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The cost of traffic congestion in Belgium

An estimate using the PLANET-model

September 2019

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Abstract – This paper seeks to quantify the cost of the most important inefficiencies in Belgian transport taxation. To this end we calculate the welfare gain of an ideal, optimal tax/subsidy system across the transport market as a whole (i.e. considering private road traffic in conjunction with public transport). We found the total welfare gain to be 2.3 billion euros, of which 1.3 billion are due to time gains of remaining road users. Our measure lies significantly above those found in the literature, since we consider the distortion cause by a wide range of subsidies.

JEL Classification – D61, D62, H21, H23
Keywords – Traffic Congestion, Optimal taxation, Externalities

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Executive summary

This report seeks to quantify the cost to the Belgian economy of major inefficiencies in transport taxation using the FPB's PLANET model. Following an important strand in the applied international literature, we calculate the welfare gains from an optimal tax system, in which traffic taxes are perfectly aligned to the marginal external cost of transport (congestion costs and environmental costs).

To this end, we first provide a full overview of the current array of external costs and traffic taxation. We show that external costs differ greatly across a limited number of geographical zones, road types and time periods. For example, an additional driver during rush hour in the Brussels Capital Region would add almost a full euro of time cost to his fellow travelers per kilometer driven. Current taxes on cars and road freight lack any substantial differentiation however, while public transport, certain forms of commuting and company cars are heavily subsidized.

Clearly policy is not aligned to reality given by great concentration of traffic during certain times of the day, on certain spaces. It follows also that (some) drivers, where and when traffic is not very dense, pay too much in taxes compared to the costs they cause to society, at least when considering congestion and the environment.

A policy that would *fully* align taxation to external costs, would yield society at least 2.3 billion euro in net welfare gains, of which 1.3 billion euro in time gains to remaining traffic. The total welfare gain is superior to that found in the literature, since we also take into account the economic distortions associated with all kinds of subsidies. Such an *ideal* policy change would yield 8.7 billion euros in additional revenue, mostly through decreased subsidies.

We stress that any congestion costs reported in this study should be considered as a lower bound. Since the model only measures time lost in traffic, we do not model the additional costs due to the need to alter plans, re-arrange appointments etc. (so-called schedule delay costs). Nor are any gains form higher productivity due to better spatial allocation of resources included.

1. Introduction

Transport is widely associated with a range of external costs. Its contribution to climate change is obvious and well known, just as air pollution through the emission of a wide range of local pollutants – from particles to nitrogen oxides. Less frequently discussed are noise, infrastructure degradation and accidents.

However, congestion costs, or the time costs associated with traffic crowding, are generally acknowledged as one of the principal components of the external costs of transport, if not the most important one. It is the latter that will be the focus of the present paper.

Our goal will be two-fold. First, we will provide an estimate of the costs in Belgium of congestion per kilometre by itself and alongside environmental externalities (climate and local pollution). Second, we will put the size of external costs in relation to the current tax and subsidy system on the Belgian transport market. This will allow us to construct and simulate an ‘ideal’ tax system, which would fully address both congestion and environmental externalities. The welfare gains (time gains and other) from this ideal tax system can be seen as the macro-economic cost of congestion.

The paper is constructed as follows. A first part will introduce the necessary concepts and the relation of this study to the literature. The second part characterizes the business-as-usual equilibrium. Current external costs are compared with prevailing tax/subsidy rates. The third part provides the results of the reference policy scenario, along with optimal rates of a kilometre charges, and effects on public finance and welfare.

2. External congestion costs – concepts and overview of the literature

When thinking about external costs, the concept 'marginal external cost' is usually most widely available. Essentially, it measures the damage borne by society of one additional unit of transport goods, which is not taken into account by the consumer. Most of the time, consumption is expressed in vehicle kilometers (vkm), but when necessary – for example in public transport or for bulky modes such as trains and water transport – measures expressed in passenger-kilometers (pkm) or ton-kilometers (tkm) (for freight) can be constructed.

Marginal external costs are important concepts since they are intrinsically linked to the theory of optimal environmental taxation. They serve as a guide when properly setting tax – and subsidy levels, with simple models prescribing optimal environmental taxes set exactly at marginal external costs. At this point the marginal benefit of the tax (the fall in pollution) is equal to its marginal costs in terms of lost utility to the consumer due to decreased demand.

In the context of local air pollution and climate change the amount of emissions per kilometre is calculated and evaluated as a measure of damage per tonne to arrive at an estimate of marginal external costs. Conceptually, these marginal environmental costs are not difficult to interpret because they are usually assumed to be a constant value, irrespective of the amount of emissions and the level of traffic demand.

It is therefore easy to construct a measure of 'total environmental costs' at any given level of demand: simply multiply the amount of traffic by the marginal external costs and the amount of 'total' macroeconomic damage in euros follows.

External congestion costs are not so easy to handle. The reason is that they depend on the level of traffic. Typically, marginal external congestion costs (MECC) will have the following form:

$$MECC = \frac{dFLOW}{dVKM} * \frac{dSPEED}{dFLOW} * \frac{dTIMECOST}{dSPEED}$$

In this formula the equivalence factor $\frac{dFLOW}{dVKM}$ measures the way an additional vehicle contributes to the flow on the underlying network. This part allows for the fact that some vehicles may take up more space than others. $\frac{dSPEED}{dFLOW}$ is the all-important speed-flow function, translating fluctuations in the flow to changes in operating speed. The factor $\frac{dTIMECOST}{dSPEED}$ can be seen as the change in time costs due to a marginal change in speed levels. It depends crucially on the value of time VOT and baseline speed levels $SPEED$.

