8. Transport of goods to and from the center of Brussels: using the port to improve sustainability

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INTRODUCTION

This chapter examines the role inland ports can play in increasing the sustainability of city distribution. By analyzing the external costs linked to incoming and outgoing good flows by barge for a particular inland city port, namely the port of Brussels, and comparing these costs with the external costs linked to road transport, one is able to calculate the societal gain that can be achieved by using barge instead of road transport when transporting goods in and out of cities.

The inland port of Brussels, equipped with 12 km of quays and 14 km of waterways, can accommodate ships up to 4500 tons, making it accessible for short sea shipping. Sailing time to the main port of Antwerp is five hours. Since the port of Brussels is located close to the center of the city, it creates the opportunity to open up Brussels for the transport of goods via inland waterways and enables city distribution from the port. The port can thus contribute to a more sustainable mobility since transporting these goods by barges represents a reduction in the number of trucks on the road. On the other hand, being located so close to the center of the Belgian capital also creates pressure on the port and its industrial and logistic activities from various societal groups and real-estate developers. These stakeholders oppose the development of logistic activities in an urban environment for various reasons. Calculating exactly how much more sustainable this mobility by barge traffic is compared to truck transport seemed a valuable contribution on this topic.

The research goal was therefore to quantify the external costs that would be imposed on society and its individuals if road transport had been used instead of barge traffic. This calculation was carried out for the goods that were loaded and unloaded in the port of Brussels in the year 2007. The focus was solely on the transport aspect, since it was assumed that the current industrial activity in the port area (e.g. concrete factories providing materials for construction sites in Brussels) would remain located in this urban area, regardless of the scenario considered. By comparing the external costs of this hypothetical situation of truck transport with the external costs of the real situation of barge transport, the yearly external cost saving generated by using the port of Brussels could be established, both on a Belgian and a European level.

However, before calculating these figures, it is important to define clearly the relevant external costs and determine appropriate key figures that can be used in a specific case study of this kind. Therefore the chapter will start with a short theoretical background on external costs. Also a brief explanation of the policy relevance of external costs within the EU will be provided. Finally this first section will conclude with a selection of relevant key figures for the different external cost categories that can be used in our research context. In the second section the results for both scenarios are calculated and discussed. In the third section we draw conclusions.

EXTERNAL COSTS: THEORETICAL BACKGROUND, RELEVANCE AND KEY FIGURES

Theoretical Background of External Costs

Externalities are changes in welfare caused by economic activities but not reflected in market prices (Weinreich et al., 1998). In the field of transport these externalities arise when transport consumers/producers impose additional costs on society and its individuals without having to bear these costs themselves. External costs are externalities expressed in monetary terms.

In the literature a distinction is made between the following external costs of transport (Schreyer et al., 2004):

- accidents
- noise
- air pollution
- climate change
- congestion
- nature (disturbance of ecosystems) and landscape (visual infringements)
- additional costs in urban areas (space availability and separation effects)
- up- and downstream processes.

Regarding the external costs of road transport, an important distinction is made between 'intra-sectoral externalities' and 'inter-sectoral externalities' (Verhoef, 2000). Intra-sectoral externalities are, like (most of) congestion and part of the external accident costs, imposed upon each other by road users. Inter-sectoral externalities are, like environmental externalities, noise nuisance and another part of the external accident costs, imposed upon society at large. It is sometimes argued that intra-sectoral externalities such as congestion are not an externality since it is almost entirely internal to the road transport sector.[1] As Verhoef (2000) states however, for a correct welfare analysis, the relevant level of disaggregation is the individual level, so that at least from a welfare-economic point of view both intra-sectoral and inter-sectoral externalities are Pareto-relevant. Given the specific case of the port of Brussels and its urban location, combined with the relatively high degree of congestion on the road network in Belgium in general, marginal congestion costs are thus most relevant in our comparison of barge traffic and road transport. Congestion will therefore be included in the analysis, but in order to avoid simply adding intra- and inter-sectoral externalities together, results will be presented both with and without external congestion costs.

Concerning environmental costs (air pollution, climate change, noise, nature), two aspects are involved: measurement of the environmental effects and monetarization of these effects. Measurement of environmental effects belongs to the domain of environmental technology (e.g. through dose–response functions), while the conversion to monetary values belongs to the field of economics. Regarding monetarization of external costs in the field of environmental effects, four evaluation methods can be identified: stated preference, revealed preference, shadow prices, and productivity effects (Blauwens et al., 2001).

Calculation of the relevant external costs in this case study is based on the best practices in the field of marginal external cost assessment currently available in the scientific literature. Note that we calculate the impact of additional units of transported goods via road or inland waterway, which means that we are interested in marginal rather than average external costs. Although there is growing consensus on the main methodological issues (Maibach et al., 2008), there remain many uncertainties when performing such an external cost assessment in practice.[2] Numerous studies have shown that marginal external costs of transport activities depend strongly on parameters such as fuel type, location (urban, inter-urban, rural), driving conditions (peak, off-peak, night) and vehicle characteristics (Euro standards) (Panis and Mayeres, 2006). As a result, the external cost of one truck-kilometer in urban areas during peak traffic can be up to five times higher than the cost of an off-peak inter-urban kilometer of the same vehicle

(Maibach et al., 2008). For this specific case, differentiation was made at the road type and congestion level. For reasons of consistency and to avoid double-counting, appropriate values of the same study for all the external cost categories were selected, since externalities are sometimes linked to other causes and/or effects in different studies and, moreover, sometimes other assumptions are made. Given the desire to work with values expressed in ton-kilometers in order to be able to take into account the origins/destinations of the good flows, the update study of INFRAS/IWW from 2004 (Schreyer et al., 2004) was chosen. Here, for the different cost categories, marginal external costs are expressed in ton-kilometers, and for road transport a distinction is made per road type where this is relevant (e.g. accidents, congestion). Table 8.1 gives an overview of the external costs being considered, as listed in the INFRAS/IWW study, indicating for each category the type of effects, the cost components, the method used for monetarization, the leverage points and variability, and the type of externality. The different categories of external costs are described in a later section.

