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The urban road pricing scheme to curb pollution in Milan: a preliminary assessment

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Abstract

Starting from January 2008 Milan implemented a charging scheme to enter an 8 km^2 area in the city centre. The term used in Italy to denote the scheme is Ecopass, conveying the stated political objective of the scheme: a PASS to improve the quality of the urban environment (ECO). The charge is set according to the Euro emission standard of the vehicles entering the area. Having recalled the main theoretical and empirical issues discussed in the literature, the paper illustrates and discusses the main features and impacts of the Milan Ecopass Scheme, and reports a preliminary cost-benefit analysis. This analysis shows that the scheme has been effective in curbing not only pollution emissions, but also congestion, and that these results have been achieved with low implementation costs and without major political opposition. The cost-benefits analysis presents an overall net benefit. The identification of the winners and losers of the policy is conditioned by penalty payments. In fact, a striking feature of the Milan Ecopass Scheme, compared to that of London and Stockholm, is that in the first year of implementation the penalty payments were higher than the toll revenues. If the penalties are included in the cost-benefit analysis, the public administration and the society at large are the main winners, whereas car users and especially freight vehicle users, are net losers.

Introduction

After its recent introduction in two major European cities (London and Stockholm) urban road pricing has been introduced in Milan, Italy, starting from January 2008. The gain in popularity of road pricing schemes among decision makers in Europe has come after transport economists had long advocated road pricing as a socially beneficial policy.

Urban road pricing, a Pigouvian tax by nature, is advocated to be a welfare increasing policy (Pigou, 1920; Vickrey, 1963, 1969; Walters, 1961), but many related issues are still controversial both at a theoretical and empirical level.

From a theoretical point of view, since the first-best, link-based, partial-equilibrium model is far too simple to represent the multifaceted issues of the real world, congestion pricing needs to be modelled in a network-based, second-best setting. It follows that the modelling framework becomes more complex and the theoretical results less clear-cut.

From an empirical point of view, the number of real world implementation is yet far too small and too case specific to allow the scientific community to draw definite conclusions. Yet, some empirical evidence does exist. The literature on the recent London and Stockholm schemes shows that road pricing:

- is effective in reducing congestion and, consequently, travel times (Transport for London, various years; Eliasson, 2008);

- causes a modal shift toward public transport and non-motorised modes;
- improves, as a side-effect, the urban and environmental quality of the urban areas where it is implemented (Banister, 2003);
- is financially beneficial for the local authorities that implement it;
- does not always raise public discontent and can be politically accepted;
- does provide substantial toll revenues to the local administration who can allocate them according to the political agreement with its constituency;
- can be a progressive tax in its own right, before any compensation scheme is implemented (Santos and Rojey, 2004, p. 38).

The scheme applied in Milan (called MES hereafter, Milan Ecopass Scheme) provides yet another possibility to test the various issues at stake. The term Ecopass summarises the meaning and the stated political objective of the scheme: a PASS to improve the air quality of the city (ECO).

The literature shows that the final results of the implemented policies depend on how they are tailored to the specific characteristics of the city and on the specific objectives pursued. No easy and robust generalization is possible, as is often the case in social sciences. However, the examination of the MES - an important scheme since, in Italy, Milan is the second largest metropolitan area in terms of population, and the most important in terms of wealth - can provide further useful evidence on the advantages and disadvantages of a road pricing policy in an urban agglomeration.

The paper is structured as follows. Section 2 summarises the main modelling and implementation issues debated in the literature. Section 3 illustrates the characteristics of the MES. Section 4 illustrates its main short-run impacts and Section 5 provides a preliminary cost-benefit analysis based on available data. Section 6 summarises and discusses the results.

Throughout the paper, comparisons will be made with the schemes implemented in London and Stockholm, and, to a lesser degree, in Singapore. Special attention will be paid to drawing, from the analysis of the MES, hints or evidence to confirm or dismiss previous literature findings.

1. Theoretical issues

Road pricing, still widely discussed in the literature[1], has proved to be a welfare-increasing policy which, when jointly planned with network capacity provision, can significantly strengthen the financial sustainability and cost-effectiveness of road infrastructure investments. However the first-best, link-based, partial-equilibrium road-pricing model (as proposed by Pigou, 1920; Knight, 1924; Walters, 1961; Vickrey, 1963, and 1969), which requires each road user to pay a price equal to the value of the congestion delay imposed on all other users, represents a mere benchmark solution as its real world implementation raises numerous theoretical, technical, social, and political issues. These have been addressed in many second- and third-best models.

Since the toll is imposed only on a sub-area or a subset of links with different levels of traffic substitution, it has been argued that the model should specify the number and location of the tolled links (Stewart, 2007), the most appropriate scheme to be implemented (area-based or cordon-based, see Maruyama and Sumalee, 2007), and the cordon location (Mun *et al.*, 2005; Shepherd and Sumalee, 2004).

Since the users are heterogeneous in terms of income, value of time, value of punctuality, trip purpose, and type of vehicle, multi-class assignment models have to be used in order to correctly estimate both the optimal charge level and the welfare benefits of the charging scheme[2].

[1] A list of recent references includes Tsekeris and Voß (2008), Small and Verhoef (2007) de Palma *et al.* (2006), Lindsey (2006) and Santos (2004).

[2] Recent discussion of this issue can be found in Han and Yang, 2008; Lu *et al.,* 2007; Zhao and Kockelman, 2006: Verhoef and Small, 2004.

Moreover, since travel demand has a time-varying nature with peak and off-peak periods within the day, dynamic pricing models are required to take into account the dynamic nature of the congestion phenomenon. To this purpose bottleneck models and dynamic traffic assignment models can be used (Kuwahara, 2007; Szeto and Lo, 2006). A further evidence is that the users' response to a congestion charge is characterised by a dynamic learning process which should be taken into account in the pricing scheme modelling (Yang, 2008; de Palma *et al*., 2005).

Various authors have shown that the efficiency of congestion charging can be significantly improved if jointly designed with other demand management and regulatory policies including fuel taxes, road parking fees, and public transport improvements (Li *et al*., 2007; Proost and Sen, 2006).

Furthermore, Mun *et al.* (2005) proved that the magnitude of the welfare benefits depends on the spatial structure, the population density and the size of the urban context.

Despite the substantial improvements in congestion price modelling, several issues still hinder the efficiency gain in the real-world implementation of the pricing schemes.

A very relevant issue is the migration of congestion spill-over effects to unpriced sections of the network (Safirova *et al*., 2007). A further issue relates to the fact that highly differentiated dynamic congestion charges, although more efficient than the homogenous ones, are characterized by high implementation costs and are more difficult to be understood and accepted by road users (Bonsall *et al*., 2007).

