of the size of a container.

Gothenburg and sea transport from there to Hamburg[5]. The two options to be evaluated are shown graphically in Figure 1.

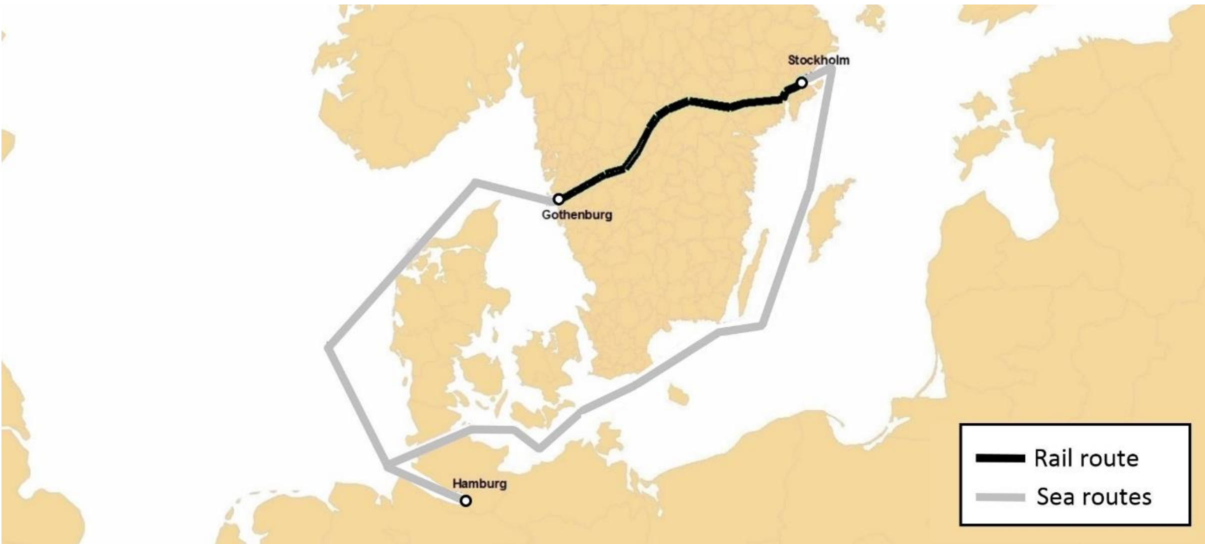

Figure 1. The two alternative transport chains to be evaluated (Illustration: Rune Karlsson)

The next section provides an overview of CBA, with a particular emphasis on its practical application through the use of the Swedish and EU CBA Guidelines. Section 3 outlines the broad methodology, encompassing the application of CBA, which has been adopted for the analysis. The external costs which are specifically addressed within the analysis are identified in section 4, and the basis for determining their value is also provided. Section 5 presents and discusses the results of the analysis, while conclusions are drawn in section 6.

2. Cost-benefit Analysis (CBA)

CBA consists of accounting for both *internal costs* (e.g. transport costs) and *social costs* (e.g. costs caused by accidents). Typically, a share of the social costs is internalized via taxes and fees or other policy instruments; the *external costs* are the remaining non-internalized social costs. Below we differentiate between a) social costs and b) external costs that are the part of the social costs that are not internalized). It is important to recognise that the analysis undertaken herein does not constitute a complete CBA, in that no account is taken of internal costs or benefits or, indeed, of any social benefits which might accrue. The focus of the study is on the short-term external costs that have not been paid by transport operators and shippers and, therefore, have not been considered when choosing a transport solution. Instead, these costs are borne by society (Mostert et al., 2017).

There is significant ongoing research on a range of aspects relating to estimating, and even identifying, external costs (Becker et al., 2017). In consequence, the treatment of external costs within CBA is continuously developing. Despite this, a remarkable consensus has emerged with respect to a consistent and reasonably standardized methodological approach, at least with respect to the major issues of concern. Thus, while there are certainly other possible costs that may be taken into account within any specific case (e.g. energy dependency – see Stigka et al. (2014) and Salas et al. (2015)), the major external costs associated with applications to a transport context are broadly agreed to comprise: congestion, accidents and emissions (including pollution,

5 Approximately 50% of the containers handled in the Port of Gothenburg are transported into and out of the port by rail, with the remainder carried mainly by road (Port of Gothenburg, 2015),

greenhouse gases and noise). The preferred methodology that is most typically applied in practice revolves around using:

1. Infrastructure costs that result from the use of the roads, rail tracks and waterways etc., especially costs related to wear and tear (Nilsson et al., 2017; Odolinski & Nilsson, 2017).
2. Speed-flow functions, values of time and demand elasticities as the basis for estimating congestion costs (Lindsney and Verhoef, 2001; Link et al., 2016; Stubbs et al., 2017);
3. Values of statistical life as the basis for estimating the marginal cost associated with accidents (Persson and Ödegaard, 1995; de Blaeij et al., 2003; Leon and Miguel, 2017);
4. The impact pathway (or damage cost) approach for estimating both air pollution and noise costs (Pervin et al., 2008; Watkiss and Holland, 2013). Even before the difficult task of utilizing the willingness-to-pay concept for determining a monetary value for lives, ill-health, lost crops etc (Breidert et al., 2006), this will involve assessing: the volume and types of emissions at source; their geographical dispersion and chemical transformation, as affected by meteorological influences; the exposure of the population at risk and; the impact in terms of mortality, morbidity and other adverse effects (on crops, water etc) (EEA, 2011);
5. The abatement cost approach for estimating climate cost. This use of this approach is justified in preference to the damage cost approach because of the long-term nature of reduction targets for greenhouse gas emissions (Stern, 2008; Nordhaus, 2017).

