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A cost-benefit analysis of tunnel investment and tolling alternatives in Antwerp[•]

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Abstract

A proposal has been made to build a new tunnel under the Scheldt river near the centre of Antwerp in order to relieve traffic congestion on the ring road and in an existing tunnel. The new tunnel is expected to cost more than €1 billion, and tolls have been suggested to help finance construction and to manage demand. This paper conducts a preliminary cost-benefit analysis of a new tunnel and three alternative tolling schemes, and compares them with a do-nothing scenario and an option to toll the existing tunnel without building a new one. The two tunnels are treated as imperfect substitutes, and a multi-year accounting framework is adopted that accounts for emissions, accidents and noise externalities, road damage, revenues accruing to the national and regional governments from existing transport user charges, and the salvage value of the new tunnel. With the base-case parameter values it is found that building the tunnel is worthwhile with all three tolling regimes and yields a higher benefit than not building the tunnel and tolling the old one. Nevertheless, the net benefit from building the tunnel differs appreciably between tolling regimes, and it is sensitive to the value assumed for the marginal cost of public funds.

Keywords: Infrastructure investment; Route choice; Congestion; Tolls.

Introduction

Urban traffic congestion is a serious and growing problem in many large cities around the world. The traditional response to congestion, building new roads, is now impeded or prevented by lack of space, high construction costs and long-lead times, environmental concerns and NIMBY (Not In My Back Yard) opposition. Emphasis has

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shifted since the 1980s towards demand-management approaches to controlling use of the car, and road pricing has slowly been gaining ground as demonstrated by successful urban road pricing schemes in Singapore, Norway, London, Melbourne, Hong Kong, North America and elsewhere. However, road pricing in urban areas is still obstructed by acceptability and other barriers that led to the rejection by referendum in February, 2005, of a cordon scheme for Edinburgh. Most transport researchers now argue that a package approach of investment and demand-side measures has the best chance of meeting both traditional efficiency-based standards for policy appraisal and public/political acceptability hurdles.

Given the large expenditures and potentially high political stakes in building new roads and designing tolling schemes, the need for careful cost-benefit and appraisal is obvious. This is all the more true for combined investment and tolling projects or schemes whose component parts need to be integrated into a consistent whole. For example, it is well known that the welfare gains from capacity investments depend on what pricing regime is in place (Small *et al.*, 1989; Winston, 1991) and that building new infrastructure can have perverse effects (*e.g.* the Braess Paradox) if congestion and other transport externalities are not internalised.

The purpose of this paper is to conduct an exploratory cost-benefit analysis of alternative tunnel investment *cum* tolling schemes in Antwerp, Belgium. Traffic in Antwerp is heavy on weekdays, and congestion is particularly severe on one of the tunnels that cross under the Scheldt river near the city centre. A proposal has been made to construct a new tunnel to alleviate congestion through the existing tunnel, and to offer a shorter route for some of the passenger and freight traffic. Tolls on the existing and new tunnels have also been suggested as a way to manage congestion as well as to pay for the construction and maintenance costs of the new tunnel. To assess the relative merits of these proposals, a recently-developed cost-benefit model is used to evaluate one toll-only and three investment *cum* tolling regimes, and to compare each scheme with a do-nothing/business-as-usual scenario. With the base-case parameter values and assumptions, constructing the new tunnel is found to be worthwhile for all three tolling regimes. Nevertheless, the net benefit from building the tunnel and the impacts on passenger and freight user groups vary appreciably across the tolling regimes.

1. Tunnel construction and tolling options in Antwerp

Antwerp straddles the Scheldt river as shown in Figure 1. Four tunnels cross the Scheldt in the general neighbourhood of the proposed new tunnel: two very small tunnels in the city centre (the St. Anna tunnel and the Waasland tunnel), the Kennedy tunnel to the south and the Liefkenshoek tunnel far north of the city. Several bridges also cross the Scheldt far to the south. Of these tunnels and bridges the two major crossings are the Kennedy tunnel and the Liefkenshoek tunnel. The Kennedy tunnel lies on the ring road R1 that circles the centre of Antwerp to the east of the Scheldt. The Kennedy tunnel conveys a daily two-way flow of about 122,000 vehicles. The Liefkenshoek tunnel lies far to the north of the city, and it carries a much smaller daily flow of about 11,000 vehicles.

A proposal has been made to build an additional tunnel under the Scheldt between the Kennedy and Liefkenshoek tunnels. The future tunnel[1], known as the "Oosterweel" connection, would branch off the ring road R1 and offer a shorter route for traffic heading to or from the north of Antwerp. R1 is a crossroad for several motorways, and it is heavily used by cars and for national and international/transit freight transport. Building a new tunnel would alleviate traffic congestion through the Kennedy tunnel and on the ring road generally.

The new tunnel is expected to cost about €1.2 billion. One option is to fund it publicly, and another is to solicit private financing with cost recovery through tolls. The Liefkenshoek tunnel is toll-financed, and offers a local precedent for private-sector involvement with road construction and operation. However, tolling is politically controversial and may be opposed by truckers and other interest groups. It is therefore of interest to compare several alternative investment *cum* tolling regimes. Five candidates are: (1) do nothing and continue with business as usual; (2) refrain from building the new tunnel, but toll the Kennedy tunnel to alleviate congestion in the tunnel and on the ring road; (3) build the new tunnel and let traffic use both tunnels toll-free; (4) have the new tunnel built by the private sector and toll it on a cost-recovery basis; and (5) build the new tunnel and toll both tunnels to support an optimal overall level and division of traffic between the tunnels.[2]

Toll collection costs and potential cost savings from harnessing the private sector aside, the socially-optimal (*i.e.* social-surplus maximising) choice would be either Option 2 or Option 5 depending on whether or not a new tunnel is warranted. Option 4 is feasible only if demand to use the new tunnel is sufficient to generate adequate toll revenues when the Kennedy tunnel offers a toll-free substitute. And, even if Option 4 is viable, an allocative efficiency loss will result if the break-even toll on the new tunnel exceeds the second-best optimal toll.

