FROM POLLUTION CHARGE TO CONGESTION CHARGE IN MILAN

Angelo Martino, TRT Trasporti e Territorio srl, Milan, Italy – martino@trt.it

Silvia Maffii, TRT Trasporti e Territorio srl, Milan, Italy – maffii@trt.it

Francesca Fermi, TRT Trasporti e Territorio srl, Milan, Italy – fermi@trt.it

Caterina Di Bartolo, TRT Trasporti e Territorio srl, Milan, Italy – dibartolo@trt.it

ABSTRACT

The paper presents two different road charging schemes (ECOPASS and Area C) that have been applied in the city of Milan in recent years. A comparison of the two schemes, focusing on their impacts, is carried out on the basis of the main relevant indicators and of official data released by the city administration in terms of private and commercial traffic levels, fleet composition, residents' trips and daily average emissions of main pollutants.
These results are then compared with the expected impacts of a mobility credit pricing system simulated with a system dynamic model applied in the same urban context, which might be seen as an alternative more equitable option.

Keywords: pollution charge, congestion charge, road pricing, evaluation, impacts, indicators, mobility credits.

INTRODUCTION

In recent years transport demand growth is putting greater and greater pressure on transport infrastructures. Consequently, and also for broader environmental and financial reasons, transport issues have risen sharply on the political agenda of most countries, especially in densely populated areas. Congestion is widely acknowledged as a critical issue regarding surface transport, especially in urban areas (DfT, 2004). Congestion causes significant costs to society: overall transport costs rise, polluting emissions increase and demand for infrastructure is artificially driven up. The social benefits of solving the congestion problem are therefore relevant.
In the 2011 White Paper on transport policy, charging for infrastructure is recognised as key instrument (together with taxes on fuel), for integrating infrastructure costs and external costs. Congestion pricing started to be advocated by transport economists and traffic planners as an efficient mean to reduce road congestion in metropolitan areas.

However, despite growing problems with urban congestion and urban air quality, and despite a consensus that investments in roads or public transit will not be sufficient to tackle these problems, congestion charging is met with public resistance in most cities.
While some cities have been reluctant to introduce congestion pricing, it has been successfully applied in London and Stockholm and, since the year 2012 also in Milan, Italy.

THE CONTEXT OF THE URBAN AREA OF MILAN AND ITS METROPOLITAN AREA

Recent mobility trends

Milan is the second-largest Italian city, with more than 1.3 million inhabitants, while its metropolitan area is one of Europe's largest with an estimated population of 3.3 million and a population density of more than 2,000 inhabitants/km². This area has also one of the highest European rates of car ownership of 0.6 cars per inhabitant. Milan daily users (persons entering the city for various purposes) are about 1 million and in total there are more than 5.2 million trips per day: 58% are trips made in the city area (internal mobility), while 42% are trips between the city and its surrounding metropolitan area (interchange mobility). Modal split differs a lot in relation to these two types of mobility: internal trips are made mostly by Public Transport[1] (PT) (41%) and by private cars (30%), followed by pedestrian mode (17%) and motorbikes and bicycle (6% each), while for interchange trips, cars are on top (59%), followed by PT (34%), motorbikes (6%) and bicycle (1%).

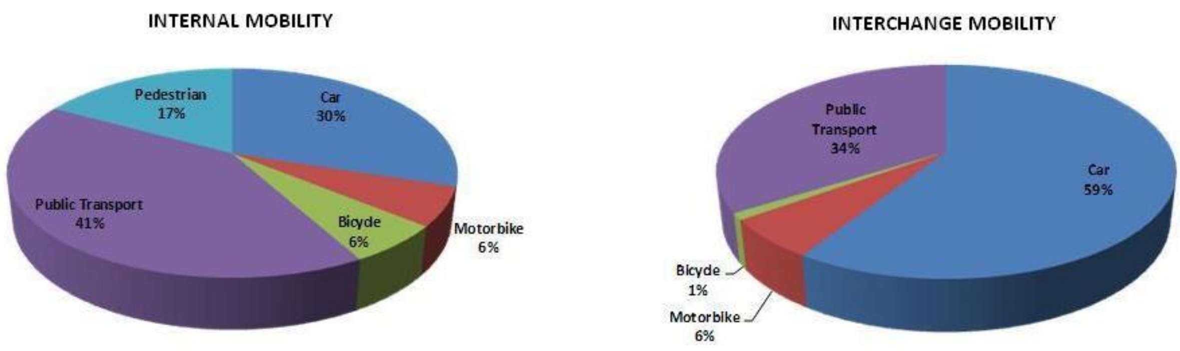

Figure 1 - Internal mobility and interchange mobility: the modal split – Source: (Campus et al., 2012)

The environment

The city ranks third amongst large European cities in atmospheric concentrations of particulate matter (PM), both in terms of average annual level and days of exceeding the EU limit (of 50 micrograms of PM10 per cubic meter). Historical data on PM10 concentration show that the diminishing trend registered until 2010 has partially inverted its direction and

[1] PT in Milan is made up of 3 underground lines (2 additional lines are under construction and planned to be operative by 2015), 17 tramways, 4 trolleybus lines and 80 urban bus lines.

PM10 concentrations started to grow again in 2011. Similar data are expected for 2012, confirming the evidence that this it is the trend, since the introduction of the EU PM threshold.

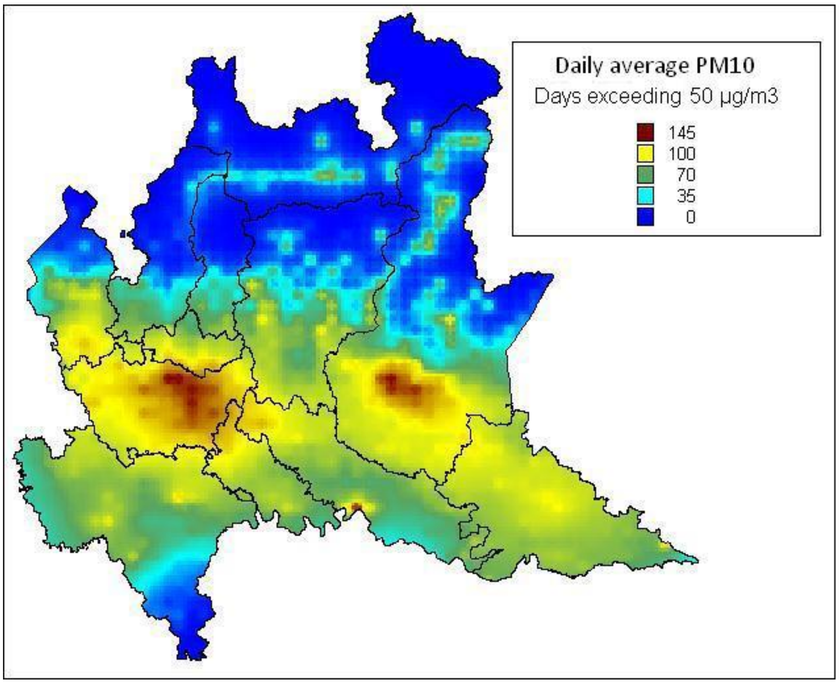

Figure 2 - Spatial distribution in Lombardy Region of number of days exceeding daily limit of PM10 in 2011,