2.1 European guidelines

The EU provides guidelines for estimating these external costs and recognizes the potential for applying the guidelines at three different levels of analysis within specific national and/or transport contexts (Ricardo, 2014). These three levels are as follows:

1. To apply the methodology described in the guidelines to its fullest and most detailed extent, using disaggregate data to derive the full range of local valuation inputs and key input parameters in a bottom-up approach.
2. To utilize existing values for specific areas and transport contexts that are provided in the guidelines as input values, in order to produce local output values.
3. Where resources are limited, highly aggregate estimates can be derived by applying the EU's country-specific output values, which are provided for each category of external cost.

Clearly, the accuracy in the valuation of external costs within any CBA is a function of the level of analysis that is applied. The analysis undertaken within this work represents a comparison of the outcomes achieved by applying levels one and two, as described above, to the context of Swedish container freight movements. In so doing, both the scale and source of differences in the results achieved can be identified, as can the specific difficulties associated with the application of CBA to the freight context (Austin, 2015), particularly in cases where shipping provides a viable modal alternative (Tichavska and Tovar, 2017).

2.2 Swedish guidelines

Sweden's national CBA guidelines are called ASEK (Trafikverket, 2015a) and have been applied in the evaluation of virtually all Sweden's major national transport investments since the 1990s (Eliasson, 2013).

In the absence of reliable cost estimates, the analysis accounts only for the external costs that arise while the container shipments are being transported. In other words, although potentially important (Tichavska and Tovar, 2017), the external costs incurred in ports and other terminals, as well as all internal costs, are not considered. Based on information from shippers, it is known that the two options analysed are priced at approximately the same level (Vierth and Sowa, 2015).

The comparison of alternative transport chains which is undertaken within this study reveals, therefore, which option imposes the least costs on entities other than transport operators and shippers. It does not, however, reveal the option possessing the lowest economic costs overall. For this, all internal and external costs would need to be included within the analysis (Bickel and Friedrich, 2013).

Various measures can be used to internalize external costs (i.e. to transfer the external costs into a firm's internal costs). The government can introduce regulations that force firms to reduce external costs. For example, the Sulphur Directive within the EU prescribes the maximum permissible sulphur emissions for ships. The government can also introduce or adjust taxes or fees where companies offset social costs and/or it can give incentives for reducing the external costs that transport gives rise to. Finally, companies can also take voluntary measures to reduce external costs. A further aspect of the analysis undertaken herein is, therefore, to account for any internalization fees which may have been paid in each of the cases evaluated.

3. Methodology

The analysis revolves around a comparison of the social and external costs of two alternative freight transport chains. The first is the currently existing base-case solution (Option 1: Rail and shipping) which has a significant land-based element. The other alternative is a theoretical solution which offers a greater use of shipping (Option 2: Direct shipping). Option 2 assumes that the freight movements take place by vessel between the port of Stockholm on the East coast of Sweden and Hamburg. In both options it is assumed that road transport is used to get to and from ports and intermodal terminals. Given the absence of treatment for external costs incurred in container terminals (rail or sea) within both Swedish and European guidelines, it should be borne in mind that Option 1 has one more transhipment point than Option 2.

3.1 Assumptions on vehicles

The assumptions on the vehicles are based on information from shippers and transport operators within the Mälardalen region (Vierth and Sowa, 2015). The trains carrying the containers from the East of Sweden to Gothenburg are assumed to have an average gross weight of 1,300 tons, a payload of 650 tonnes and to be 500 meters long. It is assumed that each train carries an average of 75 TEUs and that the maximum permissible axle load is 22.5 tonnes. The length of the rail transport journey is taken from the Swedish national freight model. About 50 kilometres of the railway line is expected to be in an urban area, corresponding to 11 % of the total rail transport distance.

As of January 1st 2015, sulphur emissions from ships have been reduced to a permitted maximum of 0.1 % within the sulphur emission control area (SECA) in the Baltic Sea, North Sea and English Channel. The owners/operators of vessels have reduced their sulphur emissions either by using low-sulphur fuel or technology for sulphur removal.

The level of a vessel's NO_x emissions is largely dependent on what engines they use. The United Nations International Maritime Organization (IMO) has developed regulations to reduce NOx emissions from ships and categorised them as Tiers 0, 1, 2 and 3, with each tier specifying the requirements that the engine must meet. Determining which Tier requirements are applicable depends on the year the vessel was constructed. It is assumed that the container vessels considered in this analysis meet the Tier 2 requirements, which means that they are built in 2011 or later.

For the purposes of the study presented herein, Unifeeder's vessels plying each of the two shipping routes are assumed to be representative: *Flottbek* (capacity: 1,638 TEUs, DWT: 15,933 tonnes[6], GT: 16,324 tonnes) operates on the Gothenburg-Hamburg route in Option 1: Rail and shipping and *Katharina Schepers* (capacity: 1,036 TEUs, DWT: 13,031 tonnes, GT: 10,318 tonnes) operates on the Stockholm-Hamburg route in Option 2: Direct shipping (see Unifeeder, 2015). According to an estimate derived from the shipping company MSC, a utilization rate of 90 % is assumed, with four vessels deployed on each route. Sailing distances are based on data from sea-distances.org.