Comparison of the various alternatives is complicated by the system of road administration in Belgium. Belgium is a federal country with three regions (Flanders, Wallonia and Brussels). The regions are responsible for road infrastructure, but the principal taxes on road use (the excise taxes on fuel) are federal. Decisions at the two levels of government are not perfectly coordinated, and current fuel excise taxes differ from optimal Pigouvian levels for internalising environmental and other traffic externalities. Because the proposed tunnel would add only one short link to the overall road network, it is unlikely that building the tunnel would trigger a change in fuel tax rates or other user charges. Thus, transport taxes other than for tolls on the two tunnels are treated as given in the study.

From this discussion it should be clear that a model is required to analyse and compare the competing tunnel construction and tolling options. The model is described in the following section.

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[1] For brevity it is called a tunnel here, but it is actually a combination of a tunnel and a bridge.

[2] Several other regimes could be entertained. One is to compensate the private concessionaire in Option 4 through shadow tolls; *i.e.* a payment per vehicle that is funded from the public purse rather than from real tolls on users. Another regime is a mixed oligopoly in which the new tunnel is tolled by the concessionaire (perhaps under toll cap or rate-of-return regulations rather than strict cost recovery) and the Kennedy tunnel is tolled by the public authority. These and other alternatives could be explored in future work.

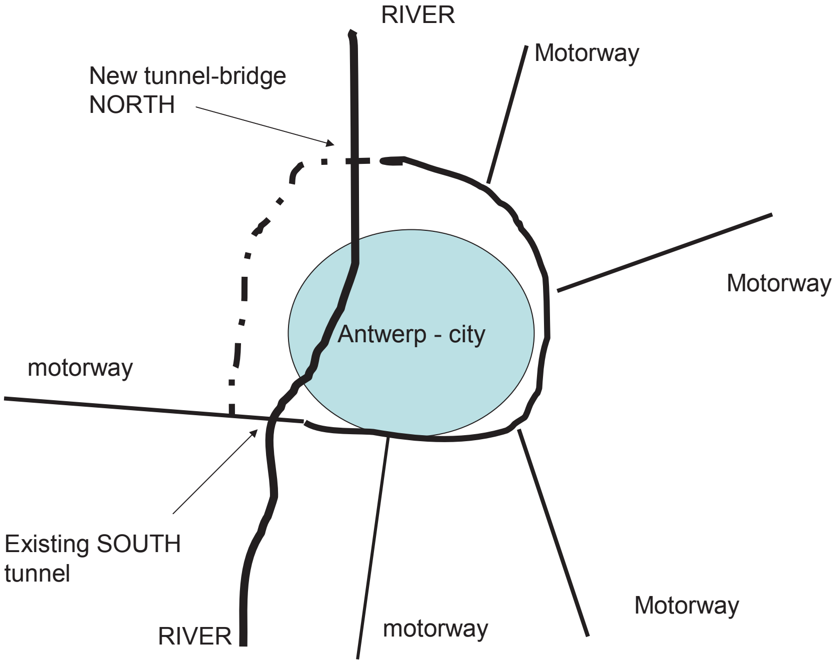

Figure 1: The ring road of Antwerp.

2. The model

The model (referred to as “MOLINO”) was recently developed as part of the European-Union funded REVENUE project to assess transport pricing, investments and regulatory regimes with emphasis on the allocation of revenues from user charges. The model is used in the REVENUE project for a variety of case studies that involve several modes. Since the model has to be applicable to many diverse problems, it is kept rather abstract and general. The present model version still has limited capabilities (in particular, it is limited to competition between two alternatives) and this application is one of the first tests of the model. The application needs further elaboration with respect to data and sensitivity analysis.

Structure of the MOLINO model

The MOLINO model is a policy assessment model, not a forecasting model. It is calibrated to an exogenous transport baseline that can be developed with any transport forecasting model. The time horizon, which can be chosen by the user, typically covers 10 to 50 years. MOLINO is a partial equilibrium model of the transport market: income levels of the private transport users, and production levels of the firms using freight services as input, are taken as given. The model includes separate modules for demand, supply, equilibrium, and the regulatory framework. In its present form the model contains two transport modes (e.g. two parallel roads, a road and parallel railway, a railway and competing air link, *etc*.).

The demand module for passenger transport features an aggregate nested CES utility function with three levels: choice between transport and consumption of a composite commodity, choice between peak and off-peak periods, and choice between the two transport alternatives. Elasticities of substitution at each level are parametrically given. Passengers can be segmented into classes that differ with respect to their travel preferences, incomes and costs of travel time. The demand module for freight transport is based on an aggregate CES cost function (production levels are given) and also features three levels. The first level encompasses choice between transport and other production inputs, and the second and third levels are the same as for passenger transport. Freight transport can be segmented into local and transit traffic.

Transport users pay a generalised cost that contains several components: a resource cost (say fuel for a car), taxes levied by central and local governments (say fuel taxes and car taxes), a user fee (toll or rail fare) and a time cost. For a given infrastructure, travel time is assumed to be a linear function of traffic flows.

For each transport alternative a distinction can be made between an operator who takes care of maintenance and can set tolls or user charges, and an infrastructure supplier who decides on capacity extensions and on infrastructure charges. The costs of the operator have a linear structure: a fixed cost, constant variable maintenance and operation costs that depend on the type of vehicle or load, and finally a payment for infrastructure use that can be specified in different ways. The infrastructure provider also has a linear cost structure where the main costs are the investment and associated financial costs for the infrastructure. Operator and infrastructure suppliers can be private or public agents, and the cost level can depend on the contractual form.

The model includes a local and a central government that can pursue different objectives and control different tax and subsidy instruments including fuel taxes, public transport subsidies and profit taxes. Given the demand and cost functions, and the regulatory framework (see below) that specifies the behaviour of the governments, operators and infrastructure suppliers, the equilibrium module computes a fixed-point solution in terms of prices and levels of congestion for the two transport alternatives. In its present version the model has myopic expectations and is solved year by year.