A distinction is also made between short- and long-run marginal costs. Short-run marginal costs are related to an additional vehicle entering the (existing) system and consider only variable costs (i.e. costs depending on traffic volume), neglecting fixed costs to run the system or additional costs for possible network improvements in the longer run. Long-run marginal costs consider future system enlargements due to increased traffic volume (Maibach et al., 2008). The focus in this study is on short-run marginal costs, excluding long-run externalities such as the long-run part of separation and space scarcity in urban areas and of up- and downstream processes, since adjustments to the transport infrastructure are not considered here.

Relevance

Although it is relevant from a societal point of view to calculate the amount of potential external cost savings from barge transport compared to road transport, these calculations are also important from a transport policy perspective. The importance of external costs and the ever-growing attention they receive in the transport sector is explained by the fact that non-internalization of external costs gives wrong market signals and thus leads to significant overconsumption and inefficiencies such as congestion, security problems and environmental nuisances. In order to develop more sustainable transport solutions, an internalization of external costs towards fair and efficient prices between transport means is considered essential. When these external effects are internalized, they are made part of the decision-making process of transport users, leading to a more efficient use of transport infrastructure. The European Commission has recommended this

Table 8.1 Overview of external cost categories and characteristics

Type of effect	**Cost components**	**Method**	**Leverage points and variability**	**Type of Externality**
Accidents	Additional costs of • medical care • economic production • losses • suffering and grief	The value of human life is estimated using studies for willingness to pay (WTP) to reduce accident risks	Depending on different factors (partly on vkm)	Partly external (part which is not covered by individual insurance), especially opportunity cost and suffering and grief
Noise	Damages (opportunity costs of land value) and human health	WTP approach for disturbed persons, medical costs and risk value due to transport noise	Depending on traffic volume and environmental performance	Fully external
Air pollution	Damages (opportunity costs) of • human health • material/ buildings • crop losses	PM_{10} dose–response functions are the basis for the repair and damage costs	Depending on vkm, energy consumption and environmental performance	Fully external
Climate change	Damages (opportunity costs) of global warming	Avoidance costs (2 scenarios) to reach Kyoto targets per country or to reach long-term reduction targets	Depending on consumption of fossil fuels	Fully external
Nature and landscape, ground sealing	Additional cost to repair damages, compensation costs	Costs are based on unit types of repair measures, based on space indicators	Fixed costs	Fully external
Additional costs in urban areas (separation and space scarcity)	• Separation: time losses of pedestrians • Space scarcity: space compensation for bicycles	Cost calculation based on random sample evaluation for different cities in Europe	Depending on traffic volume	Fully external

Table 8.1 (continued)

Type of effect	Cost components	Method	Leverage points and variability	Type of Externality
Up- and down-stream processes	Additional environmental costs (climate change, air pollution and nuclear risks)	Calculation of the impact of additional emissions contributing to air pollution and climate change based on life cycle analysis data	Fixed costs (grey energy of infra-structure and rolling stock)	Fully external
Congestion	External additional time and operating costs	Time costs and additional operating costs of road users due to congestion	Depending on traffic amount (number of vehicles)	Average costs are internal to the users. Differences between marginal and average costs are external costs

Note: vkm = vehicle-kilometer.

Source: Schreyer et al. (2004).

policy of internalization in several strategy papers such as the Green Paper on fair and efficient pricing (1995), the White Paper on the overall transport strategy (2001), its mid-term review (2006), the Greening transport package (2008) and most recently the new 2011 Transport White Paper, published in April 2011. The European Commission proposes a stepwise strategy for the internalization of external costs in all transport modes, which contemplates, among other measures, the inclusion of aviation in the EU emission trading scheme from 2012 and the introduction of internalization charges for heavy goods vehicles. To some extent the introduction of market-based instruments for internalization of external costs has already been substantiated in EU directives, most particular the Eurovignette Directive on road charges, which is under review at the time of writing.

External Cost Categories and Key Figures

In this section the different external cost categories are described. This is followed by the development of necessary scenarios for road types and congestion levels, in order to come to recommended marginal external cost key figures per category.

Accidents

External accident costs are the social costs of traffic accidents not covered by risk-oriented insurance premiums and consist of material damages, administrative costs, medical costs, production losses and the so-called risk value. This risk value is a proxy to estimate pain, grief and suffering caused by traffic accidents in monetary values. Mostly this risk value is not covered properly by the private insurance systems. This risk value for fatalities and injuries can be estimated on the basis of a risk-elasticity approach, using values of statistical life (van Lier, 2007).

It is important to note that the knowledge of marginal accident costs is quite poor. Reviewing the literature on accident costs, there are many studies and conventions available on total (social) accident costs, but not many studies have focused on marginal external accident costs (Maibach et al., 2008). Marginal accident costs are those costs induced by an additional vehicle using the road network, and this might cause positive or negative effects. On the one hand, drivers can be disturbed by the growing traffic, so that the number of accidents increases more than proportionally. On the other hand, it is conceivable that average speed slows down with increasing traffic, so that the number of accidents increases more slowly than traffic volumes. Also a shift from severe to slight accidents is possible with slower traffic speeds on congested roads (Banfi et al., 2000). Studies show very diverging results for marginal accident costs on motorways, country roads and urban roads and, on each of these road types, marginal accident costs differ for low and high traffic flows. Due to the inconclusive results concerning lower or higher marginal accident costs in low and high traffic flows, the values presented in the INFRAS/IWW update study of 2004 (Schreyer et al., 2004) used here are only differentiated by road network type (motorways, inter-urban and urban roads).

Noise

Transport noise costs consist of costs for undesired social disturbances (annoyance) and physical and psychological health damages. The annoyance costs are usually economically based on preferences of individuals (by stated- or revealed-preference methods) whereas health costs (especially due to increased risk of heart attacks) are based on dose–response figures (Maibach et al., 2008). Noise is an extremely local phenomenon, making receptor density a determining factor in assessing the marginal cost of a single additional vehicle. Notable for marginal noise costs is that they decrease with increasing traffic volumes, making the definition and measurement of these costs quite crucial and differentiated.