3.1 Calculating the amount of emissions

The calculation tool, NTM Calc, was used to compute the amount of emissions from the two options (NTM, 2016). However, in a discussion with NTM it was concluded that the amount of emissions caused by container vessels for the actual year 2015 was overestimated. This was due to the fact that parameters are embedded within the tool that are based on values from 8-15 years ago. In more recent years, however, the operating speeds of bulk, oil and container vessels have been reduced in order to achieve better fuel economy in depressed shipping markets. According to Table 4 in IMO's third Greenhouse Gas report (IMO 2014), for container vessels in the 1000-1999 TEU size range, the ratio of "average at sea speed (v0)" and "design speed (vD)" changed from 0.80 in 2007 to 0.73 in 2012. This means that the operating speed in 2012 was 0.73 / 0.80 = 0.91 * the operating speed in 2007, assuming no change in design speed. The power output is proportional to (v0/vD)^2.5. If v0 decreases to 0.91 * v0 for 2007, the power output therefore reduces to 0.91^2.5 = about 80 % of the power output in 2007. On the basis of this approximation, the emission estimates that have been used in this study (see Table 1) are 20 % lower than those produced by NTM Calc[7].

Table 1. Calculated amount of emissions (in g, kg) in Option 1 and Option 2

	NOx (g)	SO2 (g)	PM (g)	CO2 (kg)
Option 1: Rail and shipping				
Combi train 456 km	36	22	8	75
Container vessel (1,638 TEU) 593 km	2 596 800	135 760	20 728	126 320
Option 2: Direct shipping				
Container vessel (1,036 TEU) 1,074 km	3 262 400	170 560	170 560	152 720

Source: NTM (2016) and our own calculations based on IMO (2014).

3.2 Calculating the social costs

The European guidelines on external costs of transport (Ricardo, 2014) and Sweden's national CBA guidelines, ASEK (Trafikverket, 2015a) are applied in parallel in order to facilitate a comparison of outcomes. The method for calculating the social and external costs associated with each of the two options is in principle the same as applied in Vierth et al. (2013) and Mellin et al. (2013). However, a degree of updating of these works has been implemented herein in relation to both the Swedish and European guidelines and this has had an impact on the cost estimates and internalization rates. These updates relate particularly to assumptions about the characteristics of the vehicles and vessels which carry the freight, their capacity utilization and the taxes and fees which pertain.

[6] DWT = deadweight tonnage, a measure of how much mass a ship can carry

[7] The speed exponent used in these calculations has been derived from the measured average consumption curve (Gudehus and Kotzab, 2012) of the two Unifeeder container vessels, the Flottbek at 1638 TEU and the Katharina Schepers at 1036 TEU (Unifeeder, 2015).

3.3 Calculating the fees
As mentioned above, amongst other things, governments can introduce or adjust state fees to convert external costs into internal costs. For a complete analysis of external costs, it is important to calculate the social costs and to take into account the effect of the taxes and fees that seek to internalize social costs. Therefore, we calculate both the social costs and the external costs (that remain uninternalized when taxes and fees have been deducted) and the internalization rate (taxes and fees divided by the social costs).

4. Identification of social costs and basis for evaluation

Various types of social costs can be identified, some of which are more relevant to certain modes of transport than to others: infrastructure costs, accidents, congestion or scarcity of capacity, noise, air pollution (mainly in the form of nitrogen oxides (NO_x), sulphur dioxide (SO_2) and particulate matter (PM)), climate change impacts in the form of carbon dioxide emissions (CO_2) and the impact of other emissions, including noise, on the land, coastal areas, rivers, seas and the sea bottom. The social costs arising from transport are dependent, among other things, upon the vehicles or vessels used, on the routes taken, and how the overall effects per kilometre are measured in monetary terms. In particular, for the land-based modes the values for air and noise pollution will vary, depending on whether the shipment is carried through rural or urban environments. Table 2 summarises the social costs that are included in the analysis presented in this paper.

Table 2. The social costs of different transport modes

	Rail	Shipping
Infrastructure costs/wear and tear	X	
Accidents	X	
Congestion/scarcity of capacity	X	
Noise	X	
Air pollution	X	X
CO2 emissions	X	X
Pollution, noise in water, effects on coast and sea bottom		X

4.1 Infrastructure costs/wear and tear
The infrastructure costs depend upon the amount of wear and tear that results from the use of the rail infrastructure. In accordance with both the Swedish and European guidelines, the cost of wear and tear is assumed to be zero for shipping.

4.2 Accidents
The social costs of rail accidents include inter alia, health care costs, lost productivity and the costs associated with loss of life and health. In accordance with both the Swedish and European guidelines, the cost of accidents is assumed to be zero for shipping.

4.3 Congestion/scarcity of capacity
Congestion in the ordinary sense of the term does not exist on the railway system because the volume of traffic on the network is regulated; all traffic requires authorization and is scheduled. Instead, the relevant concept is scarcity of capacity. The level of scarcity is largely dependent on the time of day that the trains are running. This means that even stretches of railway line with a lot of traffic can have a good level of capacity at certain times of the day.

The Swedish guidelines do not include a formal valuation of the shortage of railway capacity. The European guidelines specify a range of unit values and a European average value for the scarcity of capacity on rail. The approach used is primarily adapted to evaluating congestion on the road and does not allow for the consideration of rail-specific aspects, such as the fact that some train paths are not granted to operators at all or that greater capacity can be achieved when trains travel at the same speed. It can also be mentioned that an increased use of the rail infrastructure tends to increase the risk of delays for passenger and freight trains. Finally, the Swedish guidelines assume that there are no congestion problems related to shipping in Sweden (Trafikanalys, 2015).

4.4 Noise
The social cost of noise is calculated in accordance with how many people are affected by the noise and depends on the vehicle length, speed and technical characteristics. Noise costs for both road and rail are a relatively new component of the Swedish guidelines and, therefore, were not considered within previous studies such as those reported in Vierth et al. (2013) or Mellin et al. (2013). For an electrically-powered freight train, an average noise cost of € 0.75 per train-kilometre is recommended regardless of where the train is running.