It is the exogenous regulatory framework that dictates the rules of the game and the ultimate outcome. This exogenous framework specifies for each alternative the objective functions of the governments, operators and infrastructure managers (public or private objectives), the nature of competition, procurement policies, the cost of capital, and the source and use of transport tax revenues. Various market structures can be modeled, including no tolls (free access), exogenous tolls, marginal social cost pricing, private duopoly and mixed oligopoly. Public decisions can be made either by local or central governments that may attach different welfare-distributional weights to agents (*e.g*. low-income vs. high-income passengers, or local vs. transit freight traffic) as well as different weights to air pollution and other (non-congestion) external transport costs. Primary outputs from MOLINO are equilibrium prices, transport volumes, travel times, cost efficiency of operations, toll revenues and financial balances, travellers' surplus and social welfare.

Application of the model to the Antwerp tunnels

The existing version of the model allows only two transport alternatives. Given the structure of the road network described in Section 1, these are selected as the Kennedy tunnel and the proposed Oosterweel connection. Henceforth they will be referred to respectively as the OLD tunnel and the NEW tunnel. The model therefore neglects the other tunnels and bridges, as well as the effects of changes in the transport flows through the two tunnels on other parts of the network. [3] The elasticity of substitution between the OLD and NEW tunnels is assumed to be finite because the model provides an aggregate behavioural representation of users with different origins/destinations and potential travel time savings from using the NEW tunnel (cf Figure 1).

A time horizon of 20 years is chosen starting in 2000: the latest year for which calibration data are available. If the NEW tunnel is built, it is assumed to become available in 2010 and a salvage value for it is computed at the end of the horizon in 2020. An annual social discount rate of 5% is used to compute present values.[4]

User groups

The model features two groups of passenger/car users and two groups of freight users. One group of car users is assumed to comprise commuters and travelers on business with high values of time; this type of traffic is referred to as *work trips*. The second group of car users have lower values of time and/or more flexibility in the timing of their trips, and are referred to as *other users*. Freight traffic is divided into *transit traffic*, and local *traffic*. For this preliminary case study the two freight groups are assumed to have the same behavioural parameters and are assigned the same weights in the welfare function. The two freight groups therefore fare identically in the various investment *cum* toll regimes. Freight vehicles have a Passenger Car Equivalent (PCE) of 2.0. Both passenger and freight traffic volumes are assumed to grow at 1% per annum, which is the growth rate commonly accepted for Belgian traffic.

Infrastructure costs and operation

The NEW tunnel is assumed to cost €1.2 billion to complete by Year 10. It is assumed to have a lifetime of 100 years, and with the 5% discount rate it has a salvage value of €751,055 at the end of Year 20.

Externalities

Every trip generates congestion externalities as well as air pollution, noise and accident externalities. (Values per vehicle-kilometre are specified in the Appendix.) In addition, freight vehicles create pavement damage of €0.27/vkm.[5]

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[3] Adding the small existing tunnels to the analysis would not change the traffic effects very much since these alternatives are already taken into account in the substitution patterns (demand functions) for the two tunnels considered. The welfare effects would change slightly if one of the other existing tunnels were tolled since the toll revenues derived from it would drop when a new tunnel is built.

[4] A five percent annual discount rate is used by the public sector in Belgium for cost benefit analysis.

[5] It could be argued that transit and local traffic should be treated separately since transit trucks tend to be heavier. Unfortunately, data limitations precluded a distinction.

Tolling costs and procedures

Differentiating tolls by vehicle size is common on both conventional and electronic toll roads around the world. This is the practice on the Liefkenshoek tunnel, and it is assumed to be implemented on the OLD and NEW tunnels if they are tolled. However, there is no discrimination between automobile travellers on work trips and other trips[6] or between local and transit freight traffic. In the regimes with tolls, trucks are required to cover at least their pavement-damage related maintenance costs.[7] In this application, the installation and operating costs of toll facilities are ignored[8] and infrastructure management and toll operation are assumed to be vertically integrated.

The remaining parameter values and data used to calibrate the model are presented in the Appendix.

3. Simulation results

This section reports the simulation results for the do-nothing and the four investment *cum* tolling regimes. For ease of reference the five regimes are listed in Table 1.

Table 1: Alternative investment *cum* tolling regimes.

	Regime	***Investment policy***	***Tolling policy***
1	Business as Usual (BAU)	No NEW tunnel built	OLD tunnel remains toll-free
2	NEW tunnel not built, tolling of OLD tunnel	″	OLD tunnel is tolled to internalise congestion and other transport externalities from traffic using the OLD tunnel
3	NEW tunnel built, no tolling	NEW tunnel built by public sector	Neither tunnel is tolled
4	NEW tunnel built & tolled to recover costs	NEW tunnel built by private sector	NEW tunnel is tolled to recover its construction costs
5	NEW tunnel built, both tunnels tolled	NEW tunnel built by public sector	Tolls are levied on both tunnels to internalise congestion and other transport externalities on the two-link road network

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[6] Under first-best conditions the optimal congestion toll depends only on a vehicle's contribution to congestion. Although motorists on work trips typically have higher values of time (and correspondingly lower sensitivity to tolls) than do motorists traveling for other reasons, the marginal external congestion costs they create are the same. In a second-best world, though, discriminatory pricing has a potential role to play in enhancing efficiency (Arnott and Kraus, 1998). Toll discounts for work trips have been endorsed on the grounds that work is discouraged by high employment taxes and other labour-market distortions. However, price discrimination of this sort is impeded by legal, practicality and acceptability barriers. Furthermore, labour-market and other distortions are largely ignored in the application of the MOLINO model undertaken here.

[7] EU legislation on heavy vehicle charges is still evolving. Nevertheless, the assumption that trucks are charged for their marginal maintenance costs is consistent with the currently accepted principle that tolls must be related to construction and maintenance costs and can vary by vehicle type.

[8] Operating costs of existing electronic systems generally run at about 10-20% of toll revenues (Small and Gómez-Ibáñez, 1998; Ramjerdi *et al*., 2004). London's congestion pricing scheme is a notable exception with much higher operating costs because employees are required to aid motorists with some forms of payment and to read the license-plate images recorded by the Automatic Number Plate Recognition technology.

