Title: “Urban road pricing: the experience of Milan”

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Abstract

Urban road pricing schemes have been designed in order to reduce externalities generated by traffic. Main impacts regard: time loss due to congestion, local pollution, noise; contribution to climate change caused by emissions of GHGs, pavement costs and road damages, increase in accidents risks, extra-fuel consumption, decrease in quality of life. Moreover road pricing schemes generate public revenues.

This paper analyzes the urban road pricing experience of the municipality of Milan, where the scheme is in operation as a “pollution charge” since 2007 and shifted to a “congestion charge” in 2012. The implementation of the schemes led to a significant reduction of traffic. A high value of elasticity of charge to traffic has been measured, confirming the effectiveness of this kind of economic instruments.

A comparison with the results of congestion charging in London and Stockholm is made, showing similar performances.

The results can be useful to design well targeted congestion charge schemes and to assess their efficacy.

JEL codes: H23, R41, R48, Q51, D12

1. The ratio of urban road charging

Negative externalities generated by mobility have been studied by economists since the nineteenth century (Newbery, 1988, 1990). Main categories of externalities concern environmental impacts, accidents and congestion.

Environmental impacts refer to local air quality degradation due to traffic emissions (causing health consequences, life expectancy reduction, real estate values reduction and damages to cultural heritage), noise (causing health consequences, stress, real estate values reduction), contribution to global climate change through CO₂ emissions.

Accidents involve material damages to vehicles, injuries and deaths to people.

Congestion is responsible for time loss, economic productivity decrease, extra fuel consumption and frustration.

Externalities can vary with respect to three main aspects: place where they are generated, time, type of vehicle (CE Delft, 2011).

Mobility in dense, highly populated and attractive areas, like city centres or main commuting roads, generates higher levels of congestion and other externalities than in scarcely populated and isolated areas.

Mobility in peak hours generates higher levels of congestion and other externalities than in daytime off-peak and night hours.
Private motorized traffic generates higher per capita emissions than public transportation and non-motorized modes. Trucks give a higher contribution to congestion than cars and motorbikes. Road users impose externalities (of variable value) to other road users and bear externalities (of variable value) from other road users. But road users also impose unilateral externalities to residents. Recent studies assess the relevance of health consequences on people resident in proximity of congested areas and roads (Invernizzi, 2011).

Estimates of externalities generated by mobility in urban areas vary European cities amounts to 55.4 €/year per person (CE Delft, 2008).

The adverse impact of traffic resulting in air pollution, noise, green house gas emissions, delays and traffic accidents causes in European cities an economic damage estimated at 100 billion euros each year, corresponding to about 1 per cent of the EU’s GDP (European Commission, 2007; Erdmenger-Frey, 2010).

Externalities can be treated in various ways. Economic instruments have proven particularly effective for this purpose. In the case of urban mobility, park pricing has been widely introduced; road pricing schemes only in a limited number of cases, but more and more cities are considering whether to adopt it. The European Commission (2011, 2013) is pushing in this direction. Actual road pricing schemes charging private vehicles have been introduced by municipal authorities mainly in an attempt to price the externalities caused by traffic. These externalities, created by the fact that road users tend to disregard the impact they cause on others, lead to a gap between private costs, as faced by the decision-maker, and social costs, as incurred by society at large; they prevent the market from reaching an efficient outcome. The introduction of a pricing scheme reduces these distortions leading to higher efficiency: journeys would occur only when benefits from driving outweigh the sum of costs, including all priced externalities (Newbery, 1988, 1990).

Charges are not set at the efficient level that equals the marginal social damage, providing a full internalization of externalities, following Pigouvian criteria (Pigou, 1920), mainly because of political and social reluctance in raising it up to the appropriate level. Moreover the amount of charges is the same for all social groups while a Pigouvian approach would require differentiated charges depending on the damage caused. Unfortunately in a world of imperfect information such degree of differentiation is unachievable, and introducing a flat tax or a differentiated but not personalized tax, would never lead to the efficient market solution, leading to second-best solutions.