The European values depend on several factors: day/night operation, dense/sparse traffic and operation in urban/suburban/rural areas. The figure used within this study is, therefore, a function of all these factors, where 15 % of all rail traffic is assumed to go through urban areas, with the remaining 85% operating in rural areas. It is also assumed that 50% of the traffic moves during the day and that this is only relatively light traffic. In parallel with both the Swedish and European guidelines, the impact of noise from shipping while at sea is assumed to be equal to zero within this analysis. This is because the noise impact from shipping arises mainly from berthing, loading and unloading in ports and narrow inlets, where there are surrounding residents and buildings.

4.5 Air pollution and CO2 emissions
The Swedish guidelines contain recommendations for the social costs of air pollution and CO_2 emissions on the basis of both per vehicle-kilometre and per kilogram emissions. This study uses the cost per kilogram of emission, since it facilitates a more precise specification of the vehicles and vessels used. This will then yield more precise estimates of the social costs of air pollution and CO_2 emissions. The social costs of one kilogram of air pollution and CO_2 emissions are presented in Table 3. The calculation is undertaken in two steps: The first step is to use the 'NTM Calc' tool to calculate how many tonnes of NO_x, SO_2, PM and CO_2 emissions different vehicles or vessels emit per vehicle-/vessel-kilometre (NTM, 2016). In the second step, these emissions are valued using the Swedish and European guidelines respectively. For the air pollution cost, it is necessary to differentiate between local or regional emissions. This is not needed for CO_2 emissions. As discussed in section 2.2, the total amount of CO_2 emissions from sea transport is dependent on the actual speeds of ships.

For sea transport, the Swedish regional values have been applied, as local air pollution is assumed not to exist. The European guidelines recommend separate valuations for land and sea transport and different sea transport costs for different sea areas. In this study, the average of the values for the North Sea and the Baltic Sea has been used.

It is assumed that all trains run on electricity, which does dominate in Sweden. Thus, rail transport is deemed to have no direct emissions, but only indirectly from the production of electricity. Sweden's energy mix in electricity production is assumed. Diesel locomotives are used to move from the main rail network to the ports. These distances are, however, so short that they are disregarded in this paper.

Table 3. Social costs of rail and shipping under Swedish and European guidelines

	Swedish Guidelines		European Guidelines	
	Rail	**Shipping**	**Rail**	**Shipping**
	€ per train-km for combi train	€ per vessel-km	€ per train-km for train	€ per vessel-km
Wear and tear	2.71	-	3.06	-
Accidents	0.13	-	0.27	-
Scarcity	-	-	0.25	-
Noise	0.75	-	0.32	-
	€ per kg of emission	€ per kg of emission	€ per kg of emission	€ per kg of emission
NO_x	Regional 9.06, local 1.59	Regional 9,06	5.55	5.21
SO_2	Regional 3.06, local 13.93	Regional 3.06	5.66	5.44
PM	Regional 0, local 476.22	Regional 0	Regional 15.40, local 207.93	14.50
CO_2	0.12	0.12	0.09	0.09

Source: Ricardo (2014), Trafikverket (2015a) and own calculations (exchange rate 8.83 SEK/EURO

As revealed through a comparison of the content of Table 3, there are sometimes large differences between the valuations provided by the Swedish and European guidelines. These differences can be caused by different circumstances, e.g. higher wear and tear costs for rail due to stronger winters in Sweden, or different valuations, e.g. of pollution caused by sea transport. For certain items, the variation can be more than a factor of two. While the European guidelines provide a valuation for scarcity of railway capacity, the Swedish guidelines are lacking in this aspect.

For air pollution, the Swedish guidelines differentiate between local and regional impacts for both road and rail but, with respect to the sea mode, the same values are applied to emissions on land and at sea. This may be problematic with respect to the significant differences in the cost of claims that may arise between land and sea (Hämekoski et.al., 2002). For shipping, it should also be noted that the Swedish values for NO_x and CO_2 are higher than the European values, while they are lower for SO_2 and PM.

4.6 Water pollution and the impact on the coast and sea bottom

These are widely-known external costs of shipping. However, both within the Swedish and European guidelines, there are no calculation values quoted for these impacts. For this reason, they are assumed to be zero within this analysis.

1. Analysis and discussion of results

5.1 Social cost calculations

The social costs of the two options for evaluation are calculated on the basis of: (1) the assumptions with respect to the train and vessels used, as outlined in section 2.1; (2) the calculated amount of emissions under the two options, as shown in Table 1 and; (3) the unit values for the social costs, as shown in Table 3 for both the Swedish and European guidelines. The results of these social cost calculations are shown in Tables 4 and 5, for the Swedish and European guidelines respectively.