Regime 1: Business as Usual (BAU)

In the Business as Usual (BAU) regime, no NEW tunnel is built and the OLD tunnel remains toll-free. The number of daily PCE trips through the OLD tunnel begins at about 117,000 in Year 1, and rises to nearly 128,000 in Year 20. This growth reflects the combined effect of an assumed 1% annual growth rate in traffic with congestion held constant, and a build-up in congestion that depends on tunnel capacity. Column 1 of Table 2 reports the present-discounted daily benefits and costs from usage of the tunnel over the 20-year horizon at a 5% annual discount rate. Auto travel surplus and freight travel costs are recorded as a benchmark to compare with the welfare changes that result in the other four regimes. The regional government incurs the maintenance costs of the OLD tunnel, and both regional and national governments collect revenue from transport taxes.

Table (2): Welfare gains and losses (present-value daily sums in euros over 20 year horizon, 5% discount rate).

Regime	**1 (BAU)**	**2**	**3**	**4**	**5**
	Welfare levels	Welfare changes			
Construct NEW tunnel?	No	No	**Yes**	**Yes**	**Yes**
Tolling of tunnels	None	**OLD, optimal**	None	**NEW, break even**	**OLD+NEW, optimal**
Auto travellers' surplus					
Work trips	24.728.541	-694.943	1.604.221	786.603	1.191.196
Other trips	12.131.229	-366.582	431.486	57.876	274.971
Freight users' costs					
Local traffic	30.328.753	-786.929	807.656	274.446	-16.169
Transit traffic	14.938.043	-387.592	397.801	135.175	-7.964
External costs other than congestion	1.367.587	283.525	-163.238	22.407	67.458
Toll revenues					
OLD tunnel	0	2.559.706	0	0	1.519.475
NEW tunnel	0	0	0	1.035.077	388.803
Tax revenues					
Regional government	344.188	-67.027	41.192	-5.088	-6.438
Central government	1.809.742	-356.431	216.487	-27.262	-43.593
Maintenance & construct. costs					
OLD tunnel	1.091.096	283.077	344.651	147.780	541.523
NEW tunnel	0	0	-2.491.796	-2.141.006	-2.367.656
Salvage value: NEW tunnel	0	0	751.055	751.055	751.055
Welfare gain	N/A	466.804	1.939.515	1.037.063	2.292.661
Welfare gain relative to Regime 5	0	20%	85%	45%	100%

Source: Authors' calculations.

Note: Positive entries correspond to welfare gains and negative entries to welfare losses.

Regime 2: NEW tunnel not built, tolling of OLD tunnel

In Regime 2 the NEW tunnel is again not built, but a Pigouvian toll is levied on the OLD tunnel. To economise on calculation, optimal tolls are computed for two years: Year 1 and Year 10. The Year 1 toll is levied from Year 1 to Year 9, and the Year 10 toll from Year 10 until the end of the horizon in Year 20.[9] Optimal toll levels in the two intervals are reported in Table 3. As explained in Section 2, the same toll is levied on auto trips regardless of trip purpose and the same toll is applied on the two categories of freight traffic. Two features of the tolls in each interval may appear odd. First, the ratio of peak to off-peak tolls is much higher for autos than for trucks. Second, truck tolls are 3-7 times larger than auto tolls although trucks have a PCE of 2, and therefore contribute only twice as much to congestion apiece as do autos. Both these oddities are due to the fact that trucks create substantial pavement damage costs that are not charged in the BAU regime, but are included in the tolls.

Table 4 reports traffic volumes in Regime 2 for each user group for the peak period, the off-peak period and all trips as a percentage of volumes in Regime 1 (BAU). Total PCE traffic declines by about 20%. Auto volumes decline proportionally more for other trips than for work trips because values of travel time are much lower for other trips, and the benefits from congestion relief are correspondingly smaller. Freight volumes decline rather more than auto trips because of the much higher truck tolls.

Column 2 of Table 2 reports the present-value changes in daily surpluses. Positive values indicate welfare gains, and negative values indicate welfare losses. Before accounting for the use of the toll revenues, all four user groups are worse off because the monetary values of the travel-time savings are more than offset by the tolls. The total losses are relatively evenly spread between passenger and freight traffic. External costs of traffic fall[10] although the benefits are fairly small compared to users' losses. Regional government is the big gainer since it receives the (sizeable) toll revenues that more than offset the increase in maintenance costs and the small loss of other tax revenues. The national government sees a modest reduction in fuel tax revenues.

The overall present-value of the daily welfare gain from tolling the OLD tunnel amounts to €466,804. A welfare gain is inevitable given the assumptions that tolls are set optimally and tolling is costless.[11] However, the gain is only 20% of the gain derived from Regime 5 discussed below (see the last row of Table 2). Moreover, all four user groups are left worse off, and their aggregate losses of nearly €2.24 million are nearly five times the welfare gain. Consequently, nearly 80% of the tax and toll revenues received by government would have to be, somehow, transferred to users in order to leave them no worse off than in the BAU regime. In principle, compensation could be effected either by rebating the toll revenues directly to users in a lump-sum fashion or by spending them in ways that benefit users.[12] Constructing the NEW tunnel, as in

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[9] Optimal tolls are evaluated for only two of the 20 years in order to economise on computation time. There are no implacable institutional barriers in Belgium to prevent annual changes in tolls. However, depending on the toll-road enabling legislation, annual toll increases might have to be approved on an individual basis.

[10] The figure of $283,525 denotes the benefits from a *reduction* in the costs.

[11] Operating costs on existing toll facilities are actually considerable (up to 45% of revenues) but it is expected that developments in tolling technology would reduce these costs below 10% of the revenues.

[12] If revenues were distributed to motorists this would raise household incomes and boost passenger travel demand. This feedback effect whereby drivers "buy back road space" is typically ignored in modeling exercises although it could be accounted for with the MOLINO model.