Air pollution

Air pollution costs are caused by the emission of air pollutants such as particulate matter (PM), nitrogen oxides (NO_x), sulphur dioxide (SO_2) and volatile organic compounds (VOC), and consist of impacts on human health, impacts on materials and buildings, agricultural crop losses and costs for further damages for the ecosystem (biosphere, soil, water, forest). Health costs (mainly caused by PM, from exhaust emissions or transformation of other pollutants) are by far the most important air pollution cost category (Maibach et al., 2008). The state of research on these costs is much more advanced than for the other components, since estimations are carried out using the impact pathway approach (developed within the EU-funded ExternE program), which is able to estimate air pollution and climate change damages based on the most important dose-response functions, making the validity for the estimation of health costs quite high and very significant (European Commission, 2005).

Climate change

Climate change or global warming impacts of transport are mainly caused by emissions of the greenhouse gases carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4), and to a smaller extent emission of refrigerants (hydrofluorocarbons) from mobile air conditioners (MAC). The estimation of the costs of climate change poses a high level of complexity due to the fact that the effects are long term and global, and risk patterns are very difficult to anticipate (Maibach et al., 2008). Therefore a differentiated approach is necessary, using both the damage cost approach, which uses the impact pathway approach (very limited in this context, however, since long-term climate change risks on a global scale are very difficult to estimate) and avoidance cost approaches, based on specific (political or scientific) reduction aims.

Nature and landscape

External effects of transport on nature and landscape include on the one hand effects caused by the provision of the infrastructure (roads, bridges, canals) such as spatial separation effects/barrier effect, reduction of quality of landscapes and loss of natural land area (loss of biotopes), and on the other hand effects caused by the utilization of the infrastructure such as pollution of soils and surface/groundwater systems and pollution caused by accidents (Banfi et al., 2000). It is important to note that these effects are largely related to transport infrastructure and do not in general depend on the level of use, and are thus only of limited relevance for the social marginal cost approach. The determination of these effects, including pollution of soil and groundwater due to transport, is based on either the repair and compensation cost approach or the prevention cost approach, but remains difficult in practice.

Additional costs in urban areas

Three major effects can be distinguished when analyzing higher specific external costs of transport in urban areas: time losses due to separation effects for pedestrians, scarcity problems expressed as the loss of space availability for bicycles, and urban visual intrusion due to transport volume and infrastructure.[3] The legitimization of these costs is based on a fairness principle, since road transport leads to space scarcity in cities, which causes additional costs, especially for non-motorized transport (Banfi et al., 2000). Only the separation effects are linked to traffic volumes, and are relevant for short-run marginal costs.

Up- and downstream processes

Indirect effects of transport such as energy production (pre-combustion processes), vehicle production and maintenance, and infrastructure construction and maintenance might cause additional external effects. These effects refer to nuisances already considered in other categories such as air pollution and climate change, but are traditionally treated separately in order to increase transparency. Only the pre-combustion processes are directly dependent on vehicle-kilometers and thus relevant for short-run marginal costs.

Congestion

Congestion arises when, due to a growing density of traffic, vehicles start to disturb each other, causing travel speeds to decrease, so that time and operating costs of all users within the transport system will increase. Since individuals only take into account their private cost function and do not consider the additional costs they impose on others in their travel decisions, there are unconsidered effects, namely marginal external congestion costs. Thus, from a welfare-economic view, 'external' congestion costs arise when additional transport users impose extra costs on other transport users (additional time losses, increased fuel consumption, reduced comfort). Marginal external congestion costs per vehicle-kilometer are thus defined as the difference between the marginal social cost the user imposes on the whole system and the private cost perceived by him. Congestion costs consist primarily of time costs and are calculated on the basis of speed–flow relationships (in the case of the delay of a traffic flow) or queuing analysis (in the case of the build-up of a queue) (Blauwens et al., 2001). Where marginal congestion costs are close to zero under relaxed traffic conditions, these figures might rise up to several euros per vehicle-kilometer under dense and congested traffic conditions.[4] Since congestion effects also differ greatly depending on the road type, there is a great diversity of marginal social congestion costs regarding different traffic situations and road types.

Due to the chosen welfare-economic approach, which concentrates on the individual point of view, congestion costs by definition appear only for transport modes where single users decide on the use they make of infrastructure. Consequently means of transport where the allocation of infrastructure is planned centrally are free of congestion (Banfi et al., 2000). This means that external congestion costs based on a welfare-theoretical definition are only computed for road transport.[5]

Scenarios and recommended marginal external costs per category

To determine the external costs, use is made of the marginal cost figures expressed in €/1000 ton-kilometer published in the INFRAS/IWW update study of 2004 (Schreyer et al., 2004). In this study a distinction is made between different vehicle categories, countries and traffic situations, making it possible to differentiate the marginal external costs of road transport by road type and congestion level.

Since it was beyond the scope of this study to split every potential road trajectory up according to network type (percentages of motorways, inter-urban roads and urban roads) to all origins and destinations, three scenarios for road transport (A, B and C) were developed, with each scenario having a different proportion of rural, inter-urban and urban road sections, coupled with different congestion levels. Due to a lack of detailed congestion figures (both on a Belgian and on a European level), scenarios for congestion also had to be developed. It was assumed that a higher proportion of urban roads is linked to a higher congestion level. Recently this assumption was confirmed on the Belgian level (Maerivoet and Yperman, 2008).[6] Another indication of higher congestion in urban networks was provided by the percentage of lost hours in road freight traffic in 2006 for the Flanders and Brussels region, namely 3.80 percent and 8.2 percent respectively (Steunpunt Goederenvervoer, 2008). The combinations of different road and congestion scenarios are represented in Table 8.2. For example, road scenario B assumes that 60 percent of the roads that would be used are motorways, 30 percent are inter-urban roads and 10 percent are urban roads. In the moderate congestion scenario related to road scenario B, 25 percent of the time traffic is slightly congested and 5 percent of the time traffic is more severely congested, with related marginal

Table 8.2 Moderate and strong congestion scenarios for road scenarios A, B and C

Road	**Thin**	**Dense**	**Dense**
	A (Low)	**B (Mean)**	**C (High)**
% motorways	75	60	40
% inter-urban roads	20	30	40
% urban roads	5	10	20
Total	100	100	100
Congestion: MODERATE	**Thin**	**Dense**	**Dense**
% low	25	25	25
% mean	0	5	5
% high	0	0	5
Total	25	30	35
Congestion: STRONG	**Thin**	**Dense**	**Dense**
% low	95	85	75
% mean	0	10	15
% high	5	5	10
Total	100	100	100

Source: VUB MOSI-T, 2008.

congestion costs (so for 70 percent of the time there is free-flowing traffic, resulting in no marginal congestion costs). In the strong congestion scenario there is, for road scenario B, 85 percent of the time slightly congested traffic, 10 percent of the time more severely congested traffic and 5 percent of the time strongly congested traffic, with related marginal costs for each traffic flow category on each road type.