Source: (Colombi et al., 2012)

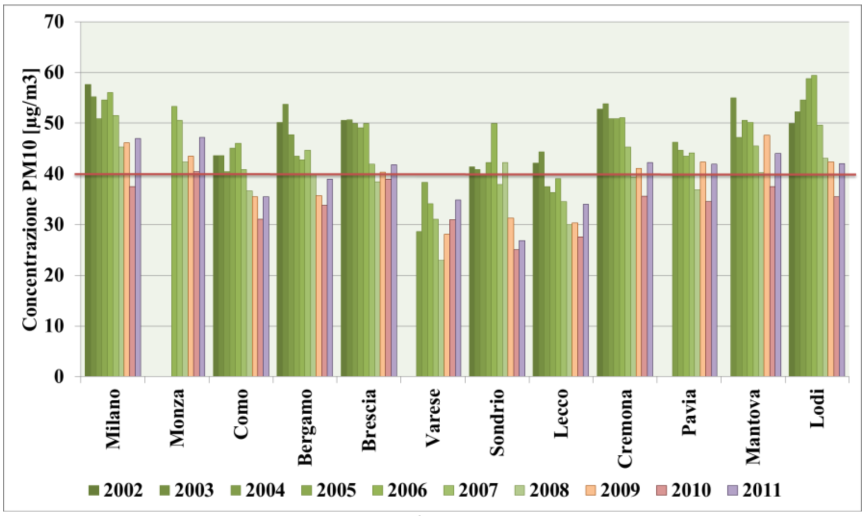

Figure 3 - Annual average concentration of PM10 [µg/m3] in Lombardy, trend 2002-2011

Source: (Colombi et al., 2012)

The table below summarizes the recent trends of major pollutant emissions[2], on a monthly basis, generated by vehicular traffic in the area "Cerchia dei Bastioni". The monthly period includes night time, non-working days and also days when vehicular circulation was interdicted.

Month	PM10 -Exhaust (Kg)		PM10 - Total (Kg)		NH3 (Kg)		NOx (Kg)		NO2 (Kg)		NMVOC		CO2 (ton)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
January	311	240	746	685	120	101	9548	9122	2459	2208	4010	4187	4103	4163
February	304	201	767	641	123	81	10335	9246	2558	2178	4205	3901	4333	4072
March	312	225	822	715	128	98	11269	10236	2766	2402	5324	4687	4760	4527
April	269	195	745	661	117	93	10504	9547	2512	2167	5731	5518	4400	4262
May	250	191	754	682	121	98	11152	9824	2602	2215	5447	5719	4620	4467
June	202	159	671	600	110	88	9943	8911	2248	2013	5600	4390	4256	3973
July	175	155	625	592	104	82	9257	8762	2114	1988	5554	4807	4036	3927
August	104	88	348	335	68	52	5704	5530	1234	1189	2298	2495	2182	2187
September	214	158	703	617	110	80	10037	9142	2337	2076	5608	5047	4435	4121
October	241	185	744	658	115	83	10549	9475	2494	2208	5146	5085	4614	4306
November	233	189	693	640	103	78	9486	9169	2293	2170	4388	4154	4255	4162
December	265	177	738	616	113	79	9562	8838	2392	2099	4055	3875	4397	4049
TOTAL	4890	4174	10366	9453	3342	3024	119356	109813	30019	26924	59376	55876	52401	50227

Figure 4 - Recent trends of pollutant emissions in the Cerchia dei Bastioni area in 2010 - 2011

Source: TRT elaboration on AMAT data

In order to reduce this increasing pressure on the environment, the city administration has started various actions (i.e. monitoring and regulating all pollutant emissions' sources, from residential heating plants, to vehicular traffic). In particular, vehicular traffic is acknowledged to be one of the most pollutant emissions' sources. All these consideration were at the basis of the decision to implement a road pricing scheme with the aim of tackling congestion and environmental issues.

FROM "ECOPASS" TO "AREA C": REASONS AND EFFECTS

The introduction of the ECOPASS system to reduce pollution

As outlined above, the city administration started to implement various measures to tackle with pressing pollution in the city. In 2007, for the first time, the city adopted a road pricing scheme (called ECOPASS): it was put in operation from January 2008. The main target of the scheme was to limit the frequent exceeding of PM10 threshold, thus improving the air quality and livability of the central area of the city. Based on the "polluter pays" principle, a charge was applied to each vehicle entering the 8 km²-wide[3] central area between 7:30 a.m. and 7:30 p.m. The charged area ("Cerchia dei Bastioni") has an outstanding attractiveness in relation to its great cultural heritage and to the presence of a great variety of business and commercial activities; moreover, it is a crucial area of convergence of several public transport lines and radial roads and it is intensively crossed by cross-cutting traffic flows. Last but not

[2] Emissions (PM10 exhaust - amount emitted at the end of the vehicle 's pipe (without considering the amount generated friction phenomena of brakes operation and rolling of tires -, PM10 total - total amount generated by traffic circulation, NH3, NOx, NO2, NMVOC-Non-Methane Volatile Organic Compound- and CO2) are estimated on the basis of registered entrances at the electronic gates of the inner area called "Cerchia dei Bastioni" and on the basis of the European public model COPERT4 (version n. 8.0 , October 2010). As input data, average daily temperature is inserted in the model as registered in the meteorological stations in the city.
[3] The charging area is relatively small compared to London (22 km² before 2005, and 40 km² after 2005) and Stockholm (30 km²), but is comparable to Singapore (7 km²).

least, this territorial area is the only one with an adequate level of PT supply and service, and so, it is the only one being able to eventually support a significant modal shift..
ECOPASS charges were structured in relation to the emission standard (EURO classes) of each vehicle. The greater the amount of pollutant emissions of the vehicle, the higher the fare applied to it.