Regimes 3-5, is one way to benefit users. However, none of Regimes 3-5 features a toll on the OLD tunnel to fund construction of the NEW tunnel. The cost recovery regime in Regime 4 entails tolling the NEW tunnel after it is built.

Table (3): Toll levels (€/vehicle).

Regime	**2**	**4**	**5**
Construct NEW tunnel?	No	**Yes**	**Yes**
Tolling of tunnels	**OLD only, optimal**	**NEW only, break even**	**OLD and NEW, optimal**

Years 1-9	Peak		Off-peak						Peak		Off-peak	
	OLD	NEW	OLD	NEW					OLD	NEW	OLD	NEW
Auto	1,8		0,7						1,8		0,7	
Freight	6,8		5,0						6,8		5,0	

Years 10-20	Peak		Off-peak		Peak		Off-peak		Peak		Off-peak	
	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
Auto	2,2		0,9			3,5		3,5	0,0	0,0	0,0	0,0
Freight	7,1		5,2			11,0		11,0	4,8	4,7	4,1	4,1

Note: No tolls are levied in Regimes 1 or 3.
Source: Authors' calculations.

Table (4): Traffic volumes, Year 20 (BAU=100).

Regime		***2***	***3***	***4***	***5***
Construct NEW tunnel?		No	**Yes**	**Yes**	**Yes**
Tolling of tunnels		**OLD, optimal**	None	**NEW, break even**	**OLD+NEW, optimal**
			Peak trips		
Auto	Work	85,3	149,6	107,0	150,3
	Other	60,8	124,3	95,5	124,5
Freight		76,0	143,0	100,3	105,3
Total		**76,4**	**140,8**	**102,7**	**137,9**
			Off-peak trips		
Auto	Work	90,0	134,7	98,3	135,3
	Other	81,2	114,5	90,6	114,6
Freight		75,7	126,5	93,2	94,7
Total		**81,3**	**123,2**	**93,5**	**116,3**
			All trips		
Auto	Work	87,5	143,0	103,1	143,6
	Other	74,8	117,5	92,1	117,7
Freight		76,0	129,8	94,6	96,8
Total		**79,6**	**130,0**	**96,7**	**120,6**

Source: Authors' calculations.

Regime 3: NEW tunnel built, no tolling

In Regime 3 the NEW tunnel is built, and both tunnels are kept toll-free. Since the 20-year accounting time horizon begins in 2000 and no plan to build the tunnel has yet been made, it is assumed that the NEW tunnel goes into operation in Year 10. At the end of the accounting period in Year 20, the NEW tunnel has a discounted salvage value of €751,055/day which is tallied in the accounting.

Building the NEW tunnel greatly reduces congestion delays throughout the accounting period, and by Year 20 traffic volumes on the two tunnels combined are 30% higher than in the BAU regime (cf Table 4). Because the NEW tunnel route is shorter than the OLD tunnel route for most users, the NEW tunnel captures over 80% of traffic from each user group in both the peak and off-peak periods (cf Table 5).[13] Despite the large cost of building the tunnel and the increase in external transport costs, the social surplus gain in Regime 3 is more than four times the gain from tolling the OLD tunnel in Regime 2 (cf Table 2) and amounts to 85% of the maximum gain derived in Regime 5.

Table (5): Tunnel market shares, Year 20 (percentages).

Regime		***2***		***3***		***4***		***5***	
Construct NEW tunnel?		No		**Yes**		**Yes**		**Yes**	
Tolling of tunnels		**OLD, optimal**		None		**NEW, break even**		**OLD+NEW, optimal**	
		OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
Peak trips									
Auto	Work	100,0	0,0	17,6	82,4	41,3	58,7	17,7	82,3
	Other	100,0	0,0	17,7	82,3	80,1	19,9	17,7	82,3
Freight		100,0	0,0	17,0	83,0	61,2	38,8	17,0	83,0
Total		**100,0**	**0,0**	**17,6**	**82,4**	**54,8**	**45,2**	**17,6**	**82,4**
Off-peak trips									
Auto	Work	100,0	0,0	17,7	82,3	50,8	49,2	17,7	82,3
	Other	100,0	0,0	17,7	82,3	82,5	17,5	17,7	82,3
Freight		100,0	0,0	17,1	82,9	70,7	29,3	17,2	82,8
Total		**100,0**	**0,0**	**17,6**	**82,4**	**69,9**	**30,1**	**17,6**	**82,4**
All trips									
Auto	Work	100,0	0,0	17,7	82,3	45,3	54,7	17,7	82,3
	Other	100,0	0,0	17,7	82,3	81,7	18,3	17,7	82,3
Freight		100,0	0,0	17,1	82,9	68,7	31,3	17,2	82,8
Total		**100,0**	**0,0**	**17,6**	**82,4**	**63,7**	**36,3**	**17,6**	**82,4**

Source: Authors' calculation.

Regime 4: NEW tunnel built & tolled to recover costs

In Regime 4 the NEW tunnel is built by private enterprise and brought into service in Year 10. But unlike in Regime 3, the NEW tunnel is tolled to cover the costs of maintaining it and to pay back the construction costs by the end of the accounting horizon in Year 20.[14] Similar to Regime 2, it is assumed that there is no toll discrimination between either the two groups of auto users or the two categories of freight traffic. But unlike in Regime 2, peak and off-peak tolls are assumed to be the

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[13] The division of traffic between the tunnels is similar for all user groups because the elasticities of substitution are assumed to be the same (cf Table A1 in the Appendix).

[14] Since the tunnel commences operation only in Year 10, cost recovery (except for the salvage value) has to be accomplished within 10 years. Alternative recovery periods could be investigated by varying the accounting time horizon.

same.[15] Consequently, only two tolls are levied: an auto toll of €3.50 and a truck toll of €11.00 (cf Table 3). These relatively high tolls depress traffic even below the levels reached in the BAU regime[16], and the NEW tunnel captures a much smaller share since the OLD tunnel is left untolled. Passengers on work trips favour the NEW tunnel because the value of the travel time savings exceeds the toll. But majorities of the other user groups continue to use the OLD tunnel.