Since congestion costs are an intra-sectoral external cost category that is best analyzed separately, calculations were made of external costs excluding congestion costs to determine the inter-sectoral external costs of transport for society as a whole. It is important to note that since marginal noise costs are decreasing with increasing traffic volumes, a distinction also has to be made as to whether traffic on a specific road section is thin or dense. For reasons of simplicity we therefore assume that traffic in scenario A is thin, while for scenarios B and C it is assumed dense.

The motivation for using the different congestion scenarios is to calculate in first instance the impact of moderate congestion, where most of the time free-flowing and relaxed traffic conditions occur and dense and congested traffic is non-existent (road A) or rare (roads B and C). In the second instance, the impact of more severe congestion scenarios, where there is at least mild congestion most of the time and severe congestion occurs frequently, is calculated. Table 8.3 gives an overview of the key figures that were used for the external cost calculations for road transport for the port of Brussels case for the moderate and more severe congestion scenarios, together with the values for barge transport and rail (in euros per 1000 ton-kilometer).

Immediately notable in Table 8.3 is, apart from the higher values for road compared to inland waterway and rail, the significant impact of congestion costs in the total of the external costs for road transport. Looking at total external costs without congestion for road transport, it becomes clear that the impact of changing the proportion of road types has only a small effect, ranging from €44.19/1000 ton-kilometers for road scenario A (less urban roads) to €50.45/1000 ton-kilometers for road scenario C (more urban roads), with €46.01/1000 ton-kilometers for reference scenario B. However, when congestion is included, the total external costs range from €46.35/1000 ton-kilometers for (very) moderate congestion in road scenario A to no less than €315.32/1000 ton-kilometers for strong congestion in road scenario C.

Thus for reference road scenario B, external congestion costs compose 52 percent of total marginal external costs in the moderate congestion scenario and 77.4 percent in the strong congestion scenario.

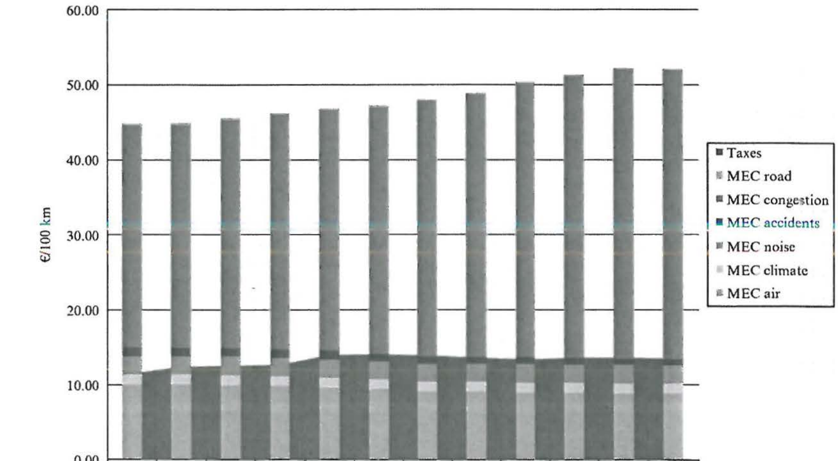
Since the external costs of road transport depend highly on the location, time and vehicle type, there are significant country-related differences. Given the magnitude of our calculated external congestion costs, it was considered useful to compare these congestion figures with specific external cost figures for road transport to be found in the literature to see if the order of magnitude of these congestion costs was confirmed. De Ceuster's study (2004) is particularly interesting in this respect for four main reasons:

- it calculates values on a Belgian level (more specifically the Flemish part of Belgium);
- it takes into account the five most important short-term marginal external cost categories: air pollution, climate change, accidents, noise and congestion.[7] In addition, the short-term marginal external cost of damage to the road caused by additional trucks on the road is taken into account (MEC road in Figure 8.3);
- it differentiates between different vehicle types, giving figures for diesel trucks;
- it takes into account the effects of taxation of road transport (including duties and VAT on fuel, traffic taxes, taxes on insurance premiums and on maintenance of vehicles, Eurovignette, vehicle purchase taxes and registration taxes) in order to determine which part of the external costs is already internalized.[8]

Table 8.3 Recommended marginal external costs per category (moderate and strong road congestion)

INFRAS 2004 €/1000 ton-km	Motorways			Inter-urban roads			Urban roads			Total				
	Low	Mean	High	Low	Mean	High	Low	Mean	High	Road A	Road B	Road C	Water-borne	Rail
Accidents	1.2	2.4	2.9	6.4	7.3	9	11.2	11.6	11.9	2.74	4.79	7.14	0	0
	Thin		Dense	Thin		Dense	Thin		Dense					
Noise	0.24		0.11	2.07		0.74	32.1		13.24	2.20	1.61	2.99	0	0.53
Air pollution	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	8.8	7.4
Climate change	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	0.6	0.6
Urban							7.1	7.1	7.1	0.36	0.71	1.42	0	0
Up & downstream	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.60	3.60	3.60	0.75	0.25
Congestion	Relaxed	Dense	Conges-ted	Relaxed	Dense	Conges-ted	Relaxed	Dense	Conges-ted					
Moderate	5.5	1017.8	1045.9	19.2	645.2	1004.1	13.3	1394	1593.6	2.16	49.78	107.27	0	0
Strong	5.5	1017.8	1045.9	19.2	645.2	1004.1	13.3	1394	1593.6	61.44	157.60	264.87	0	0
Total														
Total excl. congestion										44.19	46.01	50.45	10.15	8.788
Moderate congestion										46.35	95.79	157.72	10.15	8.78
Strong congestion										105.64	203.61	315.32	10.15	8.78

Source: VUB MOSI-T, 2008 using data from Schreyer et al. (2004).