Furthermore, the quantity and quality of information provided to road users about the toll level, optimal routing and congestion intensity over the network, substantially influences the efficiency of the charging scheme, but requires the adoption of sophisticated and costly technology which lowers the financial sustainability of the policy (Levinson and Odlyzko, 2008; Prud'homme and Bocarejo 2005).

The selection of the road pricing technology raises a number of issues including the characteristics of the chosen pricing scheme (location of the pricing cordon/area, time-frame of the scheme, type of users or vehicle charged), the specific goals pursued by the local authorities (flexibility, data requirements, accuracy and reliability of the identification system, communication and enforcement costs, evasion rates, interoperability with other demand management systems), and the users' acceptance of the charging policy (mainly related to privacy issues).

Lastly, there are important social and spatial equity issues connected with the charging scheme[3] strongly influencing its acceptability, and raising questions about the proper toll for different groups of users and about the appropriate allocation of the collected resources. The cost of misusing those resources rise with the magnitude of the revenues.

The impacts that road pricing has on transport external costs other than congestion, that is: accidents (Noland *et al*., 2008), traffic noise, air pollution and climate change, have been scarcely analysed, although their magnitude can be noteworthy.

The long-term impacts of road pricing schemes are even harder to measure and forecast as they encompass changes of the spatial distribution of economic activities and dwellings, modifications of land use and property values, increase of urban sprawl, and alteration of labour supply and net wages.

Road pricing schemes have been implemented worldwide in many cities (Singapore 1975, Hong-Kong 1980, Bergen 1986, Trondheim 1991, Oslo 1990, London 2003, La Valletta 2007 and Stockholm 2007), and numerous schemes have been studied for various European (Dublin, Cambridge, Edinburgh, Copenhagen, Amsterdam, Brussels), Asian (Seoul, Bangkok, Tokyo) and American cities (New York, Los Angeles, Washington, San Francisco). Milan is the first Italian city where a road pricing scheme has been implemented.

Although many issues and impacts have been subject to debate, as briefly illustrated in this section, we feel that, as more cities are considering applying a charging scheme, the following issues deserve urgent attention: which cities or city areas could provide the best results? Which mix of goals (congestion, pollution, accidents, revenue) is more appropriate? Which technology should be

[3] See Bureau and Glachan, 2008; Schweitzer and Taylor, 2008; Ungemah, 2007; Eliasson and Mattsson, 2006.

implemented? How gradually should a charging scheme be introduced? Which policy mix should accompany a charging scheme to enhance its effectiveness and efficiency? What is the impact of these choices on the political acceptability? What are the distributional or equity implications of road pricing?

With these issues in mind, we now turn to the illustration of the Milan Ecopass Scheme (MES).

2. The MES: characteristics and implementation

Milan is one of the largest Italian metropolitan areas. It comprises 3.7 million inhabitants (1.9 million within the city boundaries) and is the centre of the polycentric Lombardy region of about 9.5 million inhabitants (ARPA, 2006, p. 62). Although the area is served by an important transport public network (the local public transport company, ATM, runs 49 bus lines, 18 tram lines, 3 trolleybus, 3 metro lines, for a total of 1300 km, together with 3 subway lines, for a total of 75 km, http://www.atm-mi.it/ATM/Azienda/ATM_cifre.html, consulted 05/02/09) there is a perception that road traffic is excessive and generates a lot of congestion as well as air pollution. This perception is consistent with the high level of car ownership in the city : 0.6 cars per inhabitant (0.74 including all vehicles) which ranks Milan among the cities with the highest car concentration in the world. The high reliance on car use for travel in Milan, together with adverse geoclimatic conditions, results in high pollution levels. For instance, in the period 2002-2007, the 50 $\mu g/m^3$ PM_{10} concentration limit set by EU environmental regulation was exceeded during 125 days (Agenzia Milanese Mobilità Ambiente, hereafter AMMA, 2008), with an average value of 51.2 $\mu g/m^3$. The NO_2 annual average daily concentration was 60 $\mu g/m^3$ (ARPA, 2006, p. 86) and the 0_3 was about 30 $\mu g/m^3$, and both increasing. To cope with the situation the Ecopass system was introduced. The main features of this system are presented below, together with some elements of comparison with road pricing schemes implemented in other cities.

Since January 2008, vehicles entering the 8 km² area (see figure 1) between 7:30 and 19:30 are subject to the payment of a charge. The charging area is relatively small compared to London (22 km² before 2005, and 40 km² after 2005) and Stockholm (47 km²), but is comparable to Singapore (7 km²). The choice of the location and of the dimension of the charging area has been based on the historic urban layout, rather than on accurate transport planning considerations. Such an area, we reckon, is too small to allow a substantial effect on transport speeds such as the one recorded in the Stockholm case (Eliasson *et al.,* 2008).

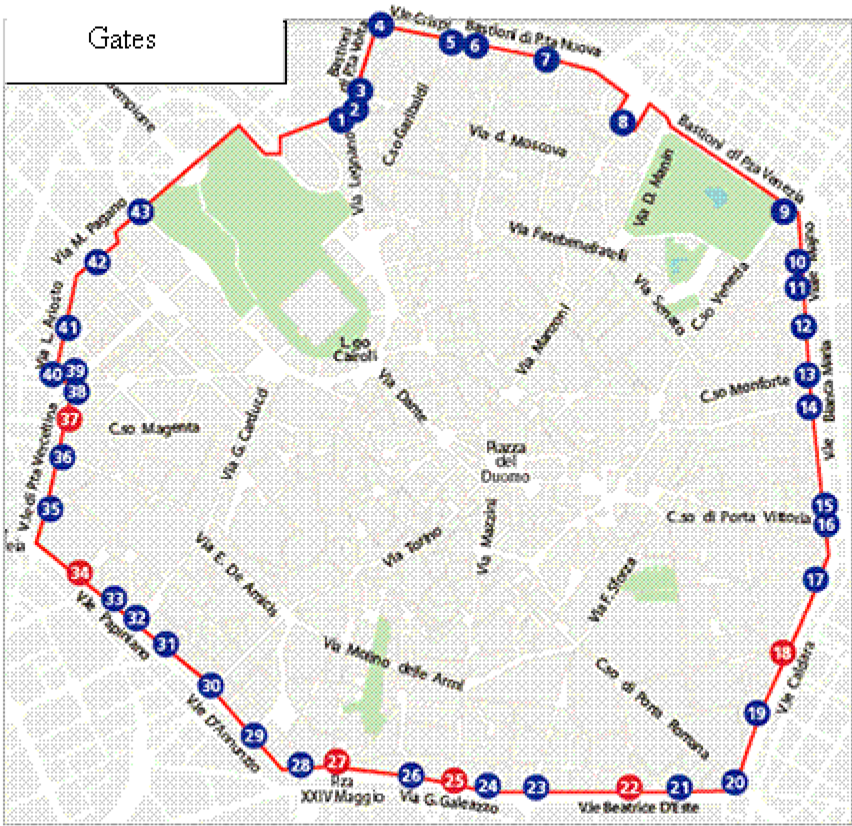

Figure 1 – The MES Area and the entry points (http://www.comune.milano.it).