In this sense road charges are not a panacea: as the economic theory of ‘second best’ suggests, they may cause distortions, as well as un wanted redistributive effects. A relevant topic is the destination of revenues from charges. Another is the need for dynamic variations in order to maintain the charge impacts: the effects can attenuate over time, either because drivers ‘get used to charges’ (‘acquaintance effect’), or because the freed-up road space is filled up by new groups of drivers, returning to the same congestion levels as before the charges (‘rebound effect’).

2. The experience of Milan^1

2.1. Scheme description

Milan is the capital of Lombardy, one of the wealthiest European regions. Population reaches 1.3 million, the Metropolitan area of 3 million, the wider industrial urbanized area, extending beyond Lombardy, 10 million. Traffic emissions are mainly responsible for poor air quality in Milan and Lombardy, reinforced by geo-climatic conditions adverse to particulate dispersion.

In January 2008, Milan introduced a cordon pricing scheme called “Ecopass”, with a “pollution charge” to be paid by most polluting vehicles to access the city center. Ecopass was a daily charge, operating 7.30 am to 7.30 pm Monday to Friday, proportional to vehicles’ PM10 tail emissions. The system started as a one year trial and was extended year by year.

In January 2012, Ecopass was replaced by a congestion charge scheme, called “Area C”, characterized by a flat charge.
The cordon toll area, common to both Ecopass and Area C, is 8 km² covering 4.5% of Milan historic urban district and 6% of urban population (90,000 people). The area attracts daily about 500,000 people.

The 43 toll entrance gates are monitored by an electronic system of cameras, reading the license plates of vehicles accessing the area.

The key assumption to design the Ecopass system was that the responsibility for emission externalities varies among vehicle categories.

Charges are described in Tab. 1.

<table>
<thead>
<tr>
<th>Class</th>
<th>Category of vehicle</th>
<th>Daily charge (€)</th>
<th>PM 10 Emission factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Low emission vehicles (LPG, methane, hybrid, electric)</td>
<td>free</td>
<td>≤ 10 mg/km</td>
</tr>
<tr>
<td>Class 2</td>
<td>Petrol Euro 3+ Diesel Euro 3+ with particulate filter installed before sale Diesel Euro 4 with particulate filter installed after sale</td>
<td>free</td>
<td>≤ 10 mg/km</td>
</tr>
<tr>
<td>Class 3</td>
<td>Petrol Euro 1 and Euro 2</td>
<td>€ 2</td>
<td>≤ 10 mg/km</td>
</tr>
<tr>
<td>Class 4</td>
<td>Petrol Euro 0 Diesel cars Euro 1, 2, 3 (and 4 without particulate filter) Diesel commercial vehicles Euro 4 without particulate filter Diesel commercial vehicles Euro 3</td>
<td>€ 5</td>
<td>&gt; 10 mg/km ≤ 100 mg/km</td>
</tr>
<tr>
<td>Class 5</td>
<td>Diesel cars Euro 0 Diesel commercial vehicles Euro 0, 1, 2</td>
<td>€ 10</td>
<td>&gt; 100 mg/km</td>
</tr>
</tbody>
</table>

Class 1 and 2 vehicles were exempt from the charge, class 3 vehicles charge was € 2, class 4 charge was € 5 and class 5 (in large majority commercial vehicles) charge was € 10.

Overall potentially charged vehicles amounted to 50% of total circulating vehicles (apart from exempt ones), but a temporary exemption was also set for diesel Euro 4 cars without particulate filter (covering about 10% of circulating vehicles), then extended over time. So actual chargeable vehicles in the base year, before implementing the charge, were 41.8%. Charged vehicles in the first month of implementation amounted to 25.3% of vehicles entering the area and progressively dropped to about 10% in 2011.

The original idea was that the rules could be made stricter dynamically, for example charging class 2. This never happened because of opposition by political parties.

The system allowed for a few exemptions, mainly public transportation vehicles, taxis, vehicles transporting disabled, and motorcycles.

Residents in the area had the option to buy yearly discounted permits. Other multiple discounted tickets could be bought, but showed scarcely popular.

In the first year the system proved very efficient in reducing congestion and emissions, thanks to both traffic reduction and substitution of older polluting vehicles with new cleaner ones. Then the effect on congestion and emissions progressively decreased because of car substitution.