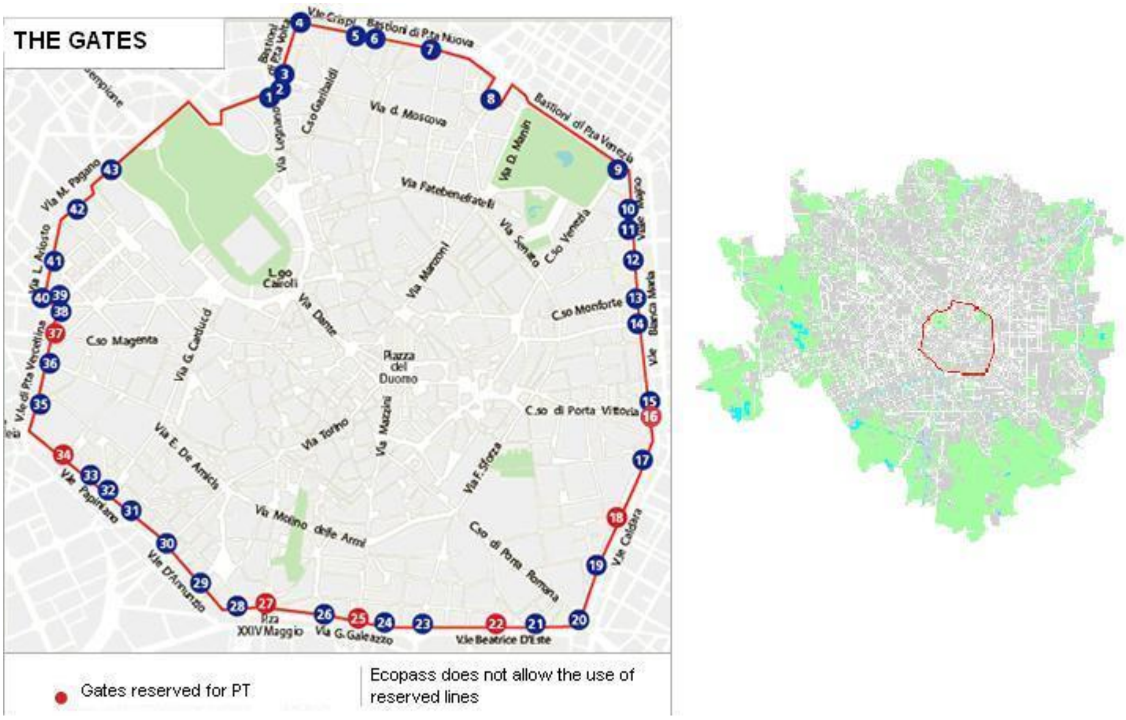

Figure 5 - The ECOPASS Area "Cerchia dei Bastioni" in the city of Milan - Source: www.comune.milano.it

The ECOPASS scheme was characterized by a relatively high level of charge differentiation: the highest fare (10€ comparable to the £8 charge used in London) was applied only to a limited number of vehicles.
Discounts available for frequent users: a 50% rebate for the first 50 entries per year and a 40% rebate for the subsequent 50 entries, although no rebate for entrances exceeding 100-per-year. Discounts were also available for the tolled area residents: 50€ for a yearly pass with a Class III vehicle, 125€ for a yearly pass with a Class IV vehicle, 250€ for a yearly pas with a Class V vehicle. LPG and CNG vehicles (which were still niche technologies) were exempted by the payment.
When the scheme was adopted, PM10 levels were mostly related to diesel vehicles' emissions: a EURO 4 diesel-powered vehicle (without the PM filter) had emission levels 40 times higher than a gasoline-powered vehicle of the same EURO standard. The situation partially changed over the years as traction technologies improved. Currently, diesel and gasoline traction emissions do not significantly differ, or at least not enough to justify different pollution charges fares.

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

Table 2 - Ecopass fees 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

Figure 6 – Vehicles' classes and fares in the ECOPASS scheme – Source: (Danielis et al., 2011)

The positive impacts of the ECOPASS scheme went diminishing over time

In three years of application, the ECOPASS scheme positively impacted on environment and congestion problems. Data calculated at the end of 2010 in comparison to pre-ECOPASS situation show the following variations: - 16.2% of commercial and private traffic during ECOPASS hours, + 7.9% in public transport operating speed and + 8.1% in public transport passengers, - 15% in daily average emissions of total PM10 and -30% in daily average emissions of exhaust PM10 in the ECOPASS area.

Overall the scheme proved to be very effective in achieving its main target of reducing air pollution and vehicular PM emissions. The "polluter pays" principle had a relevant structural impact on fleet's composition of vehicles entering the "Cerchia dei Bastioni" area: more pollutant vehicles strongly decreased, while newer vehicles, LPG and CNG vehicles substantially increased. Obviously this fleet renewal generated a rebound effect, causing a decrease in total amount of charged vehicles (and thus in municipality revenues), and an increase in congestion levels.
So, at the end of its "lifecycle" the ECOPASS scheme was stopped at the end of the year 2010 and then the Milan municipality studied different hypothesis for a new charging scheme to tackle congestion. In a referendum[4] held in June 2011, citizens voted in favour (80% YES, 20% NO) of the extension of a charged zone to the whole city and of charging all vehicles in order to raise funds to support policies for sustainable mobility and public transport improvements.

[4] Polling rate: 49%

The introduction of the AREA C congestion charge

The new road-charging scheme, “Area C”, was launched on January 2012 in the same central area of the “Cerchia dei Bastioni” as ECOPASS, using the existing 43 electronic gates system,

The scheme: objectives, area of application and fares

The overall goals of the congestion charge Area C are related to three different types of impacts. As far as the transport system, main aims are to decrease vehicular entrances to the central area, to reduce congestion (reducing travelling time of private transport, decreasing the demand for on-street parking and reducing road accidents), to improve public transport networks and finally to increase the share of sustainable transport modes. In relation to environment and society, most relevant targets are to reduce pollutant emissions caused by traffic, to reduce the healthy risks related to air pollution, to improve the quality and the attractiveness of the urban centre and to raise funds for the development of soft mobility infrastructures (cycle lanes, pedestrian zones, 30 km/h zones).

The area subject to congestion charge is approximately 4.5% of the whole Municipality. Residents are about 77,950 (42,300 families), with a residential density of 9,480 inhabitants/km^2, similar to the average density of the rest of the city. The area has an outstanding attractiveness, that determine, during the central daylight hours, an average of 39,000 persons/km^2, with a peak of almost 140,000 person/km^2 within the historic centre (between Duomo and San Babila). In the area “Cerchia dei Bastioni “ there are 295,704 employees, amounting to almost 37% of the total employees of the Municipality of Milan (Campus et al, 2012).

The Congestion Charge “Area C” started operating in Milan on January 16th 2012: the scheme is put in force every working day from 7:30 a.m. – 7:30 p.m. (with no charge on weekends and public holidays): in the latest revision, a further free-entrance slot has been implemented on Thursday evenings (cameras stop working at 6:00 p.m. instead of 7:30 p.m. in order to encourage week-day shopping activities).
A fare of 5 € is applied to all vehicles entering the gates[5]. Residents were granted with 40 entrances for free; from the 41st entrance onwards, further entrances are tolled 2 €. Two different fares apply to duty vehicles:

- 5 € for daily access (including 2 hours of free parking);
- 3 € for daily access only.