A crucial decision was made to set the charge according to the 5 Euro emission standard (Table 1). In contrast with theoretical prescriptions, no differentiation is made according to access time to the charging area, within the charging window (7.30-19.30). This is because the charge is mainly conceived and communicated as a pollution charge and not as a congestion charge.

The MES is characterized by a relatively high level of charge differentiation based on emission standards. Other comparable European schemes usually have more limited charge differentiations. Stockholm, for instance, has some temporal differentiations within a limited range of about 1 Euro, while in Milan the range of differentiation is 8 Euros. The maximum charge in Milan €10, applied only to a limited number of vehicles, is close to the £8 (about €11 using PPP conversion rates) charge used in London.

In contrast with the goals pursued in London (congestion charging), Trondheim (infrastructure financing), or Stockholm (congestion, accessibility, environment, public transport infrastructures financing), the objective stated by the Milan local authorities is to reduce air pollution. Congestion is mentioned only as a side-goal. This choice is motivated by the high air pollution levels in Milan, much higher than, for instance, in London or in Stockholm (a yearly average PM_{10} concentration levels of 51 versus 34 and 42 $\mu g/m^3$, respectively). Focusing on air pollution abatement not only indicates the interest of the local authorities for environmental issues, but is also a strategy to overcome the tax payers' reluctance to the introduction of yet another charge.

Table 1 - Toll classes based on Euro emission standards

Toll classes	*Definition*
Class I	Liquid propane gas – methane – electric - hybrid.
Class II	Gasoline Euro 3, 4 or more recent
	Diesel Euro 4 without Anti-Particulate Filter (up to 30/06/08)
	Cars and freight vehicles diesel Euro 4 o more recent with anti particulate filter
Class III	Gasoline Euro 1 and 2
Class IV	Gasoline Euro 0
	Diesel cars Euro 1, 2 and 3
	Diesel goods vehicles Euro 3
	Diesel buses Euro 4 and 5
Class V	Diesel cars Euro 0
	Goods vehicles Euro 0, 1 and 2
	Diesel buses Euro 0, 1, 2 and 3

Table 2 - Ecopass tariffs for cars

Toll classes	Daily charge	Discounted multiple entries (max 100 entries per year)		Yearly pass for residents
		50% rebate (first 50 entries)	40% rebate (successive 50 entries)	
Class I		Free		
Class II		Free		
Class III	€ 2	€ 50	€ 60	€ 50
Class IV	€ 5	€ 125	€ 150	€ 125
Class V	€ 10	€ 250	€ 300	€ 250

Charge differentiation is also obtained through discounts available for frequent users, probably with the aim of increasing political acceptability. There is a 50% rebate for the first 50 entries per year and a 40% rebate for the subsequent 50 entries. There are no rebates for accesses exceeding 100-per-year. Discounts are also available for residents in the tolled area. A number of categories are exempted. These include motorcycles and scooters, public transport, vehicles for handicapped people, Army and Police (State and local) vehicles, vehicles used for public services, ambulances and, from 10 a.m. to 16 p.m., vehicles transporting exclusively perishable and refrigerated food products, provided a permit is purchased from the municipality.

Since in Milan the objective is mainly to curb pollution rather than congestion, it was decided to implement the MES via an automatic-number-plate-recognition (ANPR) technology, previously tested in London, and Stockholm, whereas Singapore implemented a more advanced electronic road pricing (ERP) technology allowing better differentiation according to the prevailing congestion level. The decision was also influenced by the fact that the area to be charged was already monitored via cameras for the enforcement of the Limited Traffic Zone policy.

The MES is, as suggested by theory, part of a wider transport policy package including short-term policies such as traffic calming measures, new bus lanes, increased bus frequency, increase in parking restriction and fees, and medium-term policies such as park-and-ride facilities and underground network extension.

3. Impacts of the MES

In this section we illustrate the impacts of the MES on pollution, traffic, congestion, trip scheduling, modal transfer, pollution abatement and toll revenues.

Pollution abatement

It is claimed that the MES reduced air emissions of PM_{10} by 19%, of NO_x by 14%, and of CO_2 by 15% (AMMA, 2008). Interestingly, similar results were obtained in London (-16%, -13,4% and -16%, respectively) and in Stockholm (-13%, -8,5% and -13%).

Number and type of vehicles

Nine months after the introduction of the MES the number of vehicles entering the charging area had decreased by 14.2% (AMMA, 2008). It is reported that in London the vehicle-km decreased by 17% in the period 2002-3 and by 22% in the period 2002-4, while in Stockholm the number of entries decreased by 23.8% in the period January-May 2006. Although the three measurements (vehicles independently of the number of entries, vehicle-km and entries) are not strictly comparable, the traffic reductions observed in the charging area in Milan is most likely of a similar magnitude to those obtained in London and Stockholm.

The traffic composition was modified by the introduction of the charge. As expected, there has been a shift in the number of vehicles entering the charging area from tolled (III, IV and V) to toll-exempted vehicles (I and II). More in detail (Table 3), the toll-charged car classes decreased by 19,396 units per day, whereas the toll-exempted car classes increased by 2,908 units per day. Overall the cars entering the charging area decreased by 16,488 per day. Similarly, for freight vehicles, the tolled classes decreased by 3,635 units per day, whereas the toll-exempted classes increased by 961 units per day. To summarize, a large number of vehicles was discouraged from entering the area, especially those belonging to the higher-charged classes, partly compensated for by the increase in the number of vehicles belonging to the exempted classes: the tax stimulus had the expected effects both in terms of traffic reduction and vehicle composition.

Table 3 – Traffic composition by toll classes (vehicles/day, March 2008)

	Cars			Freight vehicles		
	Before MES	After MES March 2008	Variation	Before MES	After MES March 2008	Variation
Class I	1,105	1,918	813	92	410	317
Class II	50,993	53,088	2,095	3,399	4,043	644
Class III	11,898	5,960	-5,939	356	494	138
Class IV	20,992	7,535	-13,457	6,653	3,917	-2,737
Class V	0	0	0	2,674	1,638	-1,036
Total	84,988	68,500	-16,488	13,174	10,500	-2,674

Tolled cars in Milan are about 20% of those tolled in London and 80% of those tolled in Stockholm.