As the local government was not willing to update the system, a citizens committee led by the first proponents of the charge, called MilanesiMuove², promoted a referendum, under the Municipality rules for public participation, with five questions one of which regarded the future development of Ecopass. The question asked for the evolution to a congestion charge: “Would you like to extend the charged zone to the whole city and to all vehicle categories to fund policies for sustainable mobility?”.
The voter turnout was 49%, a significant participation rate compared with similar experiences, and the majority (80%) was clearly in favour of the proposed extension. The vote happened in coincidence with new municipal elections in June 2011. As a result, the pollution charge “Ecopass” was replaced by the congestion charge “Area C” in the same central area. The new system entered into force in January 2012 for a trial period and turned permanent from April 2013. Under the Area C scheme, vehicles entering the area between 7:30 am and 7:30 pm have to pay a € 5 daily charge. Gasoline vehicles (category Euro 0) and Diesel vehicles (categories Euro 0, 1 and 2) are prohibited access to the area. Exemptions have been extended to utility vehicles. Commercial vehicles are allowed to a discounted ticket of € 3. More recently, another discounted ticket of € 3 has been allowed to cars parking in private parkings. Residents are allowed 40 free entrances per year after which any additional entrance will cost € 2. The charge payment must be done by midnight of the next day of access. A fine of about € 80 is applied to violators. Since 2014 a reduced fine is applied, if paid within 2 weeks. In March 2015, the new Sustainable Urban Mobility Plan of Milan (PUMS - Piano Urbano della Mobilità Sostenibile) has been approved, setting directions for the development of mobility in Milan for the next decade. The PUMS defines the revision of the congestion charge as a long-term horizon intervention, dependent on the realization of further improvements to accessibility to the area and to parking regulation controls (Comune di Milano, AMAT, 2015).

2.2. Impacts

Main results of the Ecopass and Area C schemes regard congestion reduction, public transport speed increase and air quality improvement. Main traffic results are summarized in Tab. 2.

Tab. 2: Road charges effects as reported by AMAT (2009, 2010, 2010b, 2012b)

<table>
<thead>
<tr>
<th>Year</th>
<th>Ecopass</th>
<th>Area C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2007 (4)</td>
<td>2008</td>
</tr>
<tr>
<td>Average number of vehicles entering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charged</td>
<td>90,582 (of which 77,540 passenger)</td>
<td>71,729 (of which 62,120 passenger)</td>
</tr>
<tr>
<td>Not charged</td>
<td>38,081</td>
<td>55,407</td>
</tr>
<tr>
<td>Average number of accesses (2)</td>
<td>159,328</td>
<td>136,136</td>
</tr>
<tr>
<td>Traffic inside Area. Variation compared to 2007 (3)</td>
<td>-20.8%</td>
<td>-19.8% for passenger cars</td>
</tr>
</tbody>
</table>

(1) Our estimate applying the same variation as number of accesses.
(2) Notice that the total number of entrances differs from the number of individual vehicles entering (they may enter more than once in the area).
(3) Excluding exempt vehicles.
(4) average of 10 days period 26-30 October and 12-16 November 2007.
(5) Provisional data
Traffic reduction dropped from -20.8% in the first year to -10.8% in 2011, because of car substitution of older charged vehicles with new uncharged vehicles. In 2010 the temporary exemption for Euro IV diesel vehicles was abolished, so traffic decreased. In 2012-2013 Area C substituted Ecopass and traffic decreased by about 38% with respect to base year 2007. The analysis of traffic results presented in the table stops at 2013. Data for 2014 have just been made available and for time reasons it was not possible to incorporate them in the analysis. They confirm that, during 2014, traffic continued to decrease with respect to 2011 (-29.2%). However, traffic slightly increased in comparison with 2013 (+ 1.3%) (AMAT, 2015).