Crucially the speed-flow function will be non-constant, even highly non-linear. At low and intermediate levels of service, speed tends to fall slowly with rising traffic levels only to decrease quickly when the network saturates.

This non-linear nature complicates the analysis considerably.

First, marginal external congestion costs depend on traffic levels, so it is not easy to infer at any given state what an optimal tax should be. At the highly congested current state, without any taxes explicitly aimed at decreasing congestion, marginal congestion costs are likely to be high. As an additional tax would decrease demand, congestion costs would fall, so that the optimal tax level would settle (perhaps significantly) below the initial value of marginal costs.

Second, and related to the above observation, it is not easy to calculate the *total* costs associated with congestion and time losses. While the damage of, say, particulate matter is easily calculated by multiplying marginal costs of this pollutant with traffic levels of polluting vehicles, naively doing so for congestion costs will grossly overestimate the total cost of traffic delays. The measure of MECC at any given state only tells the analyst what the change in speed and time costs would be for *one* additional vehicle (or one disappearing vehicle). It is moot on determining what level of time costs are avoidable, and for which level of traffic one should calculate time gains.

The engineering approach, see for example Koopmans and Kroes (2003) for the Netherlands, simply calculates the difference between current speed levels and some benchmark (usually free-flow speed). This difference is deemed to be avoidable and excessive and is applied to current users to calculate total time costs.

However, there is no reason to assume why some arbitrary level of speed should be chosen as the reference to evaluate the current state. Also, there is no reason why every current road user should be considered to calculate such a total cost measure. Indeed, lower time costs may involve lowering aggregate traffic. This raises the question: how and to which level should traffic be decreased? And how should one treat the loss of those that have to leave the market?

Following handbooks of external costs, see Infras/IWW (2000) and Maibach (2004) and recently CE Delft (2019), we will define the costs of congestion as the welfare gain of optimal (congestion) taxes. Such an approach would set the level of taxation as exactly equal to marginal costs and calculate the resulting time gains for remaining users. From this value one should subtract the utility loss of those that are forced out of the market due to the policy change. The resulting measure is called the *deadweight loss of congestion*, capturing the fact that congestion is the result of a market failure requiring government intervention.

Earlier studies came up with varying results. E.g. Infras/IWW (2000) calculated the deadweight loss of congestion at 0.53% of GDP for Belgium and 0.49% for the EU as a whole. The additional tax revenue if taxes would be set at an optimal level would be a whopping 4% of GDP in Belgium. The most recent estimate (CE Delft, 2019) is more modest however: in Belgium the deadweight loss was estimated at 1.2 billion in 2016 or 0.27% of GDP, half the level of the earliest study.

Such results depend heavily on the models involved, and the assumptions of travel demand. In every instance however, a detailed network model is used, and for every link a levy is calculated so that marginal congestion costs are internalized – the so-called system equilibrium. CE Delft (2019) e.g. uses a network model on the European level, the results of which are then extrapolated to the national level. Obviously, given the highly localized nature of congestion national data would be welcome. To our knowledge only Duvigneaud e.a. (2017) perform the same exercise for a Belgian region, namely the

Brussels capital region. They do not provide an estimate of the resulting deadweight loss of taxation, though.

All studies have in common that only external costs on the road network are internalized. However, road transport does not operate on its own, but in direct competition with other modes. Those modes face different tax (-or subsidy) regimes that may or may not internalize the external costs associated with these modes. A truly consistent measure would optimize external cost on all relevant markets. This will be the goal of this paper. This is a daunting task, of course. Pushing this reasoning to the extreme, one would need to force internalization in all markets in the entire economy, considering the widest possible range of goods and externalities.

An example of a study seeking to simulate a wide-range reform is found in Proost e.a. (2001). They apply the TRENEN-model to a limited amount of agglomerations and European countries and calculate an optimal tax – and subsidy system. It is striking that even at that time (their study predates ours by about 20 years) it is found that Brussels and Belgium gain particularly by correct pricing.

In this paper we will perform a similar exercise ourselves to the dimensions of the PLANET model, outlined in the table below. Note that congestion is only modelled on the road network: congestion on the rail network, which may be substantial during rush hour, is not modelled. Bus and tram are assumed to run partially on the congested road network and partially on their own (uncongested) lanes. For all modes except for bike and walking, we model climate change as well as local air pollution. The main goal is to calculate the welfare gains of a theoretical, optimal tax system.

Table 1 Dimensionality of PLANET - Relevant markets and market failures

Market Failure	Congestion	Climate change	Local pollution
Markets (peak and off peak)			
Car-solo	X	X	X
Car-pool	X	X	X
Motor	X	X	X
Train		X	X
Bus	X (part)	X	X
Tram	X (part)	X	X
Metro		X	X
Active modes			
Trucks	X	X	X
Light duty freight	X	X	X
Rail freight		X	X
Inland Waterways		X	X

PLANET itself is described in a non-technical way in Daubresse e.a. (2018).

3. External costs and the current structure of taxation

In this section we will characterize the equilibrium in the baseline. We will provide an overview of 1) external costs and their drivers and 2) the current structure of taxation. This will lead to insights on the current rate of internalization by the tax-and-subsidy system. All reported values are projections for 2024.

3.1. External congestion costs

External congestion costs are by far the most important. As we described in the previous section, MECC consist of three factors.