Congestion reduction

According to AMMA (2008), after nine months of implementation, traffic decreased by 3.6% within the MES area, and by 12.3% outside the MES area. Congestion measured as traffic flow/capacity ratio decreased on average by 4.7%, while the network extension with a flow/capacity ratio higher than 0.9 decreased by 25.1%. Private vehicles' speed within the charging area increased by 4%, while bus speed increased from 8.67 to 9.34 km/h (+7.8%). Such a difference is probably due to the accompanying traffic management policies such as new bus lanes, revised traffic directions and reduced illegal and on-street parking.

Trip scheduling shift

The MES not only reduced the number of vehicle trips, but also modified their temporal distribution. In fact, there was a sharp decrease (-23%) of entries between 7:30 and 8:00 a.m., shifting the morning peak by one hour, an average reduction of 17% during the rest of the day, and an increase in traffic accessing the area in the 30 minutes following the end of the tolling period.

Modal transfer

Public transport use, measured as the number of passengers exiting subway stations inside the tolled area, increased by 9.2%. No data are yet reported for buses.

Revenue collection

Public administration revenues are the sum of charge payments and penalty payments. The annual charge payments are estimated to be €13.6 million, almost 25 times less than in London[4]. This is partly due to the smaller geographical extension of the tolled area resulting in fewer vehicles tolled, 4 times less than in London, and partly due to the lower average charge. In fact, in Milan the average revenue per tolled vehicle, including residents and exempted vehicles, is €1[5], while in London it is equal to €2.6. According to informal sources, penalty payments are higher than charge payments. Some sources claim they are three times as much as the toll revenues. This is a strikingly high figure when compared to London and Stockholm, which report a 58% and a 6% penalty/charge revenue ratio, respectively. The causes of such high penalty payments have not been analysed yet. Among the potential explanations is a failure in communication about the scheme.

Charging differentiation also had a noticeable impact on the allocation of the toll burden among user categories. This is illustrated in Table 4, which provides a comparison of the number of entries, the number of paying vehicles and the amount of revenues deriving from each vehicle category and toll class.

Table 4 - Distribution of entries and revenues for different categories of vehicles

	Number of entries per vehicle type		
	Freight vehicles	Cars	Total
	10,848	71,312	82,160
	Number of payments class (per day)		
III	510	6,204	6,714
IV	4,046	7,844	11,891
V	1,692	0	1,692
Total	6,248	14,048	20,297
	Revenues per class (million €/year)		
III	0.18	2.23	2.41
IV	2.54	4.94	7.50
V	2.49	0.00	2.49
Total	5.23	7.17	12.40

Source: March 2008 monthly report

Out of 82,160 vehicles per day entering the MES area in March 2008, 13% were freight vehicles and 77% cars. 20,297 vehicles paid the charge, of which 31% were freight vehicles and 69% cars. Note also that freight vehicles are relatively more represented in the higher paying classes IV and V.

[4] Other tolling schemes, compared with London and Milan, are in an intermediate situation with €69 million of revenues in Stockholm (2006 prices), and €32milion in Singapore (2003 prices).

[5] The average revenue per tolled vehicle, excluding residents and exempted vehicles, is €4.55. If residents are included it drops to €1.31.

Consequently, 42% of the charge revenue comes from freight vehicles and 58% from cars. Hence, 13% of the vehicles pay 42% of the charge.

4. Cost benefit analysis of the Milan Ecopass Scheme (MES)

Having assessed the impacts of the road pricing schemes implemented in Milan and some other large metropolitan areas, we turn in this section to the issue of efficiency: how are benefits compared to costs? We will summarise some results for London and Stockholm and then present our own estimates for Milan by using the same theoretical framework used in London.

To put the discussion in perspective, we will start by recalling the debate over and the main results on the London Congestion Charging Scheme cost-benefit estimates, we will then illustrate the results obtained for Stockholm, and finally, we will present our own estimates for Milan.

Summary of results for the London Congestion Charging Scheme

The London Congestion Charging Scheme (LCCS) has been the object of a number of cost-benefit analyses.

In October 2003, Transport for London published a report surveying the first six months of the charge (Transport for London, 2003). It showed that total costs amounted to €182 million and total social benefits to €252 million (Table 5). Total revenue from the charge was estimated to be €161 million plus the penalty payments equal to the large amount of €70 million. Hence, both benefits and charge revenues were larger than costs by a ratio of 1.4 and 1.3 respectively: a 'win-win' situation for the society at large and for the authority running the scheme. Road users also appear to be better off as a class, even not considering the benefits deriving from the use of the revenues: the total value of time savings €189 million, is higher than the total charge, €161 million, which is a surprising result.

Shaffer and Santos (2004b), in a preliminary investigation, found that the £5 LCCS charge was a reasonable approximate to the marginal cost pricing, implying that the actual charge, although only modestly differentiated over time and space, was close enough to the optimal toll, hence almost welfare maximising. They based their conclusion on an estimate of demand elasticity derived from the LCCS empirical evidence.

On the contrary, Prud'homme and Bocarejo (2005) estimated that the £5 charge was suboptimal and that the optimal charge would be £7.2, if the value of travel time savings (VTTS) is assumed to be €15.6 per hour. The finding is highly dependent upon the assumed VTTS. With the VTTS in use for the assessment of road infrastructure in France (€8.8 per hour), the charge is close to the optimal value. In fact, in 2005 the charge was actually increased to £8.

The Prud'homme and Bocarejo (2005) paper strongly challenges the conventional wisdom[6]. Using Transport for London data, they reach the conclusion (although tentative and preliminary in their own words) that the LCCS is an economic failure. They show that congestion costs in London were not high and unbearable, as frequently supposed, but relatively modest compared with the GDP of the area (0.1%) or in terms of the utility generated by trips (8%). The proceeds of the charge are estimated to be two-and-a-half times larger than congestion costs. And, more importantly, they find that the economic benefits of the scheme represent less than 60% of its implementation costs. Hence, in their own words: "The London congestion charge, which is a great technical and political success, seems to be an economic failure. It could be defined as mini Concorde." (Prud'homme and Bocarejo, 2005, abstract).

[6] As an example of conventional wisdom they quote Banister (2003) who states that "congestion charging in Central London is the most radical transport policy to have been proposed in the last 20 years and it represents a watershed in policy action".

Table 5 - Annual costs, benefits and revenues of the London congestion charging scheme (in millions of Euro)

		Transport for London (2003)	Prud'homme and Bocarejo (2005)
1	Transport for London administrative and other costs	7	
2	Scheme operation	126	139
3	Additional bus costs	28	7 (net)
4	Charge payer compliance costs	21	
5	Amortisation and interest of public sector costs		37
	Total costs	**182**	**183**
	Time savings to car/taxi		
6	Business	105	68
7	Private	56	
8	Commercial vehicles	28	
9	Bus passengers	28	31
10	Reliability benefits	14	
11	Reliability benefits to bus	14	5
12	Reductions in accidents	21	
13	Disbenefit to transferred traffic	-28	
	Total benefits	**252**	**104**
	Revenue	161	165
	Penalty payments	70	
	B/C ratio	1.4	0.6
	R/C ratio	1.3	0.9

Source: Mackie (2005, p. 289).