Some specific vehicles categories and types are exempted from the scheme[6], while entrance is forbidden for pre-EURO gasoline and pre-EURO, EURO1 and EURO2 diesel vehicles.

[5] Each ticket to enter “Area C” has daily time: the payment of an entrance covers all accesses made by the same vehicle during that day.
[6] Exemptions are valid for bicycles, mopeds, motorcycles, electric cars, vehicles displaying blue badges for disabled people, vehicles used for public utility services (police, ambulance, etc.), vehicles for public transport services, taxis, as well as hybrid, methane powered, LPG and biofuel cars (up to March 2013) are exempted from the charge.

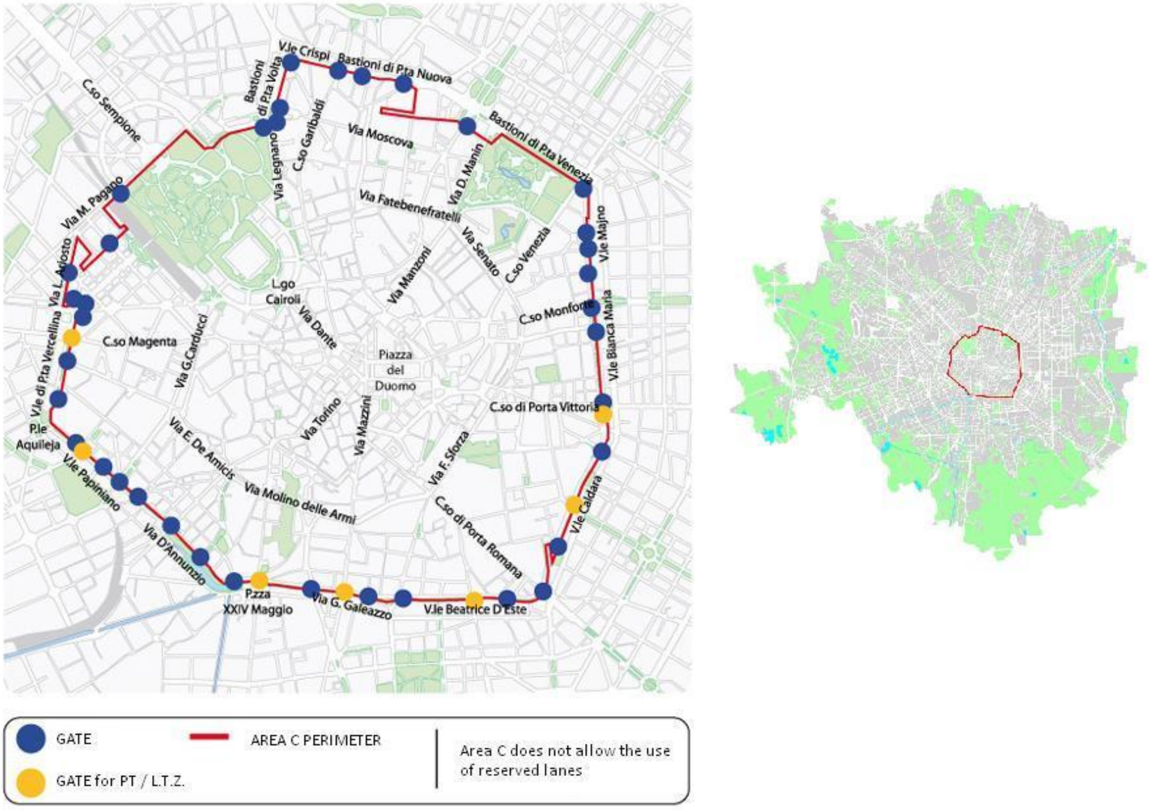

Figure 7 - The Area C Gates "Cerchia dei Bastioni" – Source: www.comune.milano.it

Vehicles entering Area C are detected (24h/24h) by a system of 43 electronic gates (of which 7 are reserved for public transport vehicles), equipped with ANPR[7] technology. The Environmental Mobility Agency of the Municipality (AMAT - Agenzia Milanese Mobilità Ambiente e Territorio) is the entity responsible for planning, implementing and monitoring the impacts of the Area C system. The system allows to analyse the transits of vehicles (also classifying them by type, by engine or by authorization) on a daily basis or on a 30 consecutive days period. These collected data are at the basis of the analysis of impacts and effects of Area C.

The results from the monitoring activity

According to the published results, referred to the first 6 months of operation from January to June 2012, the transport system seems to have benefitted from a traffic average reduction in Area C of about -34% (-46,133 vehicles entering the Cerchia dei Bastioni), and outside the area of about -7%. Importantly, results show a significant reduction in the most polluting vehicles: - 49% (- 2,400 vehicles entering every day the Area C) together with an increase in cleaner vehicles: +6.1% (from 9.6% to 16.6% of the total vehicles entering the Area C). The vehicle speed of surface PT has increased by +7% (bus) and +4.7% (tram) and car accidents have also diminished to -28%. On the environmental side, pollutants' emissions in the area

[7] Automatic Number Plate Recognition

have registered significant reductions: PM10 exhaust -19%; PM10 total -18%; NH_3 -31%; NO_x -10% and CO_2 -22%.

With respect to 2008, PM2.5 and PM10 have decreased, but what is most significant is the result related to the decrease in Black Carbon (BC)[8] percentage which indeed is the most dangerous component. Data on vehicles show that the fleet composition is gradually changing from the beginning of the scheme. Ecological[9] vehicles now account for 9% of total vehicles (+2%). Data on fleet composition are represented in the figures below, where annual entrances are sub-divided per vehicle category.