The equivalence factor $\frac{dFLOW}{dVKM}$ is the most straightforward. We assume that one vkm by trucks, trams and buses equals 2 vkm by car, one vkm by motorcycle counts as 0.75 car units. A light duty vehicle is fully equivalent to a car. On average a trip by bus is assumed to use the road network for 90% of its length, while a trip by tram takes place only 34.3% on the road network.

The relevant *values of time* (VOT) are shown in the tables below. For passengers they depend on the motive of transport: due to their complementarity to labour and its product, time spent for commuting and on business trips is valued more than other motives. The chosen values are based on KiM (2013). They are assumed to grow according to GDP per capita with an elasticity of 0.9 for car and 0.475 for other modes.

Table 2 Value of time (2024) - passenger modes
Euro2019 per hour

	Commuting	Business	Other motives
Active modes	9.06	22.66	7.12
Moto	11.01	31.08	9.06
Car	11.65	25.90	9.06
Train	13.60	23.31	8.42
Bus-Tram-Metro	9.06	22.66	7.12

For freight, the value of time is expressed at a value of time per tonne transported. Its values are assumed to grow according to the wage cost index of the freight industry.

Table 3 Value of time (2024) - freight modes
Euro2019 per hour

Trucks	6.47
Light duty vehicles	143.51
Internal waterways	2.16
Rail	0.43

Speed levels are taken from the network models developed by the Flemish and the Brussels regional administrations.

For a limited set of road types and geographical zones, these models provided average speed levels for the time periods that they modelled. These were quite detailed for peak periods. Since PLANET models year-long traffic, we had to rely on assumptions on the off-peak periods that were not provided (mostly night and weekend periods). We did this by comparing the traffic counts during these missing periods with those of the periods that were covered (mid-day) and making assumptions on free-flow speeds.

The table below reports the projected results for cars, for the year 2024. Speed levels for trucks and light duty vehicles are assumed to be proportional to these of cars, by a factor taken from the same regional models.

Table 4 Average speed - passenger car (2024)
Km/hour

	Highways	Other main arteries	Other roads
Peak			
Brussels Capital Region		12	
Agglomeration REN[1]	64	53	48
Agglomeration Antwerp	64	47	38
Agglomeration Ghent	105	67	52
Rest of Belgium	111	74	64
Off-Peak			
Brussels Capital Region		23	
Agglomeration REN	104	69	61
Agglomeration Antwerp	92	61	53
Agglomeration Ghent	112	72	60
Rest of Belgium	115	77	67

From speed levels, average time costs per kilometre driven can easily be derived.

As reported in Daubresse e.a. (2018), these 13 road-zone combinations form the synthetic ‘network’ of the PLANET model. They should be sufficiently sparse to capture the essentially local nature of congestion, but sufficiently aggregated to allow for flexible handling of the model. Choice between road types and zones is modelled through a discrete choice model.

The substitution patterns are also taken from the regional models in question. More precisely, the totals of the origin-destination matrices were increased by 5%. Such a shock increases flow and decreases speed levels, causing traffic to re-adjust. The parameters of the discrete choice function were chosen to replicate the resulting substitution as closely as possible.

This exercise also gives us insight in the crucial speed-flow relationship on an aggregate level. Indeed, by linking changes in speed from this exercise to flow changes, one can derive a coarse speed-flow curve. Of course, for off-peak periods that were not present in the regional models, assumptions needed to be made as well.

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[1] The REN zone (from Regional Express Network – a major infrastructure project) is a zone around the Brussels Capital Region, comprising the main employment basin of the capital.

Bringing everything together, we can finally derive marginal external congestion costs. Table 5 reports values for a passenger car. Values for other vehicles can be derived through multiplication by the previously discussed equivalency factors. We also present in parentheses the percentage of yearly passenger car vkm travelled in all zone/road/time period combinations.

Table 5 Marginal External Congestion Costs - passenger car (2024)
Euro2019 per vkm - (% of total kilometres driven)

	Highways	Other main arteries	Other roads
Peak			
Brussels Capital Region		1.00 (1.4%)	
Agglomeration REN	1.23 (3.0%)	0.29 (0.8%)	0.21 (3.3%)
Agglomeration Antwerp	0.66 (0.8%)	0.22 (0.1%)	0.36 (0.7%)
Agglomeration Ghent	0.17 (0.4%)	0.08 (0.1%)	0.12 (0.3%)
Rest of Belgium	0.05 (7.0%)	0.04 (3.5%)	0.04 (8.8%)
Off-Peak			
Brussels Capital Region		0.56 (3.1%)	
Agglomeration REN	0.11 (8.0%)	0.04 (1.8 %)	0.04 (6.6%)
Agglomeration Antwerp	0.23 (1.9%)	0.10 (0.4%)	0.15 (1.8%)
Agglomeration Ghent	0.05 (0.9%)	0.02 (0.1%)	0.05 (0.8%)
Rest of Belgium	0.03 (14.0%)	0.01 (8.6%)	0.02 (21.2%)

At this point an important remark is in order. Time costs in PLANET only capture the amount of time lost on the road, *during* the trip in transit. However, arguably these do not tell the whole story.

Indeed, congestion forces economic agents to adapt their plans and leave earlier or schedule their appointments later then desired. Also not included are gains arising from better spatial allocation of resources (so-called agglomeration effects). Indeed, Baert and Reynaerts (2018) show that in Brussels and Antwerp, congestion currently *overwhelms* any of the usual benefits arising from agglomeration, leading these cities to lose competitive advantage. These indirect costs are likely to be significant.