Mackie (2005), in a comment to Prud'homme and Bocarejo (2005), compares their calculations with those of Transport for London (2003) as illustrated in table 5 and underlines the main differences. The most important one is VTTS valuation. It amounts to €68 million according to Prud'homme and Bocarejo and to €189 million according to Transport for London (2003), adding up rows 6 to 8. Such a difference is largely explained by the value of time saving used: the one used by Prud'homme and Bocarejo is €15.6 per hour, while Transport for London uses several values for different travel types and purposes with an average of €36.1 per hour based on empirical evidence and guidelines published by the Department of Transport (WebTAG 3.5.6).

Not surprisingly, the VTTS appears crucial in the cost-benefit analysis of the charging scheme. As Mackie (2005. p. 288) puts it "Inevitably, just as with road scheme appraisal, one is looking at small changes in very large numbers over a wide area, against an ever changing world which, therefore, requires forecasting of the counterfactual. The scheme economics may depend heavily on a cloudy picture". Since traffic is highly differentiated, using a single VTTS may introduce errors into the calculation and a segmentation approach relative to travel purpose, mode, route, time, travel conditions and income appears necessary (Mackie et al., 2005; Santos and Bhakar, 2006). Contrary to Prud'homme and Bocarejo (2005), Transport for London (2003) makes use of different values considering whether we are dealing with cars, taxis, commercial vehicles or buses. As far as cars are concerned, a distinction is made between drivers and passengers, as well as between trip purposes (business, home-work, others). Regarding taxis, a distinction is made between driver and passenger, with the further distinction of trip purposes (work or others) (Transport for London, 2007, p. 10). In the case of Central London, the high value is probably justified since 40% of car kilometres and 50% of taxi trips are on employers' business.

Further critical aspects in using the VTTS, as discussed at length by Hensher e Goodwin (2004), are:

- the shape of the distribution of the VTTS: if it is skewed, it causes average values to overestimate toll revenues;
- the VTTS to be used: the one used for the car passengers might not be equal to that of the car driver;
- the valuation of the quality of the traffic environment as a mix of free flow and congested conditions: it represents a feature which is additional to the amount of travel time saved in using a toll road; and
- the choice of the mix of type of VTTS to be used (the ‘to or from’ determination) for changes, e.g., from an untolled to a tolled road or from private transport to public transport.

Another crucial aspect in evaluating a charging scheme is the treatment of the traffic outside the tolled area. If complementarity prevails, outer traffic will decrease together with the traffic entering the cordon, while if substitutability dominates, the contrary will happen. In the case of London the former case seems to apply (Santos and Bhakar, 2006; Transport for London, 2007).

A further aspect relates to the entity of benefits that are taken into account. Transport for London (2003), as opposed to Prud’homme and Bocarejo (2005), includes reductions in accidents, car users reliability benefits and the disbenefits to transferred traffic, but does not include improved urban quality.

A more recent evaluation is published in the study by Transport for London (2007). It comprises two evaluations, one for the £5 charge introduced in 2003 and one for the £8 charge introduced in 2005. It takes into account numerous impact types on:

- private users (car, van, and goods vehicles users) distinguishing between business users and individuals;
- bus passengers;
- trips avoided;
- society in terms of accidents, CO_2, NO_x and PM_{10} emissions;
- Transport for London\Government\boroughs, considering fuel duty, VAT, charge revenues, additional buses, infrastructure, parking revenues;
- private parking operators.

The general balance is positive to the tune of £71 million with the £5 charge and £99 million with the £8 charge. At the aggregate level, business users are the main winners thanks to the fact that they have a higher VTTS. Individuals travelling for personal purposes (including home-to-work trips) suffer a loss if they travel by car with the £5 charge, but enjoy a minor gain with the £8 charge. The gain is much larger if they travel by bus.

Lower social costs in terms of reduced accidents, harmful air emissions, and CO_2 emissions are relevant, but of smaller magnitude than travel time savings. Among them, the largest monetary gains are, perhaps unexpectedly, due to the decrease in the reported personal injury accidents. The low level of environmental benefits is in line with the relatively little emphasis on the environmental targets for the LCCS.

The local authorities gain under both charge levels, due to charge revenues being larger than the operating and implementation costs and the foregone taxes. Note that the operating and implementation costs estimated by Transport for London are lower than the ones reported by Prud’homme e Bocarejo (£109+£25=£134 million vs £172 million)

If one accepts the Transport for London (2007) estimates, the LCCS would result in a ‘win-win’ situation, as requested by Mackie (2004, p. 290) for the toll to be politically accepted. In fact, the LCCS appears to generate a net social benefit, both in general terms, and for each class of users. It also generates a government revenue which can be used to improve the transport system or reduce distortive taxation in other areas of the economy.

Obviously this optimistic scenario needs to be evaluated in detail. Unfortunately, this is neither simple, nor inexpensive. Furthermore, the results of the policy should be compared not only with the *ex-ante facto* situation, but with what would be the situation of the transport system had the policy not been implemented (taking, for example, into account the trend toward decreasing travel speed that occurred in the last decades in most major cities).

Lastly, the LCCS, like any other charging policy, is often implemented as part of a package of policies (road space management, increased number of buses, etc.). Hence, attention should be made not to attribute the effects of the package to any single part of it.

Summary of results for the Stockholm Congestion Charging Scheme

A cost-benefit analysis for Stockholm has been carried out by Eliasson (2008) based on observed, real-world data, rather than model-forecasted data. It refers to the Stockholm Congestion Charging Scheme trial implemented between 3 January and 31 July 2006. He reaches the conclusion that the scheme produces a net social benefit of a little of less than SEK700 million a year (around €80 million a year at the PPP conversion rate). The overall consumer surplus is negative, as opposed to London, but the value of the time gains is around 70% of the paid charges, which the author claims to be very high compared to most theoretical or model-based studies. This is mainly due to the significant traffic flows which do not cross the cordon and hence do not pay any charge and still gain from the congestion reduction.

Other effects – environmental effects and improved traffic safety – are valued to be equal to SEK211 million/year (around €23 million). Public finances enjoy a surplus deriving from the net revenues from the charges and increased revenues from public transport fares. Such a surplus is superior to the yearly costs due to necessary reinvestments and maintenance and to the annualized investment costs, although the author expresses some doubts about their 'real' amount.