Traffic composition in the tolled area improved as most polluting vehicles (the tolled classes 3-4-5) decreased by 70% by 2011 with respect to base year 2007 and the number of “ecological” vehicles (class 1) increased six fold. It is estimated that Ecopass reduced the area’s total PM10 emissions by 15% compared with the prior period without the Ecopass. PM10 emissions were reduced by a further 18% after the first year of the Area C system in 2012 compared with 2011 levels. A large effect on vehicles composition entering the Ecopass area happened since the first year. A 60.5% reduction of passenger chargeable vehicles occurred in the first year, as well as an impressive 47.5% reduction of commercial vehicles. The Ecopass long term effect is showed in Tab. 3.

Tab. 3.: Composition of total traffic entering Ecopass Area in 2011 (AMMA, 2012)

<table>
<thead>
<tr>
<th>Class</th>
<th>Reference pre-Ecopass</th>
<th>2011</th>
<th>Variation #</th>
<th>Variation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>1,194</td>
<td>7,348</td>
<td>6,154</td>
<td>515.4%</td>
</tr>
<tr>
<td>Class 2</td>
<td>51,307</td>
<td>62,020</td>
<td>10,713</td>
<td>20.9%</td>
</tr>
<tr>
<td>Class 3</td>
<td>11,939</td>
<td>2,353</td>
<td>-9,586</td>
<td>-80.3%</td>
</tr>
<tr>
<td>Class 4</td>
<td>23,167</td>
<td>8,709</td>
<td>-14,458</td>
<td>-62.4%</td>
</tr>
<tr>
<td>Class 5</td>
<td>2,973</td>
<td>367</td>
<td>-2,606</td>
<td>-87.7%</td>
</tr>
<tr>
<td>Total</td>
<td>90,580</td>
<td>80,797</td>
<td>-9,783</td>
<td>-10.8%</td>
</tr>
<tr>
<td>Total vehicles - paying classes</td>
<td>38,079</td>
<td>11,429</td>
<td>-26,650</td>
<td>-70.0%</td>
</tr>
</tbody>
</table>

With the passage to Area C, while more vehicles are chargeable, exemptions have increased. Only 40.7% of vehicles entering Area C are fully charged. This is confirmed by 2014 data. During 2014, the number of chargeable vehicles entering the area has slightly decreased (from 59.2% to 57.8% on total vehicles entering), whereas exempted and ecological vehicles have increased (ecological vehicles, in particular, have increased by 0.9% on total vehicles entering)(AMAT, 2015).

2.3. Costs and Revenues

Investment costs for Ecopass mainly regarded installation of cameras and system software: they amounted to 7 million €. The cost was limited thanks to sunk costs and in particular to the pre-existence of a technologically advanced traffic management centre. Operational costs of both Ecopass and Area C schemes amount to 14 million € per year, directly funded by the scheme’s revenues. Annual revenues decreased progressively from 12.1 million € in 2008 to 5.9 in 2011 in the Ecopass period. Concerning Area C and considering the period January-June 2012, revenues are equal to 11.2 million €. In subsequent years, Area C revenues amounted to about 30 million €.
An even higher amount of revenues refer to traffic sanctions of system violators. Revenues are mainly destined to increase in public transport service.

2.4. Elasticity to charge

Price elasticity can be measured in any point of the demand function with the following equation:

$$\varepsilon = \frac{\% \Delta Q}{\% \Delta p}$$

where \(Q\) is the quantity demanded and \(p\) is the price, computable in each point of the demand curve by taking the inverse of the slope of the demand function and multiplying it by \(p/\alpha\).

An alternative measure to point elasticity is arc-elasticity, which measures elasticity between two points on a curve, and is calculated as follows:

$$\varepsilon = \frac{\Delta Q}{\Delta p} \cdot \frac{(p_1 + p_2)/2}{(Q_1 + Q_2)/2}$$

Referring to \(Q\) as traffic and \(p\) as congestion charge, \(Q_t\) is traffic at time 1, after the introduction of the charge, \(Q_0\) is traffic at time 0 before the charge introduction (baseline), \(p_t\) is the charge amount and \(p_0\) is 0. If the charge has varied over time, elasticity can be measured in correspondence of the difference price variations, where \(p_t\) is the new charge amount and \(p_0\) the old charge amount.

In the case of cost increase and traffic reduction, the arc-elasticity value results slightly higher than the point elasticity value. In case of cost reductions and increased traffic, the arc-elasticity value results slightly lower.