3.2. External air pollution costs

PLANET models the emission of 4 distinct local air pollutants: sulfur dioxide, nitrogen oxides, particulate matter and volatile organic components. (Direct) emissions factors per vkm driven are taken from the COPERT database, while values per tonne rely on Delhaye e.a. (2017). Table 6 reports the resulting values for the average kilometre driven.

Table 6 Marginal External (Direct) Air Pollution Costs (2024)
Euro2019 per vkm (train per pkm)

Car	0.009
Moto	0.011
Bus	0.042
Truck	0.029
Light duty vehicle	0.022
Train	0.009

It should be noted that the damage by local air pollutants, by their very nature, are not uniformly distributed across the country. However, we only dispose of limited information on local values per tonne for one pollutant (particulate matter). Since local air pollutants are not the focus of this paper, we will stick to national values in what follows.

3.3. External climate costs

The external cost of greenhouse gas emissions is governed by the value of a tonne of CO_2-equivalent emissions and emission factors per kilometre driven. In PLANET the emission of three greenhouse gas emissions are modelled, CO_2 proper, methane and nitrous oxide. Like local pollutants, emission factors are taken from the COPERT database. We limit ourselves to direct emissions.

The value of a tonne CO_2-eq (42 euro per tonne in 2024) is taken from the central scenario of Nordhaus (2017). We are well aware that the estimate of the value per tonne CO_2 is subject to great uncertainty, is sensitive to the choice of a discount factor, while also depending on the quantitative limits one wishes to put to further temperature rises (Nordhaus' central scenario does not do so and allows for temperature rise of 3°C beyond 2100). Since the focus of this paper is on congestion costs however, we will not dwell on the sensitivity of the results with respect to this parameter.

Table 7 shows the resulting marginal external costs of climate change by mode.

Table 7 Marginal External (Direct) Climate Change Costs (2024)
Euro2019 per vkm (train: per pkm)

Car	0.008
Moto	0.005
Bus	0.047
Truck	0.032
Light duty vehicle	0.010
Train (pkm)	0.000

3.4. The tax structure

PLANET takes account of a wide range of tax-and-subsidy instruments. Suffice here to say that the array of instruments breaks down in three categories.

First, we consider the usual indirect taxes associated with transport. The most important of these are excise duties and the annual traffic tax, but we also consider such measures as differentiated VAT rates, license fees, vignettes and domestic kilometre charges, if any.

Second are the usual operating subsidies to public transport companies. They are modelled as a per kilometre subsidy rate.

Third are measures related to transport in direct taxation, of which all fiscal exemption rules to commuting reimbursements are part. As Laine and Van Steenbergen (2016) show, these rules are highly differentiated by mode. A special regime in this category is the company car regime, which is widespread in Belgium and which allows employers to offer a car as part of the compensation package. Tax rules are such that company cars are highly favoured when compared to cash so that car use is effectively subsidized. (see Laine and Van Steenbergen, 2017 and 2016). The use of a company car is, contrary to other reimbursements, not linked to commuting transport alone. In this third category, we also include a direct subsidy payment to some rail commuters (the so-called third payer system).

In what follows we will first present the resulting tax structure taking into account the first two categories, so that these figures apply to persons who do *not* enjoy any of the prevailing subsidies.

Table 8 presents the resulting tax structure for road freight. For trucks, a degree of geographical differentiation already exists due to the kilometre charge for heavy duty vehicles which is in vigour on highways and other main arteries. In fact, the differentiation by road type was chosen to match the current geographical base of the kilometre charge. Light duty vehicles are subject only to flat excise rates, annual taxes and licenses so there is no differentiation whatsoever.

Table 8 Tax structure: road freight
Euro2019 per vkm

	Highway	Other main arteries	Other roads
Trucks			
Brussels Capital Region		0.303	
Agglomeration REN	0.242	0.242	0.125
Agglomeration Antwerp	0.242	0.242	0.125
Agglomeration Ghent	0.242	0.242	0.125
Rest of Belgium	0.242	0.242	0.125
Light duty vehicles			
Brussels Capital Region	0.079	0.079	0.079
Agglomeration REN	0.079	0.079	0.079
Agglomeration Antwerp	0.079	0.079	0.079
Agglomeration Ghent	0.079	0.079	0.079
Rest of Belgium	0.079	0.079	0.079

For passenger cars too, only flat, non-differentiated taxes are relevant. Public transport is heavily subsidized on a per kilometre basis. Table 9 presents the resulting per-kilometre rates.

Table 9 Tax structure: passengers
Euro2019 per vkm (Public transport: per pkm)

Car	0.061
Moto	0.051
Bus	-0.154
Tram	-0.164
Train	-0.131

Table 10 gives the per-kilometre subsidy rates due to various commuting subsidies and other direct taxation regimes. We compare them to monetary costs to determine a subsidy rate by mode. We also give the share of kilometres driven under these various regimes by mode, for all motives.

These figures give a feel of how varied the Belgian system is. Depending on the mode, but also on the particular regime, the subsidy rate varies from 0% (car commuters without reimbursements) to 65.7% (train commuting in the 'third payer system') of monetary costs *after* regular indirect taxes or subsidies are accounted for. For the modes and regimes in question, the figures therefore come on top of those reported in table 9. The results for company cars are noteworthy. Kilometres driven by an employer-provided vehicle are effectively subsidized: the direct income tax subsidy largely surpasses indirect taxation.