	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Taxes	11.54	12.45	12.57	12.68	14.01	14.08	13.93	13.66	13.38	13.62	13.64	13.52
MEC road	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
MEC congestion	29.57	29.84	30.59	31.37	32.16	32.90	34.08	35.11	36.45	37.61	38.63	38.55
MEC accidents	1.28	1.11	1.05	1.09	1.18	0.95	0.97	0.89	0.98	0.92	0.78	0.84
MEC noise	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45
MEC climate	1.30	1.30	1.32	1.32	1.32	1.33	1.32	1.33	1.33	1.33	1.34	1.34
MEC air	10.07	10.06	10.02	9.88	9.61	9.45	9.13	9.04	9.01	8.95	8.90	8.86

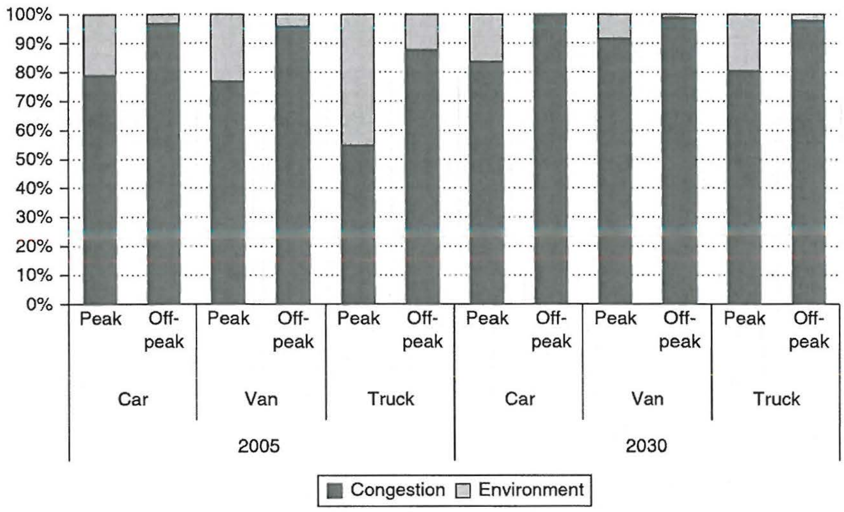
Note: MEC = marginal external costs.

Source: Based on De Ceuster (2004).

Figure 8.1 Marginal external costs versus taxes – heavy-duty diesel truck, Flanders, 1991–2002, 2002 prices

Figure 8.1 shows the values for the marginal external costs and taxes for a heavy-duty diesel truck in Flanders over the period 1991–2002. In 2002 total marginal external costs amounted to €52.18/100 ton/km, with a high and increasing proportion of congestion costs over the years, accounting for 73.87 percent of total short-term marginal external costs in 2002, which is in line with the strong congestion scenario. Therefore it is concluded that the marginal congestion values calculated in the case of the Port of Brussels are in line with other Belgian findings. It is also interesting to note that the other external cost categories in Figure 8.1 remained stable or gradually reduced between 1991 and 2002.[9]

In a recent publication of the Federal Planning Office, Hertveldt et al. (2009) calculated the proportion of congestion costs in the total of congestion and direct environmental external costs for Belgium for 2005 and 2030. The result is shown in Figure 8.2, indicating that during peak traffic the proportion of congestion is well above 80 percent, whereas it



Source: Based on Hertveldt et al. (2009).

Figure 8.2 The proportion of congestion and environmental costs in the direct marginal external costs per vehicle-km in Belgium (2005 and 2030)

is still more than 50 percent during off-peak hours, but since important external cost categories such as accidents and noise are not considered in Hertverldt et al., comparison with results from our calculations is less straightforward.

Table 8.4 compares key figures for the different marginal external costs of transport for three transport modes, provided by three different studies (from Vito, EC and Planco). The differences between the three studies show that there is no such thing as standard key figures for this type of costs. This is explained by the fact that, as mentioned before, marginal external costs of transport activities depend strongly on parameters such as fuel type, location, driving conditions and vehicle characteristics. Especially for road transport, parameters such as network type and driving conditions can vary strongly and are therefore differentiated in our calculations. However, as can be seen in Table 8.4, marginal external costs for trucks are consistently and significantly higher than for the other two modes. For air pollution and climate change, marginal external costs of barge and train are comparable; for the other categories barge has lower marginal external costs than train (for infrastructure the data are inconclusive). Table 8.4 also shows that other (European)

Table 8.4 Marginal average external costs per transport mode from various sources

€/100 km Externalities	Truck			Barge			Train		
	Vito	EC	Planco	Vito	EC	Planco	Vito	EC	Planco
Accidents	22.8	5.4	37.8	0.01	0.0	0.3	1.6	1.5	2.3
Noise	4.4	2.1	7.4	<0.1	0.0	0.0	2.8	3.5	12.7
Air	6.8	7.9	29.1	4.8	3.0	4.2	0.0–8.2	3.8	3.5
Climate	2.3	0.8	0.0	0.6	neg.	0.0	0.4–1.26	0.5	0.0
Congestion	5.4	5.5	1.2		neg.	0.0	neg.	0.2	0.0
Infrastructure	1.9	2.5	0.0	0.7	1.0	0.0	0.2	2.9	0.0
Space availability			1.3	–		0.0	–		0.4
Soil and water pollution	–		8.6	–		0.0	–		0.0
Total	**43.5**	**24.1**	**85.4**	**6.1**	**5.0**	**4.5**	**7.1**	**12.3**	**19.0**
Difference with truck	–	–	–	**37.4**	**19.1**	**80.8**	**36.4**	**11.8**	**66.3**

Note: neg. = negligible.

Source: Based on De Vlieger et al. (2004).

studies often find much smaller congestion values than those mentioned in Table 8.3 and Figure 8.1, but this might be an indication that congestion levels for Belgium are much higher than European averages, due to, among other things, a higher-than-average degree of urbanization.