Demand elasticity is always negative because of the inverse relation between quantity and price in the demand curve. We will consider its value in absolute terms.

To assess the contribution of a congestion charge to traffic reduction is quite complex. In order to take a decision about traveling, a rational traveler should consider the full cost of a trip, or at least all the components of the variable costs involved in a trip. So elasticity of traffic (demand) to the whole cost of a trip should be measured, where a congestion charge is just one of the components contributing to the cost.

In theory, travelers should be indifferent to which cost component of a trip varies. In this case we should expect that the elasticity value of traffic to the price of a single component, like gasoline, is the same as elasticity to any other component, like a congestion charge. In reality a congestion charge seems to weigh more than the increase in gasoline price or other costs in the perception of drivers. We expect elasticity values of traffic to congestion charges to be more similar to elasticity values of traffic to tolls.

In the road toll systems analysed in economic literature, the typical elasticity values range is between -0.20 and -0.50 (see Wuestefeld and Regan, 1981; White, 1984; Goodwin, 1992, 2004; Jones and Hervik, 1992; Harvey, 1994; Hirschman et al., 1995; Mauchan and Bonsall, 1995; Gifford and Talkington, 1996; Burris et al., 2001, 2003; Matas and Raymond, 2003). In some studies, elasticity was analysed in the short and the medium-long terms, showing evidence of a general trend towards a 20-50% increase (Odeck and Bråthen, 2008; Fonti, 2012).

In our specific analysis on elasticity of traffic to the Milan urban road charge scheme, some considerations are due.

It is necessary to define the variable indicating the quantity of traffic \(Q\). Available data for congestion charges can regard number of trips, number of entries or crossings in the cordon area, travelled kilometers and a congestion index. To use one or another is not always equivalent, they could involve different trends.

The contemporary presence of other policies and measures for traffic reduction can make it difficult to distinguish the effects attributable only to congestion charging.

Even the definition of a baseline quantity of traffic \(Q_0\) is difficult as a “standard day” does not exist. Traffic flows vary by months and day conditions (meteorology, road works, big events, etc.) Moreover it is almost impossible to isolate the effect of a congestion charge on traffic from other factors (economic activity, behavior, infrastructure).
Many factors also influence the real price of a trip (like inflation, gasoline price, other car use costs, public transport price, fiscal regulation on charge deductibility). Most factors are not relevant in the short term, while their influence grows in the long term. So it is possible to measure short- and long-term elasticities with a different degree of accuracy. The elasticity formulas introduced provide a rough measure, as they attribute the whole impact of traffic variation to the charge introduction or variation.

A more accurate measure of elasticity requires to consider all factors influencing the traffic variation in the period between time 0 and time 1, to describe a model where traffic \( Q \) is a dependent variable and considered factors — among which the congestion charge — are independent variables, and to measure the influence of each variable on traffic variation. This requires the availability of time series of traffic and considered independent variables. Even if some of these factors have been included in previous econometric analysis, a comprehensive framework is still lacking.

In this paper only a comparison of rough measurements of elasticities will be provided, with the risk of overestimating their values.

In the case of Milan, the difference in charge levels (depending on vehicle emission factors) determines a renunciation to the use of the private vehicle according to the corresponding charge level. The Ecopass charge categories have been selected following a criterion of potential to deter private vehicle use. The evaluation was based on a survey of Stated Preferences (SP) that took place in fall 2006.

Around 2,200 interviews were made to drivers at the 58 main entrance points of the city between 7 am and 9 pm in a weekday to assess the reaction of people to a proposed implementation of a road charge. For each proposed charge amount, the proposed alternatives were: (a) confirm the use of car and pay the charge, (b) park&ride outside the charged area, (c) public transport, (d) car pooling, (e) motorcycle or bicycle, (f) renounce the trip.

Three curves were derived, showing the will to continue to access the city by car in function of an extra cost, corresponding to:

- Obtained data (from interviews);
- A maximum Forecast (High);
- A minimum Forecast (Low).