Table 10 Monetary costs, tax expenditure and direct subsidy for rail commuters
Euro2019 per pkm

	Monetary costs PLANET	Subsidy per kilometre - tax expenditure	Subsidy per kilometre - direct subsidy	As % of monetary costs	% of total pkm to which subsidy applies (by mode)
Car commuters - no reimbursement	0.392	0.000	0.000	0.0%	**78.6%**
Car commuters - with reimbursements	0.392	0.031	0.000	5.5%	**11.8%**
Car commuters - company cars	0.392	0.216	0.000	55.1%	**9.6%**
Train - third payer	0.071	0.032	0.014	65.7%	22.2%
Train - convential reimbursement	0.071	0.031	0.000	44.5%	17.5%
BTM	0.099	0.057	0.000	57.1%	14.4%
Motor	0.609	0.023	0.000	3.7%	22.4%
Bike	0.248	0.125	0.000	50.5%	9.7%

3.5. Degree of internalisation

Next, we put the data on external costs for congestion and the environment and tax/subsidy rates together. Our goal is to characterize the current equilibrium and provide data on the degree of internalisation by mode, time period and geographical zone.

Table 11 presents the external costs that are not internalized by the tax system for road freight traffic, with a negative number for a situation where taxes paid exceed external costs.

Obviously, the degree of internalisation varies greatly across time and place. This is a direct consequence of the lack of (strong) differentiation in current tax rates, with only the kilometre charge for trucks showing some degree of differentiation across road types.

For trucks, on 73% of kilometres driven taxes exceed the external costs on consideration. This is a direct result of the relatively high level of the kilometre charge, which also applies to every tollroad, regardless of place and time. Of course, the charge for trucks seeks to achieve other goals then only addressing congestion and environment: such as having (foreign and domestic) trucks contribute to the maintenance costs of the domestic road network.

But for light duty vehicles too, for about 57% of kilometres driven taxes paid exceed external costs.

Table 11 Congestion and environmental externalities not internalized by the tax system - freight
Euro2019 per vkm - % of total kilometres driven

	Highway	Other main arteries	Other roads
Truck			
Peak			
Brussels Capital Region		1.76 (0.2%)	
Agglomeration REN	2.28 (1.1%)	0.40 (0.1%)	0.35 (0.9%)
Agglomeration Antwerp	1.13 (1.3%)	0.25 (0.1%)	0.65 (0.3%)
Agglomeration Ghent	0.17 (0.4%)	-0.03 (0.0%)	0.18 (0.2%)
Rest of Belgium	-0.06 (9.2%)	-0.10 (1.4%)	0.02 (4.4%)
Off Peak			
Brussels Capital Region		0.88 (0.7%)	
Agglomeration REN	0.03 (5.5%)	-0.10 (0.4%)	0.02 (3.8%)
Agglomeration Antwerp	0.27 (5.3%)	0.01 (0.3%)	0.24 (1.6%)
Agglomeration Ghent	-0.08 (1.6%)	-0.14 (0.1%)	0.05 (0.9%)
Rest of Belgium	-0.12 (33.1%)	-0.16 (5.1%)	-0.01 (21.7%)
Light Duty Vehicles			
Peak			
Brussels Capital Region		0.96 (1.6%)	
Agglomeration REN	1.19 (3.1%)	0.24 (0.4%)	0.16 (2.3%)
Agglomeration Antwerp	0.61 (2.3%)	0.17 (0.1%)	0.31 (0.5%)
Agglomeration Ghent	0.13 (0.7%)	0.03 (0.0%)	0.08 (0.2%)
Rest of Belgium	0.01 (13.1%)	-0.00 (2.0%)	-0.00 (6.5%)
Off Peak			
Brussels Capital Region		0.52 (2.4%)	
Agglomeration REN	0.06 (9.1%)	-0.01 (0.8%)	-0.00 (3.8%)
Agglomeration Antwerp	0.18 (5.7%)	0.05 (0.2%)	0.11 (1.0%)
Agglomeration Ghent	0.01 (1.5%)	-0.02 (0.1%)	0.01 (0.5%)
Rest of Belgium	-0.02 (27.1%)	-0.04 (3.9%)	-0.02 (12.4%)

For cars, table 12 paints a comparable picture. For highways in the REN-zone during peak hours, on average external costs are a full euro above taxes. However, during off-peak hours, taxes slightly exceed external costs on most of the kilometres driven. All in all, for about 65% of kilometres driven, taxes on average exceed external costs. We note that these figures only consider indirect taxes, such as traffic taxes and excise rates. We do not take into account the commuting or other subsidies that are described in table 10. So, for company cars one should add 0.216 euro to the figures in table 12, while for other commuters 0.031 euro should be added. In this case, driving with company cars is always under-priced, regardless of place and time.

Table 12 Congestion and environmental externalities not internalized by the tax system – passenger car
Euro2019 per vkm

	Highway	Other main arteries	Other roads
Peak			
Brussels Capital Region		0.96 (1.4%)	
Agglomeration REN	1.18 (3.0%)	0.24 (0.8%)	0.16 (3.3%)
Agglomeration Antwerp	0.61 (0.8%)	0.17 (0.4%)	0.31 (0.7%)
Agglomeration Ghent	0.13 (0.4%)	0.03 (0.1%)	0.08 (0.3%)
Rest of Belgium	0.01 (7.0%)	-0.00 (3.5%)	-0.00 (8.8%)
Off Peak			
Brussels Capital Region		0.52 (3.1%)	
Agglomeration REN	0.06 (8.0%)	-0.00 (1.8 %)	-0.00 (6.6%)
Agglomeration Antwerp	0.18 (1.9%)	0.05 (0.4%)	0.11 (1.7%)
Agglomeration Ghent	0.01 (0.9%)	-0.02 (0.1%)	0.01 (0.8%)
Rest of Belgium	-0.01 (14.8%)	-0.04 (8.6%)	-0.02 (21.2%)

4. A full optimal tax system

In the previous chapter we have shown how for both passenger and freight transport, the tax system is clearly not aligned to the reality given by the concentration of traffic on some roads in some regions during certain periods of the day. On the other hand, for public transport, subsidy rates are relatively high compared to their marginal external costs.