Although it turns out to be feasible to finance the tunnel by charging users, the tolls far exceed the external costs of autos and trucks and the auto toll adds to the distortion created by the pre-existing taxes. As a consequence, the welfare gain in Regime 4 is little more than half the gain from building the NEW tunnel without tolls (Regime 3).

Regime 5: NEW tunnel built, both tunnels tolled

In the final regime the NEW tunnel is built in Year 10 and both tunnels are tolled optimally. During Years 1-9 before the tunnel is built, tolls on the OLD tunnel are the same as in Regime 2 (cf Table 3). The auto toll drops to zero when the NEW tunnel begins operation because fuel and other user taxes exceed the combined congestion and other external costs of auto trips. Trucks are still tolled to cover maintenance costs and the small remaining congestion externality, but the toll is lower than in Years 1-9 and much lower than the truck tolls in Regimes 2 and 4.

Regime 5 turns out to be the most efficient of the five regimes (cf Table 2) and therefore achieves 100% efficiency. Auto drivers fare less well than without tolling (Regime 3) but better than with the break-even toll (Regime 4). Truckers do less well than in either Regime 3 or 4 because truck tolls are levied on all capacity throughout the accounting period. But reductions in external costs, and savings in maintenance costs, are higher than in either of these other regimes.

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[15] An alternative would be to assume that separate peak and off-peak tolls are set for autos and for trucks according to Ramsey pricing rules. There has been surprisingly little published research on temporal price discrimination by private toll road operators, and it is not obvious whether the peak/off-peak differential would be larger or smaller for a private operator than a public operator. Because private operators exercise market power by including a toll markup, congestion tends to be lower in the peak period – which suggests that the temporal differential will be proportionally smaller than on a public road. However, the elasticity of demand also varies by time of day, and this provides another incentive for a private operator (but not a public operator) to engage in intertemporal price discrimination. One bit of empirical evidence comes from Highway 407: a limited-access electronically-tolled highway in Toronto. In 1998 when the highway was publicly operated, separate peak, off-peak and night time/weekend tolls were levied with a ratio of 10:7:4 for each vehicle category. The highway was privatised in 1999, and since 2002 the maximum temporal toll differential has ranged from nothing to about 7%. While this suggests that temporal toll discrimination is less pronounced on private toll roads, there are at least two confounding factors. First, traffic volumes have grown very rapidly on Highway 407 since it went into operation in 1997, and second, tolls are subject to complicated regulations based on traffic volumes.

[16] Since the NEW tunnel provides a new option for drivers while the OLD tunnel remains as before, one might expect traffic levels in Regime 4 to remain above BAU even with very high tolls. The reason that traffic drops slightly is that the two tunnels are imperfect substitutes in the model. Introducing the NEW tunnel induces some users with strong preferences for the NEW tunnel to discontinue using the OLD tunnel, and to economise on their total amount of travel. This effect would weaken as the elasticity of substitution between tunnels (currently set at 5) is increased, and in the limit of perfect substitution the number of vehicle-kilometres would necessarily increase.

Sensitivity analysis

The simulations described above incorporate assumptions about a large number of parameter values that affect both the absolute and relative welfare gains and losses in the four investment *cum* tolling regimes. Both computation time and page constraints preclude an exhaustive sensitivity analysis, and attention in this subsection is restricted to two parameters of obvious significance: the cost of constructing the NEW tunnel, and the marginal cost of public funds.

Construction costs and private contracting

The €1.2 billion construction cost for the NEW tunnel is a conservative figure based on the premise that the tunnel is built according to best practice with no delays or cost increases due to technological, incentive or other contractual problems. Yet worldwide experience with major transport infrastructure projects indicates that substantial cost overruns are quite common (Flyvberg *et al.*, 2003) and that construction costs depend strongly on the contractual framework. We therefore tested the case where construction costs of the tunnel would increase by 20% when it is not built and operated by the private sector[17]. This means that in Cases 3 and 5, construction costs are increased by 20%, but not in Case 4 where operation and investment are private.

With the cost increases, the present-value welfare gains decrease by roughly €300,000-350,000 per day in Regimes 3 and 5 (cf panel (2) of Table 6). But the ranking of the four regimes is unchanged, and constructing the tunnel remains a viable proposition.

Table 6: Welfare gains sensitivity analysis (present-value daily sums in euros over 20 year horizon, 5% discount rate).

Regime	***1 (BAU)***	***2***	***3***	***4***	***5***
Construct NEW tunnel?	No	No	**Yes**	**Yes**	**Yes**
Tolling of tunnels	None	**OLD, optimal**	None	**NEW, break even**	**OLD+NEW, optimal**
			(1) Base case		
Welfare gain	N/A	466.804	1.939.515	1.037.063	2.292.661
Welfare gain relative to Regime 5	0%	20%	85%	45%	100%
	(2) Construction costs, maint. costs & salvage value of NEW tunnel rise 20% for Cases 3&5				
Welfare gain	N/A	466.804	1.591.367	1.037.063	1.971.823
Welfare gain relative to Regime 5	0%	24%	81%	53%	100%
		(3) Marginal cost of public funds = 1.5			
Welfare gain	N/A	2.300.043	994.783	1.051.452	2.945.536
Welfare gain relative to Regime 5	0%	78%	34%	36%	100%

Source: Authors' calculations

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[17] Private operation is not a guarantee against cost overruns. It is the nature and the power of the contract that are decisive.

Marginal cost of public funds

Estimates of the marginal cost of public funds vary widely by jurisdiction and country (Kleven and Kreiner, 2003) and they are sensitive to how revenues are collected and spent. To assess the sensitivity of the welfare results to the premium on public funds, a value of 1.5 for the marginal cost of public funds (MCPF) was used in place of the base-case value of 1. Doing so raises the effective costs of constructing and maintaining the tunnel, but it also raises the salvage value of the tunnel as well as the value attached to toll and tax revenues.