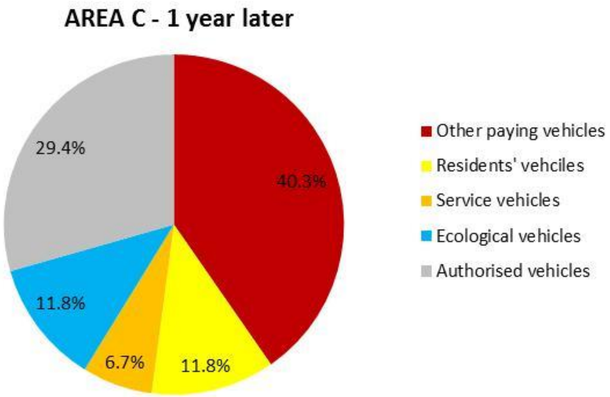

Figure 8 – Annual entrances sub-division per vehicle category – Source: Nuccio, D. (2012)

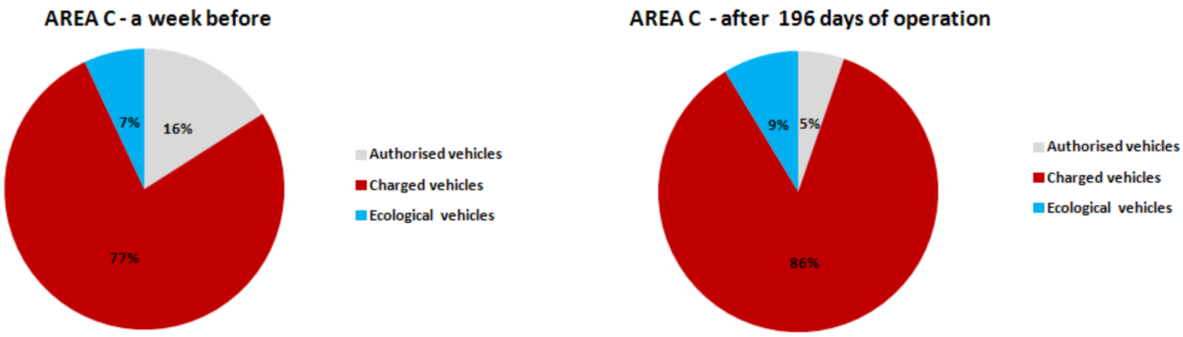

Figure 9 –Fleet composition[10] of entrances before and after Area C– Source: TRT elaboration on AMAT data

On average, each vehicle has entered the Area C 9.7 times a year. This average data however reveals a great variety of different situations: 35 days for authorized vehicles and residents, 15 for non-charged vehicles, and 6 days for charged vehicles. In general, the trend of occasional users is confirmed: 43.5% of vehicles entered AREAC only one day and 81.3%

---

8 Black Carbon (BC) is a carbonaceous aerosol. An aerosol is a suspension of fine solid particles or liquid droplets within a gas. BC particles2 strongly absorb sunlight and give soot its black colour. BC is produced both naturally and by human activities as a result of the incomplete combustion of fossil fuels, biofuels, and biomass. Primary sources include emissions from diesel engines, cook stoves, wood burning and forest fires.

9 Ecological vehicles (admitted for free) are electric vehicles. Until the end of the “test phase” also hybrid vehicles, CNG, LPG or bi-fuel (petrol/CNG or petrol/LPG) are included in this category.

10 In the first graph (situation a week before the start of the AREA C system from 9th to 13th January 2012, vehicles have been classified according to AREA C classification, though at the moment this classification was not yet in force.

has entered the area less than 10 days. Residents' registered vehicles are 32,586: up to 30th of September, 75% of residents had not finished yet their yearly amount of 40 free entrances and in particular 20% of residents made less than 5 entrances since January to June 2012.

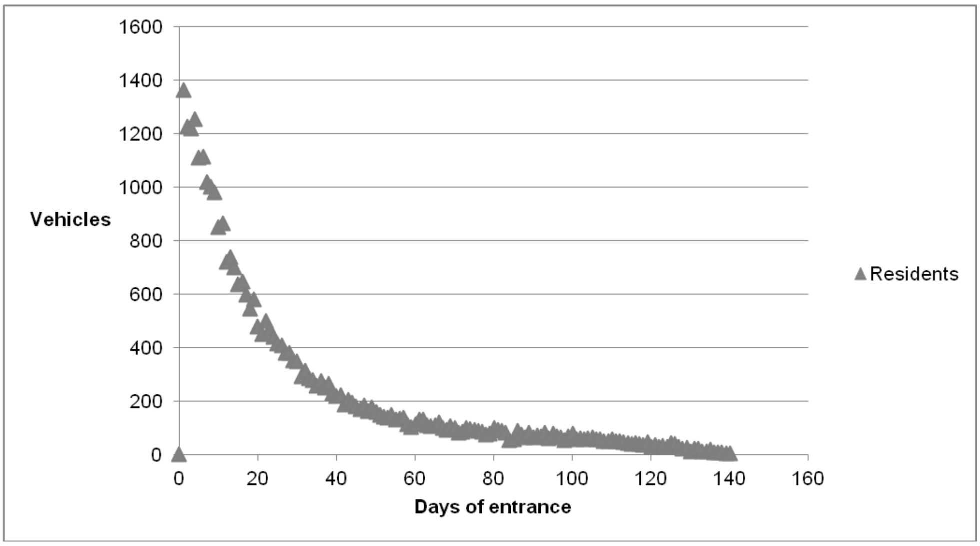

Figure 10 – Residents' entrances distribution – Source: TRT elaboration on AMAT data

Financial data at 30th June 2012 were as follows: revenues amounted at 11,176,621€ (while expected revenues at 31th Dec. 2012 were 23,526,156€) and costs amounted to 2,950,000€ (while expected costs at 31th Dec. 2012 were 6,482,111€).

ECOPASS and Area C: comparing results

As already mentioned before, the ECOPASS scheme was applied until the year 2011, while Area C started on January 2012 (and faced a stop of about 8 weeks in July and August due to some legal issues[11]) and is still active.

The comparison between the two schemes shows that in the first year of implementation the effectiveness of the two systems was comparable. On the contrary, due to the fact that the ECOPASS scheme impact weakened through time, there is a remarkable difference of their results when comparing among the last year of ECOPASS and the first year of Area C.

[11] On 26th of July the AREA C system was suspended as effect of a parking structure's petition against the AREA C scheme. The complaint was about the unequal penalisation suffered from parking structures that are located on AREA C boundaries, thus obliging parking users to pay for the ticket. Thanks to an agreement between the Municipality and two private parking structures, AREA C was put in operation again on 14th of September 2012 with reduced fares (3€) applied for entrance + parking for at least 4 hours.