In what follows, we will calculate the welfare gain from a full 'optimal' tax system, whereby we align as closely as possible taxes to marginal external costs. As has been argued above, the resulting welfare gains can be seen as a consistent measure of the cost of congestion, or more broadly, the cost of misallocation on the transport market.

In a first section, we discuss our estimation strategy in more detail. We will also argue under what circumstances our method is consistent with the optimal tax literature. After this somewhat theoretical exposé we will present the resulting optimal tax structure in a second section, after which we will show the effects on public finance, welfare and traffic levels.

4.1. Strategy

Our estimation strategy will involve moving the model iteratively closer to a situation where for all relevant modes, routes, time periods and geographical entities taxes (-and subsidies) per kilometre are equal to marginal external costs (congestion and environment).

Once this point is reached, we will consider the model 'optimised' and calculate the welfare effects. These comprise of 1) total gains in environmental quality 2) total time gains of remaining road network users, 3) the loss in utility of people leaving the transport market – or that are forced to switch modes due to increasing taxes. This last measure is called the deadweight loss of taxation. In the case of subsidies, it captures the fact that people are 'pushed' into consuming goods they would not otherwise buy so that abolishing subsidies leads to a welfare *gain*. Technically, it is approached through so called Harberger-triangles[2]. The sum of these three measures consist of the welfare gain of the reform.

The iteration will consist of abolishing commuting subsidies, ordinary subsidies on public transport and iteratively adapting a congestion tax on road traffic until an optimum is reached. This congestion tax comes on top of current excise *and* fixed taxes. The new congestion tax can be negative when this combination of existing taxes happens to exceed marginal costs.

We basically choose an equilibrium by *tâtonnement*, without explicitly maximizing a social welfare function. An important question is whether this procedure of mechanically equating taxes and marginal external costs is legitimate from a theoretical viewpoint.

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[2] Harberger triangles approach the gain/loss in consumer surplus through 'triangles' defined as half the price change times the demand change. We stress that one needs to be careful to separate the effects of (abolishing) subsidies and (raising) taxes. Both raise prices but lead to fundamentally different welfare effects. So, we proceeded in two stages: first, we abolished subsidies, after which we levied the congestion charge. In both stages, we calculated the resulting welfare gain.

The principle itself is as old as Pigou (1920), who argues that the optimal way to control externalities entails equating their marginal damages to a tax per unit of pollution (or polluting activity) – the so-called Pigouvian tax.

However, from this point on, a substantial literature has analysed the conditions under which this principle holds. Without having any ambition of being exhaustive, we will discuss points relevant for our analysis.

Fundamentally, the principle of Pigouvian taxation holds only when all relevant markets and instruments are taken into the analysis. In a transport context, we must at least take care of modelling the whole range of relevant modes along with their own external costs and tax systems.

Indeed, focusing on only one market, say road transport, and neglecting another close substitute, e.g. public transport will lead to errors. Particularly, when public transport subsidies are taken as given and cannot be touched, it is a well-known result that taxes on road transport should be kept *lower* than external costs. The reason is that pushing them too far will lead to excessive demand for public transport and excessive use of public subsidies. This is the reason why we do not only optimize taxes on the road network – as is often done in the literature on congestion costs – but also on other relevant modes within the model.

But in practice it will be impossible to take into account all relevant markets within a transport model such as PLANET. Sure enough, the closest substitutes for congested road transport are included, but we can easily think of other markets that influence the transport decision as well. One can think of the land and housing market, with its own fiscal instruments. But probably the most important market, and the one drawing most attention in the literature, is the labour market.

Bovenberg and de Mooij (1994) argue that not taking into account taxation in the labour market will lead to errors. The reasoning goes that Pigouvian taxes will erode the real wage and lead agents to cut back their labour supply, which in turn leads to losses in tax revenue.

The conclusion of these models is that the Pigouvian tax should be set *below* marginal external cost. More precisely, in partial analysis such as ours a measure of marginal cost of public funds (MCPF[3]) should be included in the tax rule, capturing the fact that other taxes not captured by the model exist to satisfy other needs in the economy apart from controlling externalities, such as financing government consumption.

These taxes have their own negative effects on the economy and when Pigouvian taxes influence the base of these taxes, these effects should be accounted for. So, even though the external cost is 10 cents per kilometer driven, when the MCPF is 1.5 – which may easily be the case when labour taxes are high – the ‘optimal’ tax is only 6.7 cents per kilometer.

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[3] The marginal cost of public funds is defined (following Jacobs (2018)) as the ratio between the social value of an extra euro for the public sector and the social value of a euro in the private sector.

Intuitively, in this point of view controlling externalities as a ‘good’ runs in competition with other public goods when all taxes have negative effects. In this case we must augment our model with the price of these other goods, the MCPF.