RESULTS

Introduction

In a first phase we calculated the number of trucks that would be added on the road if barge traffic to the port of Brussels were not possible. In a second phase we compared the external costs of two scenarios: on the one hand the existing situation where goods are transported by barge to and from the port, and on the other hand a hypothetical situation where the same goods are transported by trucks from the same origins and destinations to and from the port. In this manner it is possible to calculate the external costs that are avoided by using barge transport compared to road transport. As mentioned in the previous sections, specific attention is given

Table 8.5 Number of loaded trucks needed to replace barge traffic

(A) Loaded trucks / port-related traffic (no transit) (2007)

Product category (NSTR)	Tonnage (t)	Average truck load (t)	**# trucks**
Minerals and building materials (6)	2 291 000	18.42	124 376
Petroleum products (3)	1 036 000	17.12	60 514
Agriculture products (0)	370 000	15.33	24 136
Foodstuffs (1)	261 000	14.09	18 524
Miscellaneous – containers (9)	152 000	9.11	16 685
Ores and iron steel waste (4)	133 000	18.59	7 154
Metal products (5)	73 000	17.57	455
Total			**255 543**

(B) All trucks (empty & loaded) / port-related traffic and transit (2007)

	Total tonnage (t)	Average truck load (t)	**# trucks**
Port-related traffic	4 345 897	10.8	**402 398**
Transit	3 090 723	10.8	**286 178**
Total	7 436 620	10.8	**688 576**

Source: VUB MOSI-T, 2008.

to the impact of congestion. Also, the fact that barge transport might require road transport to bridge the last mile to final destination or from initial origin is taken into consideration.

Number of Trucks Avoided

Taking into account the proportion of different goods categories and the related average truck load (Steunpunt Goederenvervoer, 2008), calculations showed that more than 255 000 loaded trucks would be needed to replace the port-related barge traffic to and from the port of Brussels, based on 2007 figures (Table 8.5). When also taking empty trucks and transit barge traffic into account, the number of avoided trucks increased to more than 688 000. One can debate the relevance of this exercise from a Brussels perspective since it can be argued that goods transported by barge to or from the port of Brussels require pre- and post-road transport to bridge the first mile from the initial origin and the last mile to the final destination so that for the Brussels region the number of trucks would not be greatly affected. Two remarks can be made in this respect. First, the largest product category is minerals and building materials, mainly due to the presence of several concrete plants in the port area. In this case there is no last- or first-mile truck transport for the barge transport to these facilities. Second, even if the number of avoided trucks can be debated from the Brussels perspective, on a larger Belgian and European scale this effect of pre- and post-transport in Brussels is relatively short compared to the total length of the trajectories. However, this additional pre- and post-transport connected to the barge traffic in port of Brussels is taken into consideration when comparing the external costs of both scenarios.

External Costs of Barge Transport versus Road Transport

Methodology

The goal is to compare the external costs of, on the one hand, the current situation where goods are transported by barge to and from the port, and, on the other hand, the hypothetical situation where the same goods would be transported by trucks from the same origins and destinations. To calculate the total external costs of road transport including congestion, the values based on the moderate congestion scenarios were used first. In a second phase the values based on the strong congestion scenarios were considered. Road scenario B, which is representative for road transport between the ports of Antwerp and Brussels, is considered in both cases to be the reference scenario, with scenarios A and C serving as sensitivity analyses to measure the impact of changes in assumptions with regard to the proportion of road sections. The tonnages are the amounts of goods loaded and unloaded in the port of Brussels in the year 2007. Since we are focusing on the external costs linked to the port of Brussels, transit through the port was not taken into account.[10] Because the external costs are calculated based on the amount of ton-kilometers, clusters were formed based on the origins/destinations of the good flows. In this manner 98.5 percent of the goods flows were assigned to a specific origin/destination.[11] For these flows the distance was calculated separately for transport via waterway and via road in order to calculate the ton-kilometers for every transport mode, using an ArcGIS application. Concerning the international flows, transport coming via short sea shipping was taken into consideration. The remaining 1.5 percent consists of smaller inland goods flows, where an average distance was calculated based on the main Belgian origins/destinations. The calculation of the external costs was performed on a European and on a Belgian level. In the latter case only the Belgian part of the international trajectories by barge or truck is taken into account.

Table 8.6 Overview of external costs for road scenario B (year 2007)

Situation 2007	Belgian level	Road scenario B				
Inland waterway	+ extra pre-/post road transport			Road transport		
	Without congestion	Moderate cong.	Strong congestion	Without congestion	Moderate cong.	Strong congestion
3253583	7252852	11579496	20951119	14749151	30705653	65267844

Difference	Congestion		
Road transport	None	Moderate	Strong
w.r.t. inland navigation	11495567	27452070	62014261
w.r.t. inland navigation + extra pre-/post road	7496299	19126157	44316725

Source: VUB MOSI-T, 2008.

Results for 2007

Table 8.6 gives an overview of the main results for road scenario B for the three congestion scenarios (no congestion, moderate congestion and strong congestion), with an indication of the difference between the external costs of barge transport versus road transport, based on the traffic figures for 2007. Based on the linking of the goods flows to specific origin and destination regions, it was calculated that of a total of 4.3 million tons of goods loaded and unloaded in the port of Brussels in 2007, 1.4 million tons had a Belgian and 3 million tons had a foreign origin or destination.

The results show that if these 4.3 million tons had been transported via trucks on the road network in reference scenario B, this would have generated, on a Belgian level (so only looking at the part of the goods flows on Belgian territory) without taking congestion into account, a total external cost of €14.8 million. In contrast, the transport of the same 4.3 million tons via inland waterway generates an external cost of only €3.3 million (€1 million is caused by Belgian inland flows, €2.3 million is due to the Belgian component of international flows). The external cost saving of barge transport compared to truck transport in this scenario thus equals €11.5 million. Taking into account that goods leaving or arriving by barge in the port of Brussels potentially require a pre- or post-road transport of 20 km to or from the port, the total external cost of this combined transport amounts to €7.3 million (if we assume road scenario B without congestion for the road transport part). This is still only half compared with unimodal road transport. So even in this minimum scenario the external cost savings are significant (€7.5 million).