Raising the MCPF has a more pronounced effect on the results than does the increase in construction costs (cf panel (3) of Table 6). The welfare gain from tolling the OLD tunnel without building the NEW tunnel (Regime 2) increases nearly five-fold relative to the base case. By contrast, building the NEW tunnel without introducing any tolls (Regime 3) drops by nearly 50% in benefits. Not surprisingly, building the tunnel under a break-even constraint (Regime 4) yields nearly the same welfare gain as in the base case because the premium attached to the toll revenue offsets the excess burden from the construction and maintenance costs. Finally, the welfare gain from the social optimum (Regime 5) rises moderately because the net increase in toll and tax revenues exceeds the construction and maintenance costs of the tunnels net of the salvage value of the NEW tunnel.

As a consequence of these changes, the relative welfare gain from Regime 2 increases from 20% to 78% and boosts it from fourth (last) place to second place in the rankings of Regimes 2-5, while Regime 3 drops from 85% to 34% in efficiency, and from second place to last. Naturally, these results would change with alternative values for the MCPF, but they do illustrate the importance of accounting for the public finance side of infrastructure projects in the real world of second best.

4. Concluding remarks

This paper has conducted a preliminary cost-benefit analysis of a proposed tunnel under the Scheldt river in Antwerp, Belgium. The analysis was performed using the MOLINO model: a cost-benefit tool for transport pricing, investment and regulation schemes that was recently developed as part of the European-Union funded REVENUE project. The model features a CES structure in which passengers and freight shippers make nested choices. For the Antwerp tunnel case study, three choice levels were implemented: (1) whether to travel, (2) to travel during the peak or off-peak period, and (3) to travel on one of two alternative links or routes.

MOLINO was implemented in the case-study area by treating the proposed “NEW” tunnel as one alternative and an existing “OLD” tunnel as the other. Four alternative investment *cum* tolling regimes were considered that differ according to whether the NEW tunnel is built, and whether tolls are introduced on the NEW and/or the OLD tunnels. With the base-case parameter values, building the tunnel is worthwhile in all three tolling regimes and yields a higher benefit than not building the tunnel and tolling the OLD one. Nevertheless, the net benefit from building the tunnel varies appreciably between tolling regimes. Tolling both OLD and NEW tunnels results in the highest benefits since tolling costs are ignored and tolling both tunnels supports an optimal level and division of traffic between them. Building the tunnel without introducing any tolls compares relatively favourably since the new tunnel adds sufficient capacity to reduce congestion on the two-link network to a comparatively low level. By comparison, implementing a break-even toll on the NEW tunnel is far less efficient because it suppresses traffic through the NEW tunnel well below the optimal level and induces too much traffic to take the OLD tunnel.

Raising the construction and maintenance costs of the NEW tunnel by 20% in the two regimes with public operation does not affect the rankings of the regimes or other qualitative results. By contrast, setting the marginal cost of public funds at 1.5 pushes the two investment regimes with imperfect tolling down in the rankings, and raises the regime with no investment and optimal tolling of the OLD tunnel up to second place.

While the results of the case study provide some interesting insights, the analysis is preliminary and should be taken further in at least four respects. One is to extend the sensitivity analysis to include such elements as the elasticity of substitution for passenger and freight traffic between alternatives, the costs of installing and operating the tolling infrastructure, and more procurement issues related to the costs of public vs. private construction and how privately operated toll roads and tunnels should be regulated. The ramifications of reforming the existing system of transport taxes could also be explored. A second extension is to refine the analysis of the alternative investment *cum* tolling regimes by extending the time horizon beyond 20 years, optimising tolls in every year, and computing Ramsey-optimal tolls by jointly optimising peak and off-peak tolls for passenger and freight traffic. A third extension is to consider the other tunnels that cross the Scheldt river as a third alternative and to take into account the benefits or costs on the rest of the network. Finally one can study in more detail the decision making (investment and tolling the two tunnels) of the regional government when it weighs the benefits to transit users and to national government tax revenues differently.

References

Arnott, R. and Kraus, M. (1998) “When are Anonymous Congestion Charges Consistent with Marginal Cost Pricing?", *Journal of Public Economics* 67: pp. 45-64.

De Borger, B. and Proost, S. (eds) (2001) *Reforming Transport Pricing in the European Union – A Modelling Approach*, Edward Elgar, Cheltenham, UK.

De Ceuster, G. (2004) *Internalising external costs of Road Traffic in Flanders* (in Dutch), study of TML for Flemish Observatory of the Environment, MIRA

ECMT (2003) “Efficient transport taxes and charges”, CS (2003) 4

Flyvberg, B., Bruzelius, N. and Rothengatter, W. (2003) *Megaprojects and Risk - An Anatomy of Ambition*, Cambridge University Press, Cambridge.

Kleven H. J. and Kreiner, C. T. (2003) “The marginal cost of public funds in OECD countries: hours of work versus Labor force participation”, *CESifo Working paper 935*.

Ramjerdi, F., Minken, H. and Ostmoe, K. (2004) “Norwegian urban tolls”, In: Santos, G. (ed) *Road Pricing: Theory and Evidence, Research in Transportation Economics* 9, Elsevier Science, Amsterdam, pp. 237-249.

Small, K. A. and Gómez-Ibáñez, J. A. (1998) “Road Pricing for Congestion Management: The Transition from Theory to Policy”, In: Button, K.J. and Verhoef, E.T. (eds) *Road Pricing, Traffic Congestion and the Environment: Issues of Efficiency and Social Feasibility*, Edward Elgar, Cheltenham, UK, 213-246.

Small, K. A., Winston, C. and Evans, C. A. (1989) *Road Work*, Brookings Institution Press, Washington, D.C.

Nelthorp, J., Sansom, T., Doll, C. and Lindberg, G. (2001), Valuation Conventions for UNITE. ITS, University of Leeds.

Federal Department of Transport of Belgium(2001), traffic counts 2000, Brussels

Winston, C. (1991) "Efficient Transportation Infrastructure Policy", *Journal of Economic Perspectives* 5(1): pp 113-127.