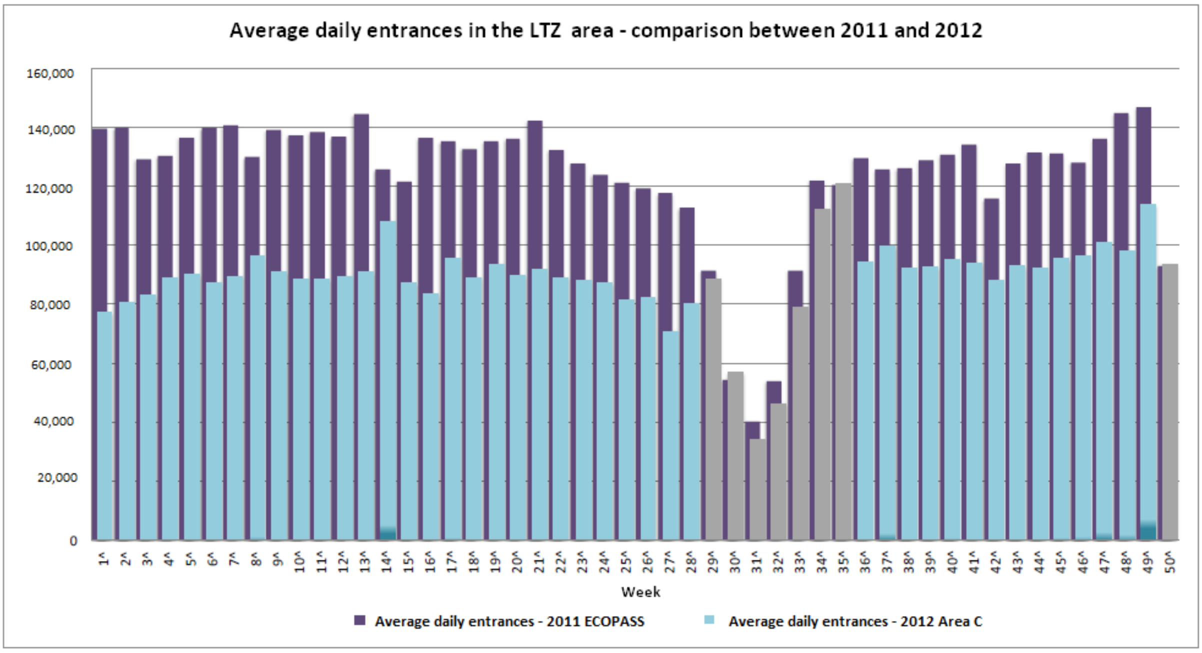

Figure 11 – Average daily entrances in LTZ per week – Comparison 2011-2012 – Source: Nuccio D. (2012)

Data reveal that a consistent reduction in traffic levels (-31% in comparison with ECOPASS 2011) can be observed during the operation of Area C. Subdividing the 50 weeks period of Area C implementation into two periods, also here a reduction of its impact can be observed: in the first period (28 weeks) traffic reduction amounts to a range of 35%-45%, while in the second period (from mid-September) traffic reduction can be calculated in -27%.

Table 1– Traffic and transport data on comparison : ECOPASS and Area C

Month	PM10 -Exhaust (Kg)					PM10 - Total (Kg)					NH3 (Kg)			
	2008	2010	2011	2012		2008	2010	2011	2012		2008	2010	2011	2012
October	9.8	7.8	6.0	5.9	October	23.5	24.0	21.2	19.5	October	4.9	3.7	2.7	1.9
November	11	7.8	6.3	5.7	November	24.0	23.1	21.3	18.7	November	5.1	3.4	2.6	1.9
Month	NO2 (Kg)					NMVOC					CO2 (ton)			
	2008	2010	2011	2012		2008	2010	2011	2012		2008	2010	2011	2012
October	n.a	80.5	71.2	60.0	October	n.a	166.0	164.0	154.4	October	122.0	148.8	138.9	111.8
November	n.a	76.4	72.3	58.6	November	n.a	146.3	138.5	130.9	November	123.0	141.8	138.7	108.4
Month	NOx (Kg)													
	2008	2010	2011	2012										
October	400.0	340.3	305.6	278.7										
November	390.0	316.2	305.6	262.4										

Source: TRT elaboration on AMAT data

The analysis of data on pollutants' emissions shows that between 2008 and 2012 average daily emissions (PM10 exhaust, PM10 total, NH_3 and NMVOC) have decreased steadily and significantly. For CO_2 the trend is partially different: as shown in the following figure, CO_2 average daily emissions have increased from 2008 to 2011. The first reduction can be registered only during the year 2012 when Area C has been implemented.

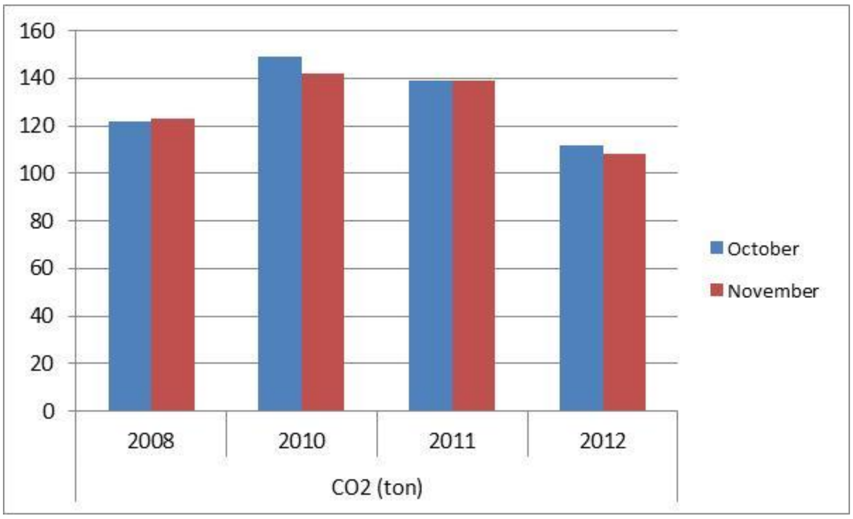

Figure 12 – Average daily CO2 emission (ton) per month – 2008-2012– Source: TRT elaboration on AMAT data

To conclude it is worth to notice that the overall effects registered on traffic levels and emissions' reduction attributed to the introduction of the Area C scheme, should be carefully considered in relation to the general downwards trend affecting the sector of mobility and transport. The impending economic crisis has invested almost all sectors, without no exclusion for the mobility and transport sector. International oil price fluctuations play a key role in driving consumers' choices towards one mode rather than one other.

Six lines are represented:

- Change €/$;
- International oil price (Europe Brent Spot Price FOB);
- Gasoline - Italy Industrial Price;
- Gasoline - International price of refined products (Platts CIF price-MED);
- Diesel - Italy Industrial Price;
- Diesel - International price of refined products (Platts CIF price-MED).