If the congestion costs are also taken into account, the difference between road and barge transport (with or without pre- and post-transport) becomes even more obvious. Looking first at the moderate congestion scenarios, reference scenario B (with 25 percent relaxed and 5 percent dense traffic congestion conditions) results in a total external cost of €30.7 million for road transport. Taking into account the more severe congestion scenarios, the external costs of road transport increase significantly. In reference scenario B (with a share of 5 percent highly congested traffic conditions), the total external cost of road transport amounts to €65.3 million. Also considering congestion in the pre- and post-transport for barge traffic to and from the port of Brussels increases the total external costs for combined transport in scenario B to €11.6 million for a moderate congestion scenario and to €21.0 million for a strong congestion scenario.[12]

Including the international component of the goods flows to and from the port of Brussels obviously increases the share of the external costs of these international flows. For inland waterways the total external cost in that case amounts to €9.7 million. Taking into account a pre- and post-transport of 20 km (based on road scenario B) the external cost increases to €13.7 million without congestion and €18.0 million and €27.4 million respectively in a moderate and a strong congestion scenario. However, if this transport had been executed entirely by truck transport, the external costs would have been €44.0 million in scenario B without congestion. Including congestion costs, the total external costs of road transport arrive at significantly higher levels: between €91.5 million (for scenario B with moderate congestion) and €194.5 million (for scenario B with strong congestion).

It becomes very clear from these calculations that the congestion levels have an enormous impact on the difference between the external costs of inland navigation compared to road transport. Using the port of Brussels saved €11.5 million of external costs in reference scenario B on a Belgian level in 2007, not taking congestion into account. Taking congestion into account, the cost saved as much as amounts to €27.5 million in a moderate congestion scenario and €62.0 million in a strong congestion scenario. Taking into account the potential pre- and post-road transport when considering inland waterway transport reduces these figures somewhat but the external cost savings remain substantially high: €7.5 million without congestion, €19.1 million with moderate congestion and €44.3 million with strong congestion.

Including the international part of trajectories, the savings further increase to, respectively, on average €34.3 million (without congestion), €81.8 million (with moderate congestion) and €184.8 million (with strong congestion). Taking into account the potential pre- and post-transport again reduces these figures somewhat, but the external cost savings remain substantially high.

CONCLUSIONS

The unique location of the port of Brussels close to the center of the city makes it possible to open up the city for freight transport by inland waterway. Due to this barge transport to and from the port of Brussels, some 255 000 loaded trucks were avoided on the road in 2007 (and even 688 000 trucks when empty trucks and transit flows are also taken into account). In this chapter the size of the external costs currently avoided by using the port were calculated. Based on loading and unloading in the port of Brussels for the year 2007, it was calculated that the avoided external cost on a Belgian level of using barge transport compared to road transport equals €11.5 million without taking into account congestion. Since congestion is an intra-sectoral externality, it was added separately to the analysis. If moderate congestion is assumed, the external cost saving increases to €27.5 million. Taking into account an average pre- or post-road transport of 20 km in the case of barge traffic, the external cost saving is still €7.5 million (without congestion) and €19.1 million (with moderate congestion). When also adding the international part of the trajectories, the external cost savings increased further.

Looking at total external costs excluding congestion, the impact of changing the proportion of road types (motorways, inter-urban roads and urban roads) had only a small effect on total external costs. But when congestion was added to the analysis, the proportion of road types had a large impact on results. Given the sensitivity of the results for the assumed congestion levels and proportion of network types, congestion data gathering on a European and Belgian level should be enhanced in order to make it possible to calculate marginal external congestion costs more exactly. The magnitude of congestion costs, 51.5 percent in the moderate congestion scenario and 77.1 percent in the severe congestion scenario, seemed, however, to be supported with other findings in literature.

NOTES

1. Effects of congestion that are also imposed on the rest of society (and thus not only on transport users) include increased noise effects (due to more accelerating and braking), increased emissions (less efficient fuel consumption) and increased up- and downstream effects (higher wear and tear). On the relation between congestion and accidents, the results in the literature are mixed: probably the number of accidents increases with higher congestion, but the severity is often lower (Maibach et al., 2008). Accidents can, mostly in urban areas, also involve other members of society such as pedestrians and cyclists.
2. For an overview on the assessment of external costs, see, among others, INFRAS/IWW (Banfi et al., 2000 and Schreyer et al., 2004), ExternE, EC (2005), Forkenbrock (2001), Witboek, EC (2001) and revision EC (2006), Mauch et al. (1995), Maddison et al. (1996), Kreutzberger et al. (2006), Macharis and Van Mierlo (2006). For a recent summary of the different external cost categories, the most relevant studies in a European context and recently recommended key figures as proposed by the European Commission, see Maibach et al. (2008).
3. The last element is very difficult to measure and no reliable estimates exist, so usually only the first two effects are taken into account.
4. In the INFRAS/IWW studies (2000 and 2004), traffic situations are categorized by 'free flow' (up to 500 PCU/h/lane) 'relaxed' (500–800 PCU/h/lane), 'dense' (up to 1000 PCU/h/lane) and 'congested' (above 1000 PCU/h/lane) (with PCU = passenger car units).
5. An economic measure of external costs due to traffic delays embracing all modes can be provided by scarcity costs (Banfi et al., 2000). Scarcity costs are the production losses of the economy due to the increased binding of material and human resources in transport. Due to a lack of delay data in barge transport, the focus in this study is on congestion costs from a welfare-economic point of view.
6. In their analysis of traffic congestion in Belgium, Maerivoet and Yperman (2008) concluded that 'time lost' (defined as the average travel time compared to the travel time in an uncongested network with free-flowing traffic) was higher on the underlying road network (regional and urban roads) compared to the main road network (motorways). For example, in the Flanders region, 'time lost' was 3.5 sec./km on motorways, 9.1 sec./km on regional roads and 15.5 sec./km on urban roads. In the Brussels region, 'time lost' was higher on the main network compared to the underlying network (8.6 sec./km on motorways, 6.3 sec./km on regional roads and 5.9 sec./km on urban roads), but time lost on urban roads in Brussels was still higher than time lost on motorways in the rest of Belgium.
7. In De Ceuster (2004), the short-term component of up- and downstream processes, which consists mainly of pre-combustion processes (= external costs due to energy production), is not taken into account as a short-run marginal external transport cost.
8. We abstract from the fact that, ideally, transport users that cause higher external costs should be taxed more heavily in order to give the correct price signal to transport users. Therefore taxes should vary according to place (urban, non-urban), time (peak, off-peak) and vehicle characteristics (Euro norm). This differentiation, however, is achieved only very partially in current legislation.
9. As can also be seen from Figure 8.1, the existing taxation system on heavy diesel trucks compensated for 25.91 percent of short-term marginal external costs in Flanders in 2002, leaving 74.09 percent of external costs non-internalized. This almost equals the proportion of congestion costs, so it could be said that this taxation system internalizes all the external cost categories, except the largest category, namely congestion. Since congestion is very time and location dependent, this implies that a full internalization of external costs requires the introduction of some form of differentiated congestion charging.