6. Appendix

This appendix describes the primary data used to calibrate the MOLINO model and to run the simulations. The model was calibrated using two sets of data: first a set of simulation results of a transport model with the NEW tunnel, and second the present equilibrium without the NEW tunnel. In the simulation with NEW tunnel, 80% of the travellers are expected to choose to cross the river using the NEW tunnel. Traffic on the OLD tunnel will be significantly reduced so that during the peak period the average speed is expected to be 100 km/h for both the OLD and NEW tunnel. During the off-peak period the average speed will be close to the free-flow speed. The parameters of the utility and cost functions were chosen to fit this simulation and at the same time also fit the present equilibrium by assuming that at present the tolls on the NEW tunnel are infinite.

Traffic volume data used for calibration

Table A1 records forecasted traffic volumes if a NEW tunnel is built and no tolls are levied. In this case 80% of the travellers are expected to choose to cross the river using the NEW tunnel. Total demand will rise from 120,000 vehicles per day to nearly 150,000. Nearly half (47%) of passenger trips are made during the peak period, with 70% of these trips taken for business or commuting purposes. During the off-peak more passenger trips are taken for other purposes than work. By contrast, only 22% of freight trips are made during the peak and local firms account for 67% of trips in both the peak and off-peak.

Table A1: Traffic volumes in base case.

Category	***Trip type***	***Peak***		***Off-peak***		***Total Peak***	***Total Off-Peak***	***Share all trips***
		NEW	**OLD**	**NEW**	**OLD**			
Passengers	Work	33,259	7,191	23,842	5,155	40,450	31,033	56.5%
	Other	14,254	3,082	29,736	6,429	17,336	32,818	43.5%
	Share pass. trips					47.0%	53.0%	
Freight	Local	3,232	669	11,460	2,373	3,901	12,129	67.0%
	Transit	1,592	330	5,644	1,169	1,922	5,974	33.0%
	Share freight trips					22.0%	78.0%	

Source: expert judgment on basis of Federal Department of Transport data (2001).

Parameters of utility functions

Passenger transport is described by a three-level decision tree with the following nested choices:

1. to cross the river or spend income on other goods
2. to cross the river in the peak or in the off-peak period
3. to take the OLD tunnel or the NEW tunnel

For freight transport the top-level choice is between transporting goods across the river and delivering the product or service to consumers using other inputs. The other two choice levels are the same as for passenger transport. Table A2 lists the elasticities of substitution at each choice level for passenger and freight transport.

Table A2: Elasticities of substitution.

Category	*Trip type*	*Transport & other goods*	*Peak & off-peak*	*OLD & NEW during peak*	*OLD & NEW during off-peak*
Passengers	Work	1.2	0.8	5	5
	Other	1.2	1.5	5	5
Freight	Local	1.2	0.9	5	5
	Transit	1.2	0.9	5	5

Source: De Borger and Proost (2001).

Travel time-flow

The travel time-flow function for each tunnel is assumed to be linear in traffic flow. To calibrate the function for the OLD tunnel, current speed and traffic flow counts on the ring road were used. The function for the NEW tunnel was calibrated using the forecasted results.

Speed data

The average distance traveled on the ring road for vehicles using the OLD (Kennedy) tunnel or NEW tunnel is 14 km. Average speed is assumed to be 60 km/h in peak, and 85 km/h during the off peak. If the NEW tunnel is built, average speed during the peak is expected to be 100 km/h for both the OLD and NEW tunnel routes and off-peak speeds are expected to be close to free-flow speeds (120 km/h).

Value of time

Values of travel time are reported in Table A3; they are assumed to be the same during the peak and the off-peak.

Table A3: Values of time (€/h).

Category	*Trip type*	*Value of time*
Passengers	Work	21.6
	Other	4.3
Freight	Local	46.2
	Transit	46.2

Source: UNITE (Nelthrop e.a., 2001).

Infrastructure costs and external costs of traffic

The cost of building the NEW tunnel ("Oosterweel" connection) is estimated to be €1.2 billion (http://www.werkenantwerpen.be/BAM/corporate.aspx). To calculate the salvage value of capacity in 2020 we used a simple annuity technique in which the present value in 2020 is equal to the discounted sum of a constant annuity for the remaining years of the technical lifetime.

Variable operating, maintenance and external costs of the NEW tunnel are listed in Table A4.

Table A4: Operator and infrastructure manager costs & external costs.

		Peak		*Off-peak*	
		NEW	**OLD**	**NEW**	**OLD**
Variable operating cost [€/veh]	Pass. veh	0	0	0	0
	Freight veh	0	0	0	0
Variable infrastructure charge [€/veh]	Pass. veh	0	0	0	0
	Freight veh	0	0	0	0
Maintenance [€/veh]	Pass. veh	0	0	0	0
	Freight veh	3.8	3.8	3.8	3.8
External cost [€/vkm]	Pass. veh	0.046	0.046	0.046	0.046
	Freight veh	0.124	0.124	0.124	0.124

Source: External costs: G. De Ceuster, (2004),. Maintenance costs: ECMT (2003).

Users costs and existing taxes

Table A5 reports the resource costs (fuel, vehicle depreciation and insurance costs) and tax costs incurred by users per vehicle kilometre.

Table A5: Monetary costs borne by users.

		Passenger vehicles		*Freight vehicles*	
		Work	**Other**	**Local**	**Transit**
Resource cost [€/vkm]	NEW	0.134	0.134	0.285	0.285
	OLD	0.134	0.134	0.285	0.285
National tax [€/vkm]	NEW	0.073	0.073	0.107	0.107
	OLD	0.073	0.073	0.107	0.107
Regional tax [€/vkm]	NEW	0.014	0.014	0.018	0.018
	OLD	0.014	0.014	0.018	0.018

Source: G. De Ceuster (2003).

Other parameters

The marginal cost of public funds is set equal to 1 so that no premium is attached in the welfare calculations to revenues collected by government from tolls and other user charges. In Regime 4, where the NEW tunnel is operated and managed by a private operator, the national government taxes profits at a rate of 35%. Profits are assumed to be allocated to the various user groups in proportion to the numbers of trips taken.

To calibrate the nested CES functions, the share of household income devoted to passenger transport was set at 20%, and the share of transport expenditures in total production costs was set at 10%.

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