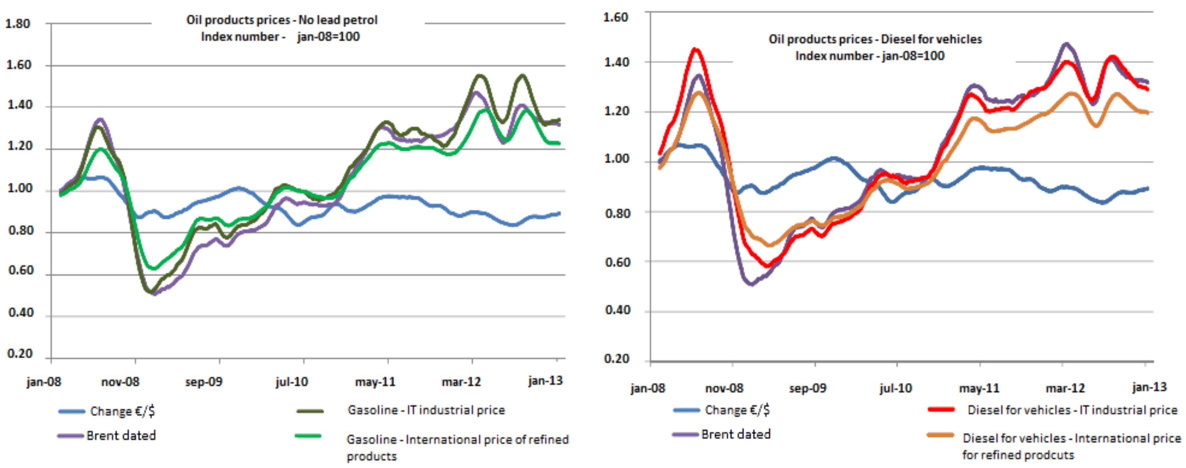

Figure 13 –Price fluctuation for fuels between 2008-2013 in Italy - Source: Min. Sviluppo Economico (2013)

The steady increase in oil price that has been registered from 2008 up to now, has forced more and more citizens to shift from the private mode to other more affordable modes (PT or bicycle). The following two graphs, represent the oil price fluctuation that has been registered in Italy from 2008 to 2012 (for petrol and diesel): main indicators are based 100 at year 2008.

Focusing on the national context, last available data on mobility and transport in Italy (AUDIMOB, 2011) confirm the decreasing trend of mobility in the last years in Italy. Main indicators for 2011 (in comparison with 2010), show – 4.5% of reduction in pax/km, -14% of total amount of trips and a reduction by 2.8% in the mobility rate.

A MODELLING TOOL FOR TESTING ALTERNATIVE ROAD CHARGING SCHEMES

The impacts of the application of the ECOPASS and Area C road pricing systems suggest that further steps could be done in the direction of a more equitable option.
In fact, one of the major criticism raised against road charging policies concerns the undesirable equity impacts on low income population groups, especially when transport alternatives (e.g. public transportation) are missing or poor. In this sense, the mobility credits approach can provide a response, based on the assignment of an initial endowment of mobility rights to all citizens. Thanks to the possibility of trading unused mobility credits, low mobility segments of population (often correspondent to lower income inhabitants) can receive a compensation. In addition, the cost of additional mobility credits can be differentiated according to several dimensions (i.e. trip length, quality of public transport from zone of residence, etc.), in order to take into account the availability of effective alternative modes.
Actually, since the Area C congestion charge already envisages an endowment of free entrances to residents in the charged area, it can be considered a first step toward the application of the "mobility credits" principle.
This concept is described with more details in the following paragraphs, together with an estimation of the main impacts of alternative mobility credits scenarios resulting from the application of a modelling tool developed in this context.

An alternative approach: the concept of mobility credits[12]

The application of mobility credits has been initially proposed by Viegas (2001) in order to improve the equity and acceptability of road charging schemes aimed primarily at addressing congestion. It is the application of a wider concept, i.e. the application of transferable permits. This concept combines economic incentives and regulation by quantity. According to Raux (2008): transferable permits cover a variety of instruments that range from the introduction of flexibility into traditional regulation to the organization of competitive markets for permits.

[12] The concept of the "Mobility Credits" was originally developed with the support of Fondazione Italiana Accenture (owner of the trademark "Crediti di Mobilita"TM). The concept was further explored and analysed in the DEMOCRITOS research project (http://www.democritos.ipacv.ro/).

These instruments have in common: the setting of quantified physical constraints in the form of obligations, permits, credits or rights allocated to target groups of agents consuming scarce resources; and the permission granted to the agents to transfer these quotas between activities, products or places (offsetting), periods of time (banking) or to other agents (trading, hence “tradable permits”).

The use of transferable (and specifically tradable permits) has been experienced in non-transport contexts like fisheries and construction and it is rooted in the theoretical concept of rights allocation introduced by Coase.

The main steps for applying this system in the transport sector are the following (as shown in figure below):

- the identification of the sustainable level of mobility load on the urban network;
- the definition of the “budget” of urban mobility for the mobility individuals, distributing the sustainable mobility load among all the individuals: the mobility credits are the measure of this “budget”;
- the creation of pricing exchange mechanisms between the individuals, in order to allow the system to reach the equilibrium which satisfies all mobility needs;
- the definition of rules for consuming the credits.

The level of sustainable mobility load has to be defined from the local administration, according to the policies which application is pursue (e.g. congestion sustainability, environmental sustainability, energy consumption sustainability, etc.). Depending on their mobility habits, people could have needs higher or lower than the common mobility budget assigned: as a reaction, exchange mechanisms develop in the system, regulated through a sort of bank where credits are bought by the individuals or returned with monetary benefit in case they have been unused.

The definition of the tariff for buying additional credits and its differentiation is the most important aspect of the mobility credit system, because it leads to the policy measures which the Administration pursues.

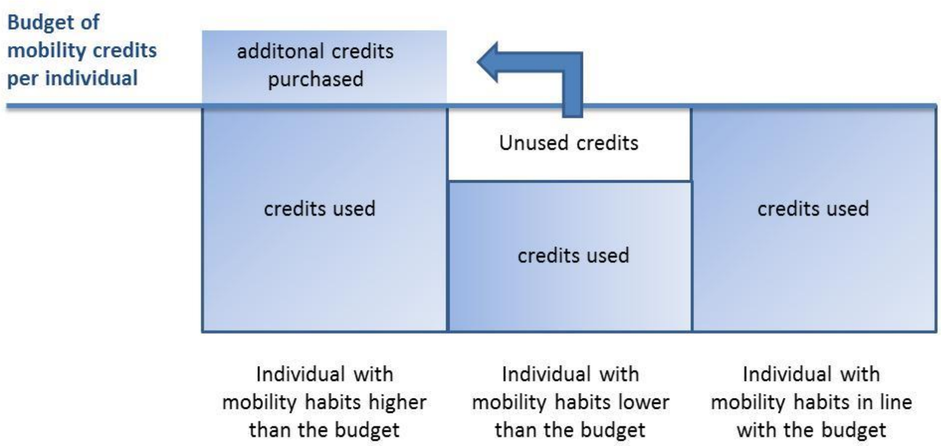

Figure 14 –Reaction of individuals in front of the mobility credits system – Source: Democritos Project (2011).