Table 4. Social costs of the two options (in €) based on Swedish guidelines

	Wear and tear	Accidents	Scarcity	Noise	Air pollution	CO2 emissions	Per train/ship	Per TEU
Option 1: Rail and shipping								
Train	1234	58	0	341	1	9	1644	22
Vessel					23942	15450	39392	27
Total								49
Option 2: Direct shipping								
Ship/Total					30079	18679	48758	52

Source: Trafikverket (2015a) and own calculations (exchange rate 8.83 SEK/EURO)

Table 5. Social costs of the two options (in €) based on European guidelines

	Wear and tear	Accidents	Scarcity	Noise	Air pollution	CO2 emissions	Per train/ship	Per TEU
Option 1: Rail and shipping								
Train	1394	124	114	145	1	7	1784	24
Vessel					14567	11445	26011	18
Total								42
Option 2: Direct shipping								
Ship/Total					18300	13836	32137	34

Source: Ricardo (2014) and own calculations

5.2 Scarcity of rail capacity

It is important to emphasize that the Swedish guidelines do not include any consideration of shortages of track space on the rail system – i.e. the opportunity cost of the pathways for either passenger or freight trains which cannot be accommodated on the existing tracks between Stockholm and Gothenburg. If a larger proportion of containers are transported direct by sea between Mälardalen and mainland Europe, this will release capacity for other trains, either passenger or freight. The Swedish Transport Administration's compilation of the Annual Railway Timetable 2015 (Trafikverket, 2014a) makes it obvious that there are capacity problems between Stockholm and Gothenburg. Figure 2 shows that some of the biggest bottlenecks are located on the line between Gothenburg and Stockholm, mainly in the areas close to these and other cities.

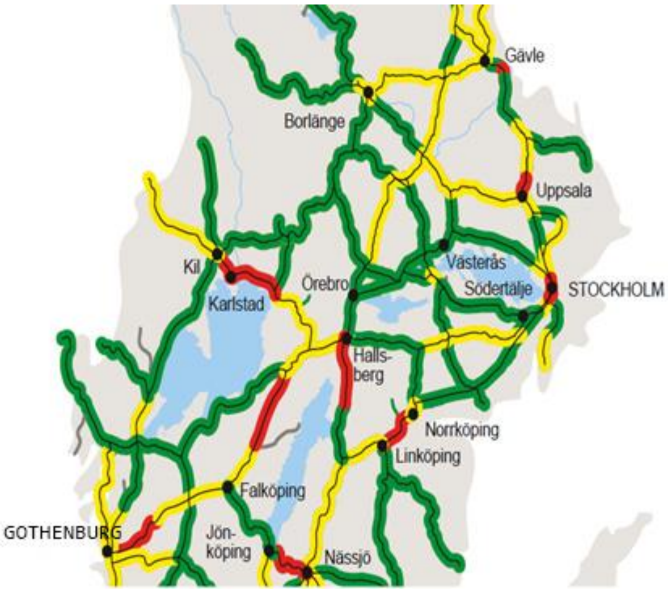

Figure 2: Capacity constraints on Swedish rail network between Stockholm and Gothenburg

Source: Trafikverket (2014b) Capacity limitations are shown as green for low, yellow for medium and red for severe.

Based on the results of the analysis contained in this paper, the adoption of the direct shipping option would mean that about 1,600 freight trains per annum would be removed from the route (120,000 TEU / 75 TEU). The greater use of shipping would mean that four to five fewer freight trains per day would need to operate on this already busy route; this represents about 15-20 % of all the freight trains on the route and about 4-5 % of all trains. It would thus reduce the scarcity of capacity in the rail network and reduce the social costs.

While the Swedish guidelines do not address how a reduction in the scarcity of rail capacity should be valued, the European guidelines place a value on this of € 0.25 per train-kilometre as a European average. This translates to € 114 per train or € 1.52 per TEU for the movement between Stockholm and Gothenburg. Within Europe, social cost values for shortage of rail capacity range from € 0.13 to € 0.65 per train-kilometre. There is reason to believe that Sweden (on average) should apply a value which falls within the upper part of this range, since the country has relatively many congested sections of the rail network. Hylén and Wikberg (2013) point out that Sweden has nine congested sections, compared to one each in Germany and Austria and no congested section in France and Switzerland. The fact that the line between Stockholm and Gothenburg is one of the most congested routes in Sweden suggests a quite high value for this line, as compared to other lines in Sweden and other parts of Europe.

As shown in Table 4, under the Swedish guidelines the total calculated social costs per TEU is lower for Option 1: Rail and shipping (€ 49 per TEU) than for Option 2: Direct shipping (€ 52 per TEU). This is largely due to the fact that the scarcity of rail capacity is not considered in the Swedish guidelines. In fact, as shown in Table 5, under the European guidelines, where the scarcity of rail capacity does have an social cost value, the result is different; with Option 2 yielding a lower social cost (€ 34 per TEU) than Option 1 (€ 42 per TEU). Thus, the issue of valuing any change in the scarcity of rail capacity is critical to the evaluation as undertaken herein.

5.3 Other aspects

It is important to emphasize that neither of the results achieved under the Swedish or European guidelines say anything about which of the two options is more expensive for society. This is because internal costs also need to be taken into account for a full CBA. For the rail mode, wear and tear to the infrastructure accounts for by far the largest proportion of social cost (75%). For sea transport, air pollution is the largest social cost, accounting for about 60 % using the Swedish valuations. NOx emissions account for approximately 94% of the air pollution.

The results achieved herein are different than those in Vierth et al. (2013) who analysed a similar transport case. The main reason for the difference is that Vierth et al. (2013) assumed a train size of 25 40-foot containers with a total weight of 960 tonnes, compared to a train size of 75 TEU and 1 300 tonnes assumed herein. Another contributory factor is that the unit values of social costs and fees have changed since that time.

5.4 Accounting for the internalization of the social costs via fees

Whilst taxes are not relevant to either of the two options, information on fees is derived from the responsible state agencies. The internalizing fees for the modes of transport considered within this study are simply track charges for rail and both fairway dues and passage/canal dues for shipping. Pilot fees are not included as internalizing fees as no accident costs are assumed. The inclusion of the pilot fees would lead to double counting, as the social costs of accidents for sea transport are assumed to be zero. This assumption is a simplification, as the pilotage regulations do not remove the possibility of any accident.