Cost benefit analysis of the Milan Ecopass scheme (MES)

Based on a framework similar to the one used for London, we have assessed the costs and benefits generated by the MES. The assessment is based on data referring to the first eleven months of implementation. This implies that the observed situation does not incorporate medium to long-term adjustments. Moreover, many of the data that would be necessary for an accurate assessment are not available, or have not been collected or estimated yet. Despite these limitations, the assessment provides an overview of the effects of the MES and a rough estimate of whether the it is welfare improving or not. Moreover, it is useful to identify which user categories are the winners and the losers of the tolling scheme, to understand how the MES differs from other tolling schemes, and to pinpoint the data needed to perform a more accurate cost-benefit analysis.

In this assessment, one needs to define the special boundaries of the cost benefit analysis. We decided to take into account, contingent to data limitations, the impacts of the scheme for the society as a whole[7].

The main results are presented in Table 6. Details regarding the hypothesis and calculations are presented in the Appendix.

[7] Considering only the trips inside the toll cordon would be insufficient and could provide distorted results, as many of the impacts of the charging scheme take place outside the area (not to mention the costs that are at least spread over all the taxpayer of Milan). Considering the City of Milan would be deceivingly attractive. Although it corresponds to the boundaries of the administrative body which supports the implementation costs of the toll scheme, it is not satisfactory since the changes in the transport system spill-over the boundaries of the city jurisdiction.

Table 6 - Costs and benefits of Milan Ecopass (million € per year)

Category	Sub-category	Travel time and reliability	Operating costs	Other costs and services	Financial impacts (excluding penalties)	Total
Car, freight vehicles, taxi	Passenger vehicles	14.6	1.2	-4.7	-7.2	3.9
	Freight vehicles	2.2	0.2	-0.7	-5.2	-3.5
Buses	Passenger transportation	8.6				8.6
Deterred trips	Passenger vehicles		2.5	-2.7		-0.2
	Freight vehicles		0.4	-0.4		0.0
Social costs	Accidents			6.6		6.6
	CO_2			0.6		0.6
	NO_x and PM_{10}			1.8		1.8
Administrations (City adminstr., Region, State)	Fuel duty				-3.4	-3.4
	VAT				-1.4	-1.4
	Tolls		-7		12.4	5.4
	Infrastructure			-0.6		-0.6
	Parking revenues				-1.2	-1.2
Private parking	Net revenues				-0.8	-0.8
Total		25.4	-2.7	-0.1	-6.9	15.7

The MES is estimated to generate an annual net benefit of €15.7 million.

Transport users as a whole have a net gain equal to €8.4 million (= 3.9-3.5+8.6-0.2). The distribution of this net benefit among user categories is differentiated. Because of data limitations, we could distinguish only by type of vehicle (not by type of user, as in London), between passenger cars and freight vehicles. Passenger cars gain a net benefit of €3.7 million (net of deterred trips), mainly due to time savings (€14.6 million). Freight vehicles instead suffer a loss of €3.5 million. Bus users have a net benefit of €8.6 million.

These results are based on: 1) the estimation of time savings inside and outside the MES area as reported by AMMA (2008) and 2) the value of time assumed to be €20 per hour for both vehicle types. This assumption is based on an adaptation to the local context of London VTTS since no Italian evaluation is available. A sensitivity analysis shows that the overall net surplus reduces to zero when the VVTS is assumed to be equal to €2 per hour. In such a case, the passenger cars would lose €0.8 million and freight vehicles €5.6 million.

Note that the toll costs do not include the penalties. Official data on penalty revenues are not available, but according to informal sources they are higher than the toll revenues. If they are accounted for both passenger and freight vehicles incur in net losses.

Results regarding externalities also deserve attention. Net benefits amount to €9 million. Reduction of harmful emissions has been estimated by AMMA (2008) based on monthly data from the monitoring reports, and using the Copert model, a simulation model built within an EU research project, which computes emissions based on the emission standards of the vehicles and the traffic conditions. Conversion to monetary value has been made based on the recent European Guidelines (Maibach et al., 2007). Resulting values are €1.8million for the NO_x and PM_{10}. CO_2 reduction has been computed based on traffic reduction, using the same car emissions coefficients as in London. Reduction in accidents, the second most important source of social benefit, has been computed at €6.6

million based on the estimated reduction of accidents in the charging area. This result was already observed for London, but the share of benefits derived from a reduction of emissions is much higher in Milan (1/4) than in London (1/14), reflecting the differences in the charge design in the two cities.

As far as public finances are concerned, the net impact is €-4.8 million, quite different from the result gained in London by the public authorities. Official data on the MES implementation costs are not available yet, but, according to informal sources, total infrastructure costs amount to €7 million, while annual management costs are €0.6 million. They are much lower that the LCCS costs due to the fact that in Milan the charging area is smaller, the technological infrastructure was already set up for the enforcement of a Limited Traffic Area, and the MES is managed by existing local administration offices (AMMA, ATM) rather than an *ad hoc* private company as in London. Toll revenues, however, are much lower than in London, essentially due to the fact that in Milan the average toll (exempted vehicles included) is lower than in London.

Toll revenues are higher than the decrease in fuel duties, VAT and public parking revenues. As a result there is a net gain for the Milan administration, but a net loss for the public administration as a whole: the net impact, considering all administrative levels, is €-1.3 million, quite different from the result obtained in London by the public authorities.

The above figures, however, do not take into account penalty payments. In London they were 58% of the charge payments (Transport for London, 2007, p.4), while in Milan in 2008, according to informal sources, penalty payments have been as high as 3 times the toll revenues. If these informal sources are reliable, the total revenue of the MES, including penalties, would be equal to about €50 million, implying opposite conclusions to the one stated above, that is, a 'lose-win' situation, as transport users as a whole suffer a net loss, whereas the public finances gain a net benefit. It is uncertain whether the penalty payments realized in 2008 will keep on being so high in the next few years. There is no in-depth analysis about the causes of the violations. Lack of information might have played a role, especially for occasional users, who make up a large part of the observed entries in the MES area.

The loss to private parking companies is to be added to the picture.

Considering these preliminary results, and while waiting for the availability of more detailed data to achieve a more definite assessment, one can try to provide some indications on the dynamics that are taking place due to the introduction of the MES.

The relevant question is whether these dynamics will increase or reduce the net social benefit of the tolling scheme. With regard to this question, one of the most relevant mechanisms for the future of the MES is the incentive it provides to vehicle substitution. Some empirical results are already available to show that MES is bound to accelerate the natural rate of substitution of vehicles, with the implication that the number and share of vehicles that can enter the area free of charge will increase. This will reduce the toll revenues, increase congestion and reduce the time savings and reliability benefits. The effect on pollution is uncertain, and will combine three mechanisms: an improvement of the vehicles' environmental standards, an increase in the number of vehicles entering the area and, hence, an increase in congestion causing an increase in emissions. However, the end result is expected to be a decrease in pollution when compared with the pre-charge pattern as even in the extreme speculative case where all currently tolled vehicles were to be substituted with exempted vehicles, the traffic flow would return to its pre-charge pattern, but with reduced emissions.