However, Jacobs and de Mooij (2015) argue that this reasoning suffers from its own drawbacks. Indeed, it does not give a solid reason why ‘other public goods’ should be financed by taxes that have adverse effects on the economy. If one wishes to avoid distorting people’s choices, then a simple solution is possible: levy a tax per head of the population, i.e. a poll tax or a so-called (non-individualized) lump-sum tax.

It is immediately clear that such a measure may run counter to wide-spread conceptions of redistributive justice. Indeed, one can consider redistribution to be a public good by itself and other taxes, such as (progressive) labour taxes, serve to provide this good. The negative effects of these taxes are then seen as the price to pay to achieve a more equal distribution of incomes. If one assumes that these labour income taxes are themselves optimized i.e. the cost and the benefit of equality are balanced, there is no compelling reason to deflate Pigouvian taxes by a measure such as the MCPF. Jacobs and de Mooij (2015) show that the MCPF = 1 in such a case. More strongly, imposing MCPF > 1 (or < 1) by the modeler can even be seen as an ideological choice: one then assumes the cost of achieving distributional justice exceeds its benefit (or vice-versa). Arguably, this is not up to the analyst to impose.

Jacobs and de Mooij (2015) therefore discharge the modeler of the task to calculate a measure of the MCPF in partial equilibrium analysis (such as ours). The only condition is that the government has at least potentially access to (non-individualized) lump sum taxes in its full set of instruments, which is not such a heavy assumption to make. Controlling externalities does not compete with other public goods, in that case.

This is not to say that the Pigouvian tax should always equal marginal external costs. For our purposes, Jacobs and de Mooij (2015) derive useful conditions under which deviations from the principle are mandated.

In general, deviations from the Pigouvian principle should be allowed only when the corrective tax can complement the labour income tax in its function of redistributing income.

One case is particularly relevant, namely when the polluting good in question may be more complementary/substitute to labour than other, clean goods. In that case taxing the polluting good *indirectly* discourages/stimulates labour supply and exacerbates/alleviates the distortion of the labour income tax. The Pigouvian tax should be set lower/higher than marginal costs.

Second, the willingness to pay for avoiding the externality itself rises/falls with labour supply, or the externality itself is more/less complementary to labour than the clean good. In that case providing for less externalities encourages/discourages labour supply so again the negative effect of the labour income tax is alleviated/enhanced.

Ultimately, whether this hold is an empirical matter. But in a transport context, the caveat mentioned above may be very relevant. Indeed, commuting transport is evidently intrinsically linked to labour supply, which suggests that congestion taxes should be set below marginal external cost. On the other hand, the externality itself involves time costs or the cost of going to work, which would work in favour of higher congestion taxes. Exploring the extent to which these mechanisms play is obviously a question for further research.

4.2. The optimal tax structure

As is discussed previously, we will proceed by first by eliminating subsidies to public transport and commuting subsidies. VAT rates on public transport are equalized to the reference of 21%, from a reduced rate of 6%. Rail is then taxed with a small levy of 0.9 cents per kilometre on average to account for direct emissions from diesel trains and non-exhaust emissions of PM2.5.

Finally, a differentiated kilometre charge on road transport (both private and public, the latter for the part that they make use of congested roads) is levied to internalize the combination of congestion and environmental costs. Since congestion costs are endogenous to traffic levels, this involves some trial-and-error. This kilometre charge is added to existing indirect taxes (traffic tax, excise rates, kilometre charge for trucks, …).

The following tables present the tax structure as it follows from this optimization procedure, both for road freight and cars.

Table 13 Optimal kilometre charge – passenger cars
Euro2019 per kilometre

	Highway	Other main arteries	Other roads
Peak			
Brussels Capital Region		0.63	
Agglomeration REN	0.30	0.15	0.13
Agglomeration Antwerp	0.23	0.13	0.21
Agglomeration Ghent	0.10	0.02	0.06
Rest of Belgium	0.01	-0.01	-0.00
Off-Peak			
Brussels Capital Region		0.29	
Agglomeration REN	0.04	-0.01	0.00
Agglomeration Antwerp	0.12	0.04	0.07
Agglomeration Ghent	0.01	-0.02	0.01
Rest of Belgium	-0.01	-0.04	-0.02

Both tables show that the optimal tax structure involves heavy differentiation by time and place. This is not illogical, given the extent of variation of external costs. Some special cases are worth discussing in depth.

In the Brussels region, the optimal average tariff is rather high in peak as well as off peak periods. This should not surprise us given the metropolitan characteristics of the Region. In other urban regions, only Antwerp faces a significant rise in tariffs both during peak and off-peak hours. Undoubtedly, the intense and constant goods traffic from the seaport is a major cause.

Furthermore, the large difference in rates on highways in the REN zone between time periods is striking, falling from 30 cents in rush hour, to barely 4 cents in off peak hours.

Last, for all modes, zones exist with *negative* rates of the kilometre charge, showing that current flat taxes are too high from an efficiency perspective.