The rail track charges for the train are calculated with the help of the Swedish Transport Administration's calculation tool (Trafikverket, 2015b). Fairway dues are mandatory for ships sailing in Swedish waters and levied by the Swedish Maritime Administration (Sjöfartsverket, 2016). They consist of two parts: a GT charge (based on the vessel's gross tonnage) and a cargo fee (depending on the amount of cargo loaded or unloaded). These fees are € 0.29 per GT and € 0.31 per tonne of cargo. The levels of the fairway dues payable in Options 1 and 2 have been calculated with the help of the Swedish Maritime Administration, taking into account the fact that a vessel pays the GT charge only for the first two calls per month. For Option 2: Direct shipping option, a passage fee for the Kiel Canal of € 1,509 is included as well.

The fees that internalize the social costs are significantly higher for the rail mode than for the sea mode. Referring to Table 6, the fees paid by the firms are € 17 per TEU in Option 1: Rail and shipping and € 6 per TEU in Option 2: Direct shipping. The reason why the sea link pays lower fees in Option 1 (€ 4 per TEU) than in Option 2 (€ 6 per TEU) is that the latter involves the payment of a fee for transiting the Kiel Canal.

Table 6. Internalization fees for the two options

	€ per train/vessel	€ per TEU
Option 1: Rail and shipping		
Train	958	13
Ship	6555	4
Total		17
Option 2: Direct shipping		
Ship/Total	5136	6

Source: Trafikverket (2015a) and own calculations (exchange rate 8.83 SEK/EURO)

As shown in Table 7, when the fees are subtracted from the social costs, Option 1: Rail and shipping looks more beneficial than Option 2: Direct shipping under both the Swedish and European guidelines. The external costs are € 32 per TEU in Option 1: Rail and shipping compared to € 46 per TEU in Option 2: Direct shipping. The fact the fairway dues and the Kiel Canal passage fee are not distance dependent, unlike most of the fees for the other transport modes, means that the internalization rate for sea transport decreases as distance increases.

Table 7. External costs (after accounting for internalizing fees)

Swedish Guidelines			European Guidelines	
	External costs € per TEU*	Internalization rate**	External costs € per TEU*	Internalization rate**
Option 1: Rail and shipping				
Train	9	58%	11	54%
Vessel	23	17%	14	25%
Total	32	35%	25	41%
Option 2: Direct shipping				
Ship/Total	46	11%	28	16%

Source: Trafikverket (2015a), Sjöfartsverket (2016), Ricardo (2014) and own calculations
Notes: *Social costs minus internalizing fees, **internalizing fees divided by social costs.

When the European guidelines are applied, as also shown in Table 7, the same results are obtained in terms of the ranking of the alternative options, where both the (non-internalized) external costs are considered and when the internalization rate is considered. The difference between the options is less, however, than under the Swedish guidelines.

5.5 Summary comparison

Given that the annual container volume moved is 120,000 TEU, the results mean that the annual social costs amount to about € 5.9 million for Option 1: Rail and shipping and about € 6.2 million for Option 2: Direct shipping. After accounting for internalizing fees, Option 1: Rail and shipping yields external costs of € 3.8 million per year and Option 2: Direct shipping yields € 5.5 million per year (applying the Swedish guidelines). The difference between the results for the external costs (after accounting for the internalizing fees) of the two options is largely due to the fact that higher fees are paid for the use of the rail mode than for the sea mode.

2. Conclusions

Based on the Swedish guidelines, social costs for the rail and shipping option are estimated to be lower than for the direct shipping option. When using values from the European guidelines, however, the social costs of the rail and shipping option are found to be higher. When the internalizing fees that are paid are subtracted from the social costs, the result favours the rail and shipping option, using either Swedish or European guidelines.

These estimates do not provide a comprehensive picture, however, because the social cost associated with the scarcity of rail capacity has not been accounted for under the Swedish guidelines. This is potentially important since the direct shipping option would release about 1,600 freight trains per year from the Stockholm-Gothenburg rail line. Several factors indicate that the valuation of the capacity on the Stockholm-Gothenburg line is significantly higher than the European average.

Given the global proliferation of policy objectives which seek to promote the greater use of shipping for the movement of freight (Suárez-Alemán et al., 2015), there exists significant further potential for the generalizability of the approach, results and conclusions of this study. In order to justify and facilitate policies which promote freight modal switching, it is clearly pivotal that infrastructure investment and the imposition of various policy instruments and measures are appropriate. The outcomes from a CBA will often provide the political justification for such decisions, so it is important that not only are these conducted rigorously, but that the assumptions and input parameters which drive them, as well as their associated shortcomings, are well understood.

As has been seen within the context of the study undertaken herein, the decision on methodological design could have a significant impact on the outcome of a CBA and the ultimate decision which might be based on it. As was the case within this study, the degree of disaggregate analysis and local tailoring embedded within the design of a CBA could actually bring about differential rankings in the social and external costs associated with modal alternatives. However, there is a trade-off with achieving greater accuracy in that increasing the specificity of the methodology will obviously also increase the cost of the analysis.

As a case in point, the results of this study highlight the need to supplement the Swedish guidelines by including an element relating to the social costs of the scarcity of railway capacity. This is especially important because there are existing capacity problems on several parts of Sweden's rail network and these are likely to increase in the future. This information is also needed in order to account for the fact that track utilization rates affect the robustness of the rail system and the risk of delays, etc. The need to give due consideration to rail capacity issues is generalizable to other countries when hinterland transport by rail increases on lines which already have high capacity utilisation, typically on mixed lines that are used by both passenger and freight trains (Armstrong and Preston, 2017).