These dynamics may require an adaptation of the tolling scheme. It is not unusual for pricing policies to change over time. The need to make them politically acceptable and to make them easy to use when they are introduced contributes to making their original design temporary. Second, the effects of the toll are not easily predictable, as many of the adjustment process are medium to long term. For these reasons, it is a good idea for an administration to adapt the tolling design to the evolution of land use and travel patterns in the cities where tolling is implemented. Eventually, given the magnitude of the financial flows that they can represent, there is a powerful motivation for local administration to modify (increase) the toll. Such changes already occurred in various situations, as illustrated by the change in price and tolled perimeter that took place in London in 2005.

Taking into account these mechanisms, one possible evolution of the toll scheme in Milan could take the form of a toll increase for different categories of vehicles, including the charging of currently uncharged categories. This would be consistent with the erosion of the parking fees, and the findings that most of the benefits are linked to reduced congestion and not to reduced pollution.

It is thus very likely that adjustments will be necessary to avoid that the socio-economic benefits of the toll disappearing.

5. Conclusions

The paper has firstly summarised the main conclusions of the literature regarding road pricing. Road pricing is a historically central theme for transport economics, promoted in particular by Pigou in the 1920's and by the Smeed Report in the 1960s. The theme showed decreasing interest until the recent revival thanks to its adoption in Singapore, and most of all in London and Stockholm and, at interurban level, in the United States. To the list of relevant applications, starting from January 2008, one should add Milan.

Theoretical analysis showed, on the one hand, the undisputed desirability of road pricing policy to reach an optimal level of congestion. It also showed the complexity of introducing such a policy when one takes into account the road network, the technical constraints, the implementation costs, the impossibility of charging the entire network and the potential failures in interconnected markets.

To the picture, one also has to add that the political acceptability is *a priori* low since the number of negatively affected users is high: firstly, the ones which are forced to cancel their trip or to change mode; secondly, the users who have a value of travel time saving lower than the toll; and finally those who do not pay the toll but are impacted by the increase in traffic due to transfers to other modes or to other times of the day. The only users who benefit from the toll are those who have a value of travel time savings higher than the toll. Consequently, it comes as no surprise that the politicians were rather reluctant in proposing road pricing schemes to their constituencies.

It should also be kept in mind that a road pricing scheme transfers resources from the private to the public operators, with no guarantee that these are used correctly and efficiently.

Therefore, it is intellectually very stimulating to understand why in some contexts, road pricing schemes have been applied and, often, with success.

The Milan application has very specific characteristics which have been described in detail in Section 3 and compared with those of other large cities such as London and Stockholm. It showed that the MES, more than congestion, focused on pollution, given the relevance of this issue in Milan. This led to the introduction of a highly differentiated toll considering emission standards but with little or no differentiation based on congestion. Moreover, the toll was set at a low average level.

The results obtained are nonetheless significant both regarding pollution, congestion and modal shift. They can be compared to those of London with a toll one third as high. A side effect is that the toll revenue is relatively modest, slightly less than expected by local authorities.

From the technical and political point of view, the complex and differentiated tariff structure could have caused acceptability and implementation problems. Overall, this appears not to have been the case to a considerable extent: the technical issues were dealt with successfully, and the implementation costs were kept at a very low level compared to the other European cases. Informal sources, however, state the penalty payments are strikingly high. Although their causes have not been explored yet, one may conceive them as signalling an implementation and communication issue.

Overall, however, one might claim that MES has been a technical and political success: it decreased congestion and pollution and still increased bus patronage. In fact, the MES, presented by the politicians as experimental for the year 2008, has recently been extended, still as being experimental, to the year 2009.

From the economist point of view, this does not suffice: it is necessary to compare costs with benefits and understand how they are distributed among the public and private actors that live and operate within the urban area. Making use of the valuation framework applied to the LCCS, in section 4 we produced a preliminary efficiency analysis of the MES. Given the recent introduction of the scheme and the scarcity of the available data (yet to be collected or estimated), the analyses should be considered as tentative and preliminary. However, we think it is interesting both from a methodological point of view and because it shows the critical aspects of the MES on which more attention should be paid.

The main result is that, not including the penalties, there are net benefits for passenger transport and negative ones for freight transport since the toll scheme imposes much of the burden on freight vehicles, which belong to the more polluting vehicle engine classes. If the penalties are considered, both types of transport incur a net loss.

The largest social benefits appear to be linked mostly to decreased congestion and a reduction in accidents more than to the environmental benefits, albeit that this was the claimed objective of the policy. As far as public finances are concerned, notwithstanding the low implementation costs, the modest toll revenue (not considering the penalty revenue which might be transitory) generates the need to collect further public funds to implement the planned mix of policies.

Furthermore, one has to fear that the effectiveness of the policy will be reduced in the medium run due to the increased substitution rate induced in the fleet of private vehicles. This will, on the one hand, help to reach the environmental goal, but on the other hand will lead to a decreased effectiveness of the policy instrument (on congestion) and to reduced toll revenues. Consequently, it would be advisable, in order to strengthen the effectiveness of the policy, to extend the area of application, as was done in London, or as applied in the first instance by Stockholm, with a tolled area 5 times larger than in Milan.

From the analytical point of view, the cost-benefit analysis of the MES would require better information and estimates regarding, ranked by relevance : a) the VTTS per trip purpose, per trip user, per income level, per origin\destination, b) the vehicle-kms by speed categories within and outside the area for the scenarios with and without the Ecopass; and c) the effects on localization of economic activity.

All in all, however, it seems to us that the introduction of the MES is a courageous policy. On the basis of the available data, it was both effective and efficient. One relevant issue is its effectiveness in the medium run. Politicians have, consequently, a difficult task: to continuously find a good balance between acceptability and efficiency. In so doing communication skills are important, however, they should be based, in our view, on an in-depth knowledge of the various economic aspects that we tried to focus on in this paper, in particular:

- the effects of an extension of the charging area;
- the effects of the rate of substitution of the vehicles;
- the effects of any change in the pricing scheme on the congestion levels prevailing outside the charging area.