10. Without the presence of the port these transit flows would still pass along the canal, assuming the working of the locks and bridges would not be affected.
11. For the Belgian locations, exact origins and destinations were used. For the port of Antwerp, goods flows were considered on an aggregate basis (coming from a central point in the port). For the Netherlands, the flows were considered to originate mainly from the port of Rotterdam. For the other foreign flows, points of origin/destination were selected based on information provided by the port of Brussels.
12. It is important to stress that in these scenarios, based on INFRAS/IWW values, inland waterway traffic is assumed completely free of congestion (see also above).

REFERENCES

Banfi, S., C. Doll, M. Maibach, W. Rothengatter, P. Schenkel, N. Sieber and J. Zuber (INFRAS/IWW) (2000), *External Costs of Transport: Accident, Environmental and Congestions Costs in Western Europe*, Karlsruhe/Zürich/ Paris: The International Union of Railways (UIC).

Blauwens, G., P. De Baere and E. Van de Voorde (2001) *Vervoerseconomie*, Antwerpen: Standaard Uitgeverij.

De Ceuster, G. (2004), *Internalisering van externe kosten van wegverkeer in Vlaanderen*, study performed for Vlaamse Milieumaatschappij, MIRA, MIRA/2004/4, Transport & Mobility Leuven.

De Vlieger, I., E. Cornelis, H. Joul and L.I. Panis (2004), *Milieuprestaties van de binnenvaart in Vlaanderen; Eindrapport*, study performed for Promotie Binnenvaart Vlaanderen, Vito.

European Commission (1995), *Green Paper: Fair and Efficient Pricing in Transport*, Brussels.

European Commission (2001), *White Paper: European Transport Policy for 2010: Time to Decide*, Brussels.

European Commission (2005), *ExternE: Methodology 2005 update Report*, 2nd edn, Brussels.

European Commission (2006), *Keep Europe Moving. Mid-term review of the European Commission's 2001 transport White Paper*, Brussels.

European Commission (2008), *Greening Transport Package*, Brussels.

European Commission (2009), *A Sustainable Future For Transport*, DG Energy & Transport, Luxembourg.

European Commission (2011), *White Paper: Roadmap to a Single European Transport Area – towards a competitive and resource efficient transport system*, Brussels.

Forkenbrock, D.J. (2001), 'Comparison of external costs of rail and truck freight transportation', *Transportation Research Part A: Logistics and Transportation Review*, **35**, 321–37.

HEATCO (2005), *Developing Harmonised European Approaches for Transport Costing and Project Assessment (HEATCO), Deliverable 2: State-of-the-art in project assessment*, Stuttgart.

Hertveldt, B., B. Hoornaert and I. Mayeres (2009), 'Langetermijnvooruitzichten voor transport in België: referentiescenario', Federaal Planbureau, Planning Paper 107.

Kreutzberger, E., C. Macharis and J. Woxenius (2006), 'Intermodal versus unimodal road freight transport – a review of comparisons of the external costs', in B. Jourquin, P. Rietveld and K. Westin (eds), *Transportation Economics: Towards Better Performance Systems*, Abingdon, UK: Routledge, pp. 17–42.

Macharis, C. and J. Van Mierlo (2006), 'Intermodaal vervoer: Milieuvriendelijker ook in de toekomst?', *Tijdschrift Vervoerswetenschap*, **42** (1), 8–11.

Maddison, D., D. Pearce, O. Johansson, E. Calthrop, T. Litman and E. Verhoef (1996), *Blueprint 5: The True Costs of Road Transport*, London: Earthscan.

Maerivoet, S. and I. Yperman (2008), *Analyse van de Verkeerscongestie in België*, Transport & Mobility Leuven, Rapport 07.15, Leuven.

Maibach, M., C. Schreyer, D. Sutter (INFRAS), H. P. Van Essen, B. H. Boon, R. Smokers, A. Schroten (CE Delft), C. Doll (Fraunhofer Gesellschaft-ISI), B. Pawlowska and M. Bak (University of Gdansk) (2008), *Handbook on Estimation of External Cost in the Transport Sector. Internalisation Measures and Policies for All external Cost of Transport (IMPACT)*, Version 1.1., European Commission DG TREN, Delft, CE, the Netherlands.

Mauch, S.P., S. Banfi and W. Rothengatter (1995) *External Effects of Transport*, Paris: International Union of Railways.

Panis, L.I. and I. Mayeres (2006), 'Externe kosten van personenvervoer', in M. Despontin and C. Macharis (eds), *Mobiliteit en (groot)stedenbeleid. 27ste Vlaams Wetenschappelijk Economisch congres*, 19 and 20 October, Brussels, pp. 417–46.

Schreyer, C., C. Schneider, M. Maibach, W. Rothengatter, C. Doll and D. Schmedding (INFRAS/IWW) (2004), *External Costs of Transport: Update Study*, Karlsruhe/Zürich/Paris: The International Union of Railways (UIC).

Steunpunt Goederenvervoer (2008), *Indicatorenboek Duurzaam Goederenvervoer Vlaanderen 2007*, Universiteit Antwerpen, Antwerpen.

van Lier, T. (2007), *De Economische Waardebepaling van een Mensenleven*, thesis, Vrije Universiteit Brussel, Brussels.

Verhoef, E.T. (2000), 'The implementation of marginal external cost pricing in road transport. Long run vs short run and first best vs second best', *Papers in Regional Science*, **79** (3), 307–32.

Weinreich, S., K. Rennings, C. Geßner, B. Schlomann and T. Engel (1998), 'External costs of road, rail and air transport – a bottom-up approach', paper presented at the 8th WCTR, Antwerp.