Recognising the potential inappropriateness of utilising off-the-shelf input parameters and/or output costs, such as those provided by the EU (Ricardo, 2014) is pivotal to interpreting the summary output of a CBA, particularly in relation to the potential influence exerted by the valuation of social costs. As a specific example of this, an important difference between the Swedish and the European guidelines is that the NOx valuations are significantly lower in the European guidelines (€ 5.5 per tonne) than in the Swedish guidelines (€ 9.1 per tonne). Such a significant difference in valuation could have important implications for both the policies and targets for freight modal split.

Similarly, unlike the Swedish guidelines, the European guidelines provide specific costs for sea transport. This gives reason to believe that the true social cost values for shipping are closer to the European guidelines than to the Swedish guidelines. To increase the quality of CBAs within the Swedish context, therefore, social costs which are specifically adapted to sea transport should be developed. Alternatively, the use of European unit values for air pollution from ships could be recommended. However, the social costs of sea transport largely depend on vessel engines and speed (in that these directly affect fuel consumption, air pollution and CO2 emissions), and the optimal speed of ships is largely determined as a function of fuel prices and the economic situation in specific shipping markets (Tichavska and Tovar, 2017). As such, vessel speeds will vary over time and this means that the social costs of shipping will also vary over time. Hence, as illustrated when applying the NTM Calc tool in this analysis for estimating the emissions, another generalizable lesson to be learned is that it is desirable that continuous updates of emission factors for sea transport are undertaken.

This again is an aspect which is generalizable to all freight modal choice contexts where shipping is a viable alternative but where national guidelines on CBAs do not adequately deal with the social costs of shipping; it is important that the social costs of sea transport are accounted for and there may even be a case, with greater research, for the development of both 'at sea' and 'in port' valuations, particularly where port or terminal elements of a freight movement fall within the scope of the analysis (van Veen-Groot and Nijkamp, 1999; Cadarso et al., 2010; Ambrosini et al., 2016; Zhu et al., 2018). There is also clearly a need to develop social costs associated with the water pollution of ships and the impacts that this has on the sea bottom and the coast.

Acknowledgements

The authors are grateful to Sweden's East Coast Ports Coalition for funding this study. For valuable comments received on an earlier version of the paper, thanks are due to Katarina Händel (Swedish Maritime Administration), Gunnel Bångman (Swedish Transport Administration), Henrik Swahn (HSAB) and Mattias Haraldsson (VTI). The authors would also like to thank Rune Karlsson for the use of Figure 1 and two anonymous referees who provided valuable feedback on an earlier draft of the paper. The conclusions and recommendations expressed within the paper are the views of the authors alone and do not necessarily reflect the opinions of the VTI as an authority.

References

Armstrong, J., Preston, J. 2017. Capacity utilisation and performance at railway stations. Journal of Rail Transport Planning & Management, 7(3), 187-205.

Ambrosino, D., Ferrari, C., Sciomachen, A., Tei, A. 2016. Intermodal nodes and external costs: re-thinking the current network organization. Research in Transportation Business & Management, 19, 106-117.

Austin, D. 2015. Pricing Freight Transport to Account for External Costs, Working Paper 2015-03 Working Paper Series Congressional Budget Office, Washington.

Becker, U. J., Becker, T., Gerlach, J. 2017. The True Costs of Automobility: External Costs of Cars Overview on existing estimates in EU-27.

Bickel, P., Friedrich, R. (Eds.). 2013. Environmental external costs of transport. Springer Science & Business Media.

Breidert, C., Hahsler, M., Reutterer, T. 2006. A review of methods for measuring willingness-to-pay. Innovative Marketing, 2(4), 8-32.

Cadarso, M.A., López, L.A., Gómez, N. Tobarra, M.A. 2010. CO2 emissions of international freight transport and offshoring: Measurement and allocation. Ecological Economics 69, 1682–1694.

de Blaeij, A., Florax, R. J., Rietveld, P., Verhoef, E. 2003. The value of statistical life in road safety: a meta-analysis. Accident Analysis & Prevention, 35(6), 973-986.

EEA 2011. Revealing the costs of air pollution from industrial facilities in Europe. EEA Technical Report No. 15/2011, European Environmental Agency, Copenhagen.

Eliasson, J. 2013. Project appraisal in Sweden, In Mackie, P. and Worsley, T. International comparisons of transport appraisal practice: Overview report. Institute for Transport Studies, University of Leeds.

European Commission. 2011. White Paper: Roadmap to a single European transport area – Towards a competitive and resource efficient transport system. COM(2011) 144. Brussels.

Gudehus, T., Kotzab, H. 2012. Comprehensive Logistics, Springer, New York.

Hämekoski, K; Tervonen, J; Otterström, T; Anton, P. 2002. Estimation of marginal environmental emission costs of maritime transport. Pilot study based on the ExternE methodology. Elektrowatt-Ekono, Jaako Pöyry Group, 8.5.2002. Study commissioned by SIKA and the Swedish Maritime Administration.

Hjelle, H. 2014. Atmospheric emissions of short sea shipping compared to road transport through the peaks and troughs of short-term market cycles, Transport Reviews, 34(3), 379-395.

Hylén, B., Wikberg Å. 2013. Banavgifter i ett urval av EU-länder och Schweiz, VTI, Stockholm.

IMO. 2014. Third IMO GHG Study 2014. London: IMO

Leon, G., Miguel, E. 2017. Risky transportation choices and the value of a statistical life. American Economic Journal: Applied Economics, 9(1), 202-28.