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Appendix

Table A – Hypothesis, data and computations

A1 - Project data and initial conditions

84,988	Passengers vehicles/day	Number of cars entering the charging area (before Ecopass)
13,174	Freight vehicles/day	Number of freight vehicles entering the charging area (before Ecopass)
-7.2	M€/year	Tolls paid by passenger vehicles. Based on €11 million (total revenues Jan-nov 2008, AMMA, 2008, p.33) and adjusted according to the ratio of passenger vehicles (58%) entering the charging area.
-5.2	M€/year	Same as above for freight vehicles (42% of the vehicles entering the charging area).
-7	M€/year	Value of the operating costs of the toll system based on press information.
-0.6	M€/year	Value of the infrastructure costs based on press information (10 years lifetime assumed).
6.4	Ton/year	PM_{10} emissions produced by vehicles in the charging area during the charging time window in a year in the tolled area (AMMA, 2008)
72	Ton/year	NO_X emissions produced by vehicles in the charging area during the charging time window in a year in the tolled area (AMMA, 2008).

A2 - Effect on traffic and emissions

68,500	Passengers vehicles/day	Number of cars entering the charging area (AMMA March report), that is 87 % of total vehicles
10,500	Freight vehicles/day	Number of freight vehicles entering the charging area (AMMA March report), that is 13 % of total vehicles
58	%	Share of passenger vehicles
42	%	Share of freight vehicles
168,000	Hours/year	Time savings per year (20 days per month x 11,2 months) in the tolled area based on the daily time savings of 720 hours estimated by AMMA (2008, p.7)
571,200	Hours/year	Time savings per year (20 days per month x 11,2 months) in the tolled area based on the daily time savings of 2,550 hours estimated by AMMA (2008, p.7)
23	%	PM_{10} emission reduction in the charging area during the charging time window (AMMA, 2008).
20	%	NOx reduction in the charging area during the charging time window (AMMA, 2008).

A3 - Parameters for the evaluation

20	€/h per person	We assume a Value of Travel Time Savings per person equal to €20/hour on the bases of the values used for London (average VTTS, in London central area: £25/hour ; National average value : £18. Transport for London, 2007, p. 26).
5,700	€/T	Values of NOx emission for road, rail, waterways for Italy as reported in (Maibach, 2008, Table 13).
450,000 and 180,000	€/T	Values per tonne of PM_{10} emission for exhaust particles in big cities (€450,000) and for abrasion and re-suspension emissions (€58,000$_{2002}$ up to €180,000) as reported in (Maibach, 2008, p.51).

A4 - Socio economic costs and benefits

3.360.000	€/year	Total annual value of travel time savings inside the charging area
11.424.000	€/year	Total annual value of travel time savings outside the charging area,
2.026.234	€/year	Value of increased reliability. It is based on the hypothesis that the ratio of the increased reliability and of the value of travel time savings is similar to the ratio estimated for London, that is 13.7% (Transport for London, 2007 p. 11)
16.8	M€/year	Value of annual total time savings and increased reliability
14.6	M€/year	Value of total time savings and increased reliability for passenger vehicles estimated on the bases of the ratio of passenger/freight vehicles entering the charging area.
2.2	M€/year	Value of total time savings and increased reliability for freight vehicles estimated on the bases of the ratio of passenger/freight vehicles entering the charging area.
1.2	M€/year	Operating costs reduction for passenger vehicles based on the average operating costs reduction per vehicle estimated for London (€31/year) multiplied by the number of cars entering the charging area in Milan adjusted for : ▪ the ratio of average distance travelled per trip ▪ the difference of national fuel duty rates ▪ the difference in the number of months /year of operation of the toll
0.2	M€/year	Same as above for freight vehicles.
2.5	M€/year	Operating costs reduction for cancelled passenger trips based on the average annual operating costs reduction per vehicle not entering *ex post* in the London charging area (€260 per year per vehicle) multiplied by the number of passenger vehicles not entering *ex post* in the Milan charging area (17,447/day) and adjusted for the average distance travelled ratio ▪ the ratio of average distance travelled per trip ▪ the difference of national fuel duty rates ▪ the difference in the number of months /year of operation of the toll
0.4	M€/year	Same as above for freight vehicles not entering *ex post* in the Milan charging area (2,527/day) based on (€260 per year per vehicle).
4.7	M€/year	Transaction costs for cars based on the compliance costs estimated for London (Transport for London, 2007, p.13) adjusted for

		▪ the ratio of tolled vehicles charged in Milan and in London (20,200/316,000) ▪ the ratio passenger/freight vehicles entering the charging area in Milan.
0.7	M€/year	Same as above for freight vehicles
8.6	M€/year	Value of travel time savings for public transport users based on London estimates (43M€/year, Transport for London,2007, p.16) adjusted according to the ratio of the charging area in Milan (8km^2) and in London (40km^2). No specific information is available for Milan.
-2.7	M€/year	Value of the economic loss for passenger trips cancelled, estimated as the average charge (1,3€) divided by two (in application of Rule of Half) and multiplied by the reduction of passenger vehicles entering *ex post* the charging area.
-0.4	M€/year	Same as above for freight trips.
-3.4	M€/year	Value of the reduction of fuel duty revenues based on the value estimated for London (25 M€/year) adjusted for ▪ the ratio of the reduction of vehicles entering the charging areas in Milan and in London, ▪ the average distance travelled ratio ▪ the national fuel duty rates.
-1.4	M€/year	Value of the reduction of VAT revenues based on the value estimated for London (25 M€/year) adjusted for ▪ the ratio of the reduction of vehicles entering the charging area in Milan and in London ▪ the ratio of average trip distance.
-1.2	M€/year	Value of the decrease in public parking revenues based on the value estimated for London (15 M€/year) adjusted for : ▪ the ratio of the reduction of vehicles entering the charging area in Milan and in London ▪ a factor of ¼, which is assumed to represent the difference in parking supply and parking costs of Milan compared with London.
-0.8	M€/year	Same as above for private parking, based on the value estimated for London (10 M€/year).
12.4	M€/year	Value of annual toll revenues based on data reported for the first 11 months (AMMA, 2008, p.33).
6.6	M€/year	Value of cost related to the reductions in accidents calculated multiplying the number of personal injury accident decrease in Ecopass area as reported by AMMA and the costs per accident used for London (€85,000, Transport for London, p.17). As for London, only 50% of the personal injury costs related to the reductions in accidents are attributed to the Ecopass.
0.6	M€/year	Value of CO_2 emissions reduction based on London estimates and adjusted for the ratio of the reduction of vehicles entering the charging area in Milan and in London.
0.81	M€	Value of PM_{10} emission reduction inside the tolled area based on the values per tonne of PM_{10} emission for exhaust particles in big cities (€450,000) and for abrasion and re-suspension emissions (€58,000$_{2002}$ up to €180,000) as reported in (Maibach, 2008, p.51).
0.10	M€	Value of NOx emission reduction inside the tolled area.

1.83	M€	Value of PM_{10} and NOx emission reduction for Milan assuming that the emission reduction outside the Ecopass is equal to that of the Ecopass area.

M€ = million Euro