Table 14 Optimal kilometre charge - road freight
Euro per kilometre

	Highway	Other main arteries	Other roads
Trucks			
Peak			
Brussels Capital Region		1.11	
Agglomeration REN	0.53	0.23	0.28
Agglomeration Antwerp	0.37	0.17	0.45
Agglomeration Ghent	0.09	-0.04	0.17
Rest of Belgium	-0.07	-0.10	0.02
Off-Peak			
Brussels Capital Region		0.42	
Agglomeration REN	-0.01	-0.10	0.02
Agglomeration Antwerp	0.15	0.00	0.18
Agglomeration Ghent	-0.08	-0.13	0.04
Rest of Belgium	-0.12	-0.16	-0.02
Light Duty Vehicles			
Peak			
Brussels Capital Region		0.63	
Agglomeration REN	0.31	0.16	0.13
Agglomeration Antwerp	0.23	0.13	0.21
Agglomeration Ghent	0.09	0.02	0.07
Rest of Belgium	0.01	-0.01	-0.01
Off-Peak			
Brussels Capital Region		0.29	
Agglomeration REN	0.04	-0.01	0.00
Agglomeration Antwerp	0.12	0.04	0.08
Agglomeration Ghent	0.01	-0.02	0.01
Rest of Belgium	-0.01	-0.04	-0.00

4.3. Effects on traffic, welfare and public finance

The following table presents the resulting public finance effects. The total operation would yield 8.7 billion euro in total, the bulk of which comes from commuting and direct subsidies, both of which would yield about 3 billion each. The remainder comes from private road traffic, netting 2.3 billion.

Table 15 Public finance effects (2024)
Mio euro2019 wrt baseline

Excise	-76.9
VAT on public transport	+383.6
Kmtax freight	-152.0
Kmtax passengers	+2521.2
Annual traffic tax	-23.4
Operating Subsidy Public Transport - train	+1383.8
Operating Subsidy Public Transport - Bus-Tram-Metro	+1607.5
Tax expenditure	+3029.6
Third payer system rail	+40.5
Total	+8673.3

Of course, such large interventions have large effects. Table 16 presents the changes in traffic, speed and emissions, as well as the resulting welfare effects.

Demand for public transport collapses, with the main beneficiary being the active modes (bike and walking). The latter are indeed the closest substitutes to Bus-Tram-Metro whose demand suffers the most due to declining subsidy levels.

Interestingly, demand for passenger traffic by car does not change much. Even though the new traffic tax and declining company car subsidization ought to cut into car traffic, declining rail subsidies work against this dynamic. All in all, significantly better traffic conditions – at peak times, speed in the congested zones jumps by a quarter – contribute to diminish the rising monetary cost of traffic. In other words, the effect on car traffic of the kilometre tax is more about redistributing across time and space than diminishing car demand.

Road freight demand actually rises slightly, both though lower kilometre taxes as well as better road conditions.

Emissions also drop, mostly due to lower public transport demand.

Table 16 Traffic and welfare effects (2024)

Traffic effects (% change wrt. baseline)	
Pkm car	-0.3%
Pkm public transport	-48.0%
Pkm Active modes	+34.7%
Tkm road freight	+1.2%
Speed in agglomerations on main arteries	+25.7%
CO_2 – emissions	-1.9%
NOx – emissions	-2.4%
$PM_{2.5}$ – emissions	-5.6%
Welfare effects (million euro2019)	
Time gains – passengers	984.3
- Of which commuting and business trips	691.3
Time gains – freight	287.3
Efficiency gains/losses	903.0
Environmental gains	113.5
Total welfare	2297.1

Monetizing these welfare effects, we estimate time gains to be worth about 1.3 billion euro, with about 1 billion accruing to passenger traffic. Environmental gains are 0.1 billion. We note particularly the relatively high gains in economic efficiency. Even though the kilometre tax causes welfare losses due to people having to adjust their schedule, they are more than compensated for by gains due to lower subsidies.

Putting these figures together we are at an estimate of a welfare gain **of 2.3 billion per annum.** Our estimate is much higher than the one obtained by CE Delft (2019) although that figure was for the year 2017, since we take into account welfare gains to decreased subsidies as well.

5. Conclusion

This paper has shown that congestion costs, defined as the welfare gain from a fully optimized (transport) tax system, are substantial. In our exercise we show them to net 2.3 billion euro, of which 1.3 billion gross time gains for road users. In terms of budgetary size, such a policy would be substantial: 8.7 billion euro. In terms of complexity, we show that such policy would lead to highly differentiated tax rates across place and time. We also emphasize the importance of taking transport subsidies into the analysis: economic welfare gains from decreased subsidies may indeed be substantial.

We conclude by discussing missing elements and points for further research.

First, the analysis focusses on congestion and as such does not include some lesser known external costs, such as infrastructure decay, noise, accidents or external health benefits. More importantly, congestion is only modelled in road transport, either private or public transport to the extent that it also uses the road network. Perhaps importantly other sources of congestion in public transport are not modelled. One can easily think of potential issues there, such as crowding and bottlenecks on the rail network.

Second, not every source or effect of road congestion cost is modelled. PLANET models congestion the traditional way, i.e. with a speed-flow function and external costs for a limited number of periods. As such, we do not model congestion in terms of schedule delay costs. Models that approach congestion this way, e.g. the bottleneck model, typically allow for a fine tolling regime which would in theory lead to completely disappearing cues. Are model does not allow for such fine tolling so that are results should be seen as an imperfect approximation – and therefor an underestimate – of such an optimum/

We also do not allow for productivity gains following a better spatial allocation of resources. Literature suggest these are particularly important for major Belgian cities.

Third, even though we took great care of modelling a wide range of markets within the transport sector, this analysis is necessarily incomplete since PLANET is only a transport model. However, when there is a close relationship to transport outcomes and other markets a larger view should be taken. More precisely we may expect a close link to the labour market due to the complementarity to commuting and a possible feedback effect from congestion to work decisions. In fact, in this case our procedure of equating external costs to tax rates may break down. A more complete model may therefore be in order.

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