Link, H., Nash, C., Ricci, A., Shires, J. 2016. A generalized approach for measuring the marginal social costs of road transport in Europe. International Journal of Sustainable Transportation, 10(2), 105-119.

Lindsney, R., Verhoef, E. 2001. Traffic congestion and congestion pricing. In Handbook of transport systems and traffic control (pp. 77-105). Emerald Group Publishing Limited.

Mellin, A.; Wikberg, Å.; Karlsson, R.; Vierth, I., 2013. Internalization of external effects in European freight corridors. CTS Working Paper 2013:2.

Mostert, M., Caris, A., Limbourg, S. 2017. Road and intermodal transport performance: the impact of operational costs and air pollution external costs. Research in Transportation Business & Management. 23, 75–85.

Nilsson, J.-E., Svensson, K. & Haraldsson, M. (2017). Estimating the marginal costs of road wear. Working Paper. Stockholm: Centre for Transport Studies.

Nordhaus, W.D. 2017. Revisiting the social cost of carbon. Proceedings of the National Academy of Sciences, 201609244, https://doi.org/10.1073/pnas.1609244114.

NTM, 2016. NTM Calc 4.0, https://www.transportmeasures.org/ntmcalc/v4/basic/index.html#/.

Odolinski, K. & Nilsson, J-E. (2017) Estimating the marginal maintenance cost of rail infrastructure usage in Sweden; does more data make a difference? Economics of Transportation, 10, 8-17.

Persson, U., Ödegaard, K. 1995. External cost estimates of road traffic accidents: an international comparison. Journal of Transport Economics and Policy, 29(3), 291-304.

Pervin, T., Gerdtham, U.G., Lyttkens, C.H. 2008. Societal costs of air pollution-related health hazards: A review of methods and results. Cost Effectiveness and Resource Allocation, 6(1), 19.

Port of Gothenburg, 2015. Railport Scandinavia, www.portofgothenburg.com.

Ricardo, 2014. Update of the Handbook on External Costs of Transport (Final Report), London: Ricardo-AEA.

Salas, P., Mercure, J.F., Lange, R.J., Grubb, M. 2015. Cost-benefit analysis of climate action in adaptive economic systems: a technology production and supply chain perspective. In Energy Security, Technology and Sustainability Challenges Across the Globe, 38th IAEE International Conference, May 25-27, 2015. International Association for Energy Economics.

Sjöfartsverket. 2016. Fairway Dues. http://www.sjofartsverket.se/en/About-us/Finances/Fairway-Dues/, June 28th.

Stern, N. 2008. The economics of climate change. American Economic Review, 98(2), 1-37.

Stigka, E.K., Paravantis, J.A., Mihalakakou, G.K. 2014. Social acceptance of renewable energy sources: A review of contingent valuation applications. Renewable and Sustainable Energy Reviews, 32, 100-106.

Stubbs, P.C., Tyson, W.J., Dalvi, M.Q. 2017. Transport economics (Vol. 21). Routledge, Oxford.

Styhre, L; Roso, V; Bergqvist, R; Woxenius, J; Lumsden, K. 2014. Development of the Short Sea Shuttle Concept. Gothenburg: IVL Swedish Environmental Research Institute Ltd.

Suárez-Alemán, A., Trujillo, L., Medda, F. 2015. Short sea shipping as intermodal competitor: a theoretical analysis of European transport policies. Maritime Policy & Management, 42(4), 317-334.

Tichavska, M., Tovar, B. 2017. External costs from vessel emissions at port: a review of the methodological and empirical state of the art. Transport Reviews, 37(3), 383-402.

Trafikanalys, 2015. Transportsektorns samhällsekonomiska kostnader 2015,: Trafikanalys (Rapport 2015:4).

Trafikverket. 2014a. Begränsad Kapacitet i Tågplan 2015. Borlänge: Trafikverket, TRV 2013/76110.

Trafikverket. 2014b. Trafikverkets Årsredovisning 2014 Borlänge: Trafikverket

Trafikverket. 2015a. Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 5.2. Borlänge: Trafikverket (Version 2015-04-01).

Trafikverket. 2015b. Avgiftskalkylator. http://www.trafikverket.se/Foretag/Trafikera-och-transportera/Trafikera-jarnvag/System-och-verktyg-for-jarnvag/Avgiftskalkylator1/.

Tzannatos, E.; Papadimitriou, S.; Katsouli, A. 2014. The cost of modal shift: a short sea shipping service compared to its road alternative in Greece: European Transport 2014 Issue 56, paper 2, ISSN 1825-3997.

Unifeeder. 2015. Vessels and vessel tracking. http://www.unifeeder.com.

van Veen-Groot, D.B., Nijkamp, P. 1999. Globalisation, transport and the environment: New perspectives for ecological economics. Ecological Economics 31, 331–346.

Vierth, I. Mellin, A. Karlsson, R. 2013. Externa kostnader och avgifter för fem svenska, gränsöverskridande godstransporter. Stockholm: VTI Notat 10-2013.

Vierth, I., Sowa, V. 2015. Externa kostnader i transportscenarier med utökad användning av sjöfart. Stockholm: VTI Report 848.

Watkiss, P., Holland, M. 2013. The Impact pathway methodology, In Bickel, P., & Friedrich, R. (Eds.). Environmental external costs of transport. Springer Science & Business Media, Heidelberg, pp. 5-11.

Zhu, Y., Shi, Y., Wu, J., Wu, L., Xiong, W. 2018. Exploring the Characteristics of CO2 Emissions Embodied in International Trade and the Fair Share of Responsibility. Ecological Economics 146, 574-587.