Elasticity of traffic to cost of charge can be derived from the curves (see Fig. 1)\(^4\).
Fig. 1: Stated preferences in the renounce to use of cars as a function of level of charge in Milan (Croci, 2008)

An average elasticity of -0.40 is estimated by AMAT. AMAT used the subsample of drivers directed within the “Bastioni ring” to measure elasticity only for drivers entering what later on became the Ecopass area. The average elasticity drops to about -0.24.

Stated preferences were compared with revealed preferences obtained by real behaviours of car drivers after the first nine months of Ecopass, shown in Fig. 2.

Fig. 2: Observed behaviours in the renounce to use of cars as a function of level of charge in Milan (Croci, 2008)

A charge of €2 causes a renunciation by 27% of drivers to enter the Ecopass area. A charge of €5 a renunciation of 43%. For commercial vehicles, the renunciation rate is not relevant when the
charge amounts to €2; at €5 the renunciation is around 3%, reaching almost 9% when the charge is €10.

The deterrent effect resulted higher than expected. Renunciation to private car use rates were close to those obtained with the Stated Preferences survey, but it is also possible to observe renunciation among commercial heavy duty vehicles.

In this paper we provide a new measure of arc-elasticity of Ecopass for passenger cars referred to year 2011 (the last one for Ecopass) using more recent AMAT data reported in Tab. 1. We estimate a long term value of -0.66 for class 3 and -0.46 for class 4. It is not possible to provide a measure for class 5 as too few passenger cars fall into class 5. Values for commercial vehicles show lower values (between -0.15 and -0.17).

3. Comparison with other European urban road pricing schemes

The two main road pricing systems at city level, currently operating in Europe beyond Milan, are in London and in Stockholm. The three systems have some common as well as differentiated features, as shown in Tab. 4.

<table>
<thead>
<tr>
<th>Main features of the schemes</th>
<th>London</th>
<th>Stockholm</th>
<th>Milan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Starting year</strong></td>
<td>February 2003&lt;sup&gt;a&lt;/sup&gt;</td>
<td>January 2006 (7 months trial) Permanent from August 2007&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Pollution charge from January 2008 Congestion charge from January 2012 (formally a trial until April 2013)&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td>21 km&lt;sup&gt;z&lt;/sup&gt; (1.3% of the city surface) Western extension from February 2007 to January 2011 Metropolitan area 14 m inhab.&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30km&lt;sup&gt;z&lt;/sup&gt; (16% of the city surface). Stockholm County 1.9 m inhab.&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8 km&lt;sup&gt;z&lt;/sup&gt; (4.5% of the city surface) Metropolitan area 3 m inhab.&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Charge level</strong></td>
<td>£ 5 £ 8 from July 2005 £ 10 from January 2011 £ 11.50 (about € 14.50) from June 2014&lt;sup&gt;a&lt;/sup&gt;</td>
<td>SEK 20 (about € 2.16) during peak periods (7:30-8:30, 16:00-17:30), SEK 15 30 minutes before and after the peak periods and SEK 10 during the rest of the period 6:30-18:30. The total charge per day is capped at SEK 60.&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Pollution charge: proportional to vehicles’ emission class, of € 0, 2, 5 or 10 per day. Congestion charge: flat charge of € 5 per day.&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Application of charge</strong></td>
<td>Cordon pricing Daily fee Pay for entrance, exit, intra-area trips&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Cordon pricing Single passage fee (with daily limit) Pay for entrance and exit of the area&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Cordon pricing Daily fee Pay for entrance in the area&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Time of application</td>
<td>London</td>
<td>Stockholm</td>
<td>Milan</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
<td>-----------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>Weekdays, 7:00-18:00</td>
<td>Weekdays, 6:30-18:30</td>
<td>Weekdays, 7:30-19:30</td>
</tr>
<tr>
<td>Reduction of whole traffic with respect to reference year</td>
<td>London</td>
<td>Stockholm</td>
<td>Milan</td>
</tr>
<tr>
<td>-19% (2010)</td>
<td>-20% (2011)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congestion reduction</td>
<td>London</td>
<td>Stockholm</td>
<td>Milan</td>
</tr>
<tr>
<td>0% (2007)</td>
<td>-20% (2009)</td>
<td>-18% (2007)</td>
<td></td>
</tr>
<tr>
<td>Reduction of potentially chargeable traffic</td>
<td>London</td>
<td>Stockholm</td>
<td>Milan</td>
</tr>
<tr>
<td>-33% (2003)</td>
<td>-36% (2006)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>£8 charge drove to a 53% reduction of fully chargeable traffic in 2007</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs and revenues</td>
<td>London</td>
<td>Stockholm</td>
<td>Milan</td>
</tr>
<tr>
<td>Set up investment</td>
<td>160 m £ (203.5 m €)</td>
<td>1,900 m SEK (207.2 m €)</td>
<td>7 m € (excluding sunk costs)</td>
</tr>
<tr>
<td>Annual operating cost</td>
<td>90 m £ (114.4 m €)</td>
<td>220 m SEK (23.9 m €)</td>
<td>14 m €</td>
</tr>
<tr>
<td>Gross revenues per year (excluding fines)</td>
<td>from 138 m £ to 227 m £ in 2012 (from 175.5 m € to 288.6 m € in 2012)</td>
<td>763 m SEK (83.2 m €)</td>
<td>from 12 m € in 2008 to 5.9 m € in 2011 (Ecopass); 30 m € in 2012 (Area C)</td>
</tr>
<tr>
<td>Ratio operating costs / revenues</td>
<td>37% (in 2008; falling from initially 42%)</td>
<td>25% (in 2010 falling from initially 40%)</td>
<td>22% (falling from initially 40%)</td>
</tr>
</tbody>
</table>

After the first year (2008) Ecopass reduced chargeable passenger traffic on average by 60.5% and in the last year (2011) by 79.8% and 63.2%, respectively for a € 2 and € 5 charge.
| Elasticity values | 0.47\(^b\) | 0.70 in 2006 to 0.85 in 2009 onwards\(^a\) | 0.46 – 0.66 (for different classes of emissions of vehicles). (own estimation) |

**Tab 4. data sources:**


c. Transport for London (2008 b)  
d. http://www.stockholmsforsoket.se/  
e. Börjesson M. et al. (2012)  
f. http://www.comune.milano.it/portale/wps/portal/lut/p/c1/04_SB8K8xLLM9MSSzPy8xBz9CP0os_hA  
   c8OgAE8TlwMDJ2MzAyMP1zdfHw8_Y28jQ_1wkA6zeD9_o1A3E09DQwszV0MDlzMPEyefME8Dd  
   xdjLwBDuBooO_nkZ-bqI-  
   QnZ3m6KioCADDl1TNQ/dl2/d1/L2dJQSEvUUt3QS9ZOnB3LzFJQU01UJBNDlwT1RTMzAySEtMV  
   Es5TlnmMDA/!/?WCM_GLOBALCONTEXT=/wps/wcm/connect/ContentLibrary/elenco+siti+tematici/elenco+siti+tematici/area+c  

The main aim for all systems is reducing congestion. A secondary aim is to reduce air pollution (this was prevalent in the first phase in Milan). In all systems a flat rate is imposed. In the first phase in Milan, the charge was differentiated on the basis of PM10 emission factors. Charges are on daily basis in London and Milan and on number of accesses in Stockholm and operate only in the daytime.

In London circulation in the area is charged, in Milan access to the area is charged, in Stockholm crossing of the area is charged.

Similar technologies are in place, using cameras automatically recognizing car plates. All systems evolved through time in aspects like area, charge level, exemptions, and so on. In the case of Milan there was a major change in the structure of the scheme itself, shifting from a pollution charge to a congestion charge.

Political and public debate were relevant factors in setting up and decide permanency of the systems. In the cases of Stockholm and Milan, a referendum was a key factor to that purpose. The ratio operating costs / revenues fell from 42% to 37% for London, from 40% to 25% for Stockholm (Erdmenger C, Frey K, 2010) and from 40% to 22% for Milan.

In all cases a robust increase of public transportation was announced and implemented, and a substantial part of revenues are invested for sustainable mobility. In all cases the following trend effects, though in different measures, are demonstrated: traffic reduction and modal shift, mainly through an increase of passengers of public transport. A huge pollution emissions’ reduction happened in Milan and a significant one in Stockholm, while the effect was negligible in London. In Stockholm and Milan accidents reduction and speed increase in public transportation were experienced (in London a connection with accidents does not seem to exist, while bus speed decreased). In all cases, traffic reduction happened also in the area surrounding the charged one. No negative effects were registered on retail and real estate values in the area.

All cases show a high deterrent effect of the charge, as measured on travel behaviour changes referred to all traffic and in particular to chargeable traffic.

The demand elasticities of car travel in response to a congestion charge are considerably higher than the values in response to fuel costs in literature.\(^6\) Results and elasticity estimates reported in Table 4 show how urban congestion charging, though limited to pioneer experiences, is able to reduce congestion in an effective way.
4. Conclusions

In 2008 Milan introduced a cordon pricing scheme called “Ecopass”, with a pollution charge to be paid by most polluting vehicles to access the city center, proportional to vehicles’ PM10 tail emissions. In the first year the system proved very efficient in reducing congestion and car emissions, thanks to both traffic reduction and substitution of older polluting vehicles with new cleaner ones. Then the effect on congestion progressively decreased because of car substitution. Following the results of a public referendum regarding the future of the system, Ecopass was replaced in 2012 by a congestion charge named “Area C”, characterized by a flat charge for all vehicles.

Both schemes have delivered relevant results regarding congestion reduction, public transport speed increase, air quality improvement. Traffic reduction dropped from -20.8% in the first year of Ecopass to -10.8% in 2011, because of car substitution of older charged vehicles with new uncharged vehicles. In 2012 and 2013, Area C substituted Ecopass and traffic decreased by about 38% with respect to base year 2007.

As far as elasticity to charge is concerned, our own measures for Milan indicate an elasticity referred to the Ecopass system varying between -0.46 and -0.66. These values are systematically higher than elasticity to fuel price and even to traditional tolls for roads and bridges.

Bibliography


URL: [https://drive.google.com/folderview?id=0B1yqkoznVqZcm45RzR5MHFrX2s&usp=sharing](https://drive.google.com/folderview?id=0B1yqkoznVqZcm45RzR5MHFrX2s&usp=sharing)


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**Web sites**

http://tfl.gov.uk/modes/driving/congestion-charge

Endnotes

1 See the official web site: http://www.comune.milano.it/portale/wps/portal/lut/p/c1/04_SB8K8xLLM9MSSzPy8xBz9CP0os_hA c8OqAE8TlwMDJ2MzAyMPIzdfHw8_Y28jQ_1wka6zeD9_o1A3E09DQwszV0MDlzMEyefME8Dd xdjlWbDu0ooO_nkZ-bql- QnZ3m6KioCADL1TNQ/dl2/d1/L2djQsEvUUt3QS9QnB3LzZfQU01UBJNDlwT1RTMzAySEtMV Es5TTMwMDA!/?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/ContentLibrary/elenco+siti+tema tici/elenco+siti+tematici/area+c
See also ICLEI case study: www.iclei.org/casestudies

2 www.milanosimuove.it

3 This was part of a wider sample interviewed on travel behaviours of commuters, who are responsible for half of the traffic in town.

4 Elasticity is calculated per type of employment and per motivation of entrance in the Ecopass area. Results show that students fall in the high elasticity class (elasticity level: -1.1) while retired people, housewives and unemployed are medium-elastic (-0.56). Businessmen and entrepreneurs instead, as expected, fall into the low elasticity class (around -0.25). Similarly travel trips result being much less elastic than pleasure trips, with elasticity of -0.39 and -0.65 respectively.

5 Fonti (2012) provides slightly different values of elasticities: -0.6 for class 3 and -0.41 for class 4 in 2011. She also provides average elasticity values for the whole Ecopass period (2008-2011): -0.44 for class 3, -0.37 for class 4, -0.58 for class 5. Values show stability over time.

6 A charge represents a much larger change in cost than a 10% increase in fuel cost (which is normally considered in literature). For London a charge of £8 is equivalent to a 191% cost increase in fuel cost (TfL, 2008 b), considering average trips of 17 km.