The modelling tool

Within the DEMOCRITOS project specific tools have been developed to analyse the impacts at urban level of the “Mobility Credits” system. The Mobility Credits model is a System

Dynamics application implemented in VENSIM®. The choice of setting up a System Dynamics model has two main justifications. First, this methodology is capable of modelling feedback effects and simulating adaptation over time rather than just provide an estimation of an equilibrium at a given time point. Second, the structure of a System Dynamics application is inherently open to further developments, addition of new modules, etc.

For the purpose of this paper, the Mobility Credits model has been applied to the urban area of Milan: the implementation of the policy is assumed starting at the year 2012, while the tool runs from 2006 to 2020 on a quarterly basis.

The model is necessarily a synthetic representation of the real world. A number of assumptions were required to translate the complexity of the mobility and of the policy into a workable tool. The analysis is based on the total number of trips generated from each zone of the Lombardia region and directed to the urban area of Milan where the mobility credit policy (or a cordon pricing policy) is applied. Therefore, since the model does not include a representation of the road network, only trips generated in or destined to Milan are modelled, whereas mobility in transit through the urban area is excluded.

The model simulates the expected impacts of mobility credits (or pricing) schemes on private transport demand (in terms of trips suppressed, shifted to other mode, etc.) as well as the impact on the economic budget of households (expenditure/revenues related to credits purchase/sale) and the revenues for the local authority.

The pricing policy is simulated by setting the area of application and the price for purchasing mobility credits (according to the car trips characteristics), as well as by defining the number of free credits available for each individual in age (i.e. for residents in the area). The price of mobility credits can be differentiated according to several dimensions, like vehicle type, trip length, day of the week, time of the day, etc.

Changes in travel behaviours of individuals are produced on the basis of a large segmentation of passenger demand (employment and income level of individual, trip purpose): in fact, people with different characteristics and trip purpose react differently in front of a pricing policy. The reactions are simulated in terms of variations with respect to their reference mobility pattern, taking into account the following alternative options:

- consuming the mobility credits available for free (for residents in the area only),
- suppressing trips, on the basis of a maximum monetary budget affordable by population group,
- modify the mode choice, i.e. shifting to public transport,
- purchasing credits to access by car the area.

The following figure summarises the structure of the model to simulate the impacts of a pricing policy.

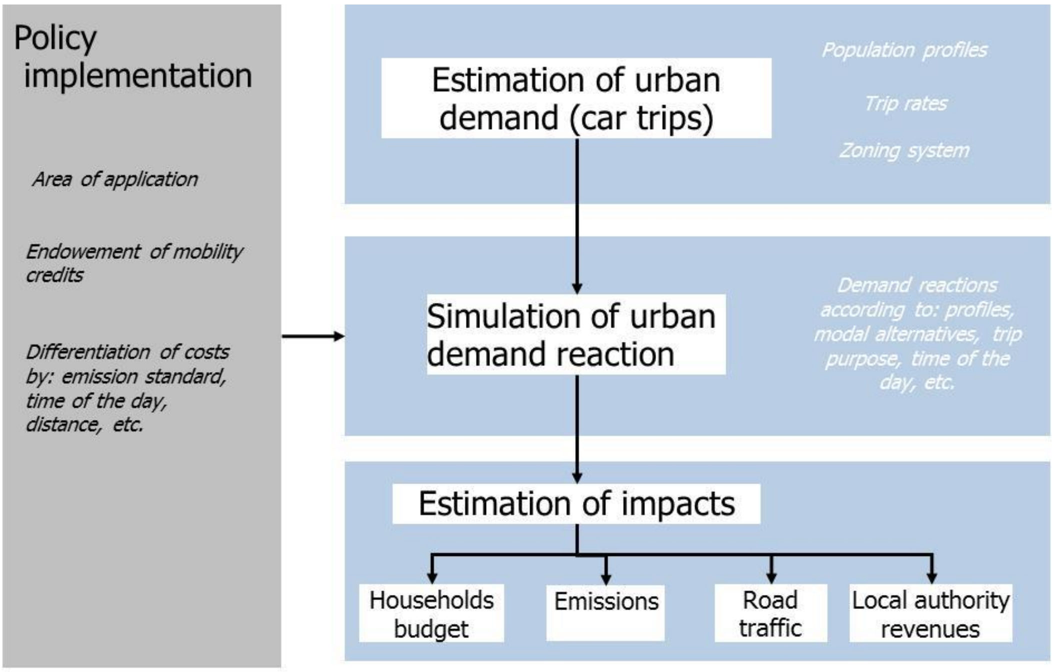

Figure 15 –Structure of the Mobility Credit model – Source: TRT

The modelling simulation of "Area C" and other mobility credits scenarios

The Mobility Credit model applied to the urban area of Milan allows to simulate the current structure of the Area C congestion charge as well as additional scenarios enlarging the area of application and the concept of the Mobility Credits.

In the model, the Area C congestion charge has been simulated using the following assumptions:

- the identification of the central zone of the city, where the congestion charge applies,
- the cost of 5 € per car to access the area,
- the distribution of 40 credits per year to the residents in the area C,
- the application of the congestion charge from Monday to Friday during the whole day.

The alternatives mobility credits scenarios tested with the tool have been applied to a larger area, including the whole Municipality of Milan. In a first scenario (Mc1), the same scheme of the Area C congestion charge has been implemented; in a second version (Mc2), a reduced charge is applied, to take into account that a larger area is involved and to reduce the expenditure for the individuals. In a third scenario (Mc3), based on the same approach of Mc1, the charge has been differentiated with a distance-based approach, decreasing with the distance travelled (shorter trips pay more), combined with an evaluation of the availability of public transport services (i.e. where there is no or poor alternative in terms of public transport, the charge is significantly reduced).

Table 2– Modelling assumptions of scenarios simulated

Modelling assumptions	Area C	Credits Mc1	Credits Mc2	Credits Mc3
Area of application	**City Center**	**Municipality of Milan**	**Municipality of Milan**	**Municipality of Milan**
Charge for access and travel within the area (euro/vehicle)	**5**	**5**	**2**	**5**
Credits distributed to residents in the area of application (#/quarter)	**10**	**10**	**10**	**10**
Temporal application	**Monday to Friday, whole day**	**Monday to Friday, whole day**	**Monday to Friday, whole day**	**Monday to Friday, whole day**
Charge segmentation	**none**	**none**	**none**	**Distance-based and availability of public transport services**

Source: TRT

The model computes a number of indicators that illustrate the overall impacts of the policy in different domains: transport, economy, environment. The following figures and tables summarise some results obtained from the simulation of the charging schemes described above.

In general terms, the quantitative scenarios simulated show that both the Area C congestion charge and the Mobility credits scenarios are valid instruments, with different levels of effectiveness, to reduce private transport demand in the area of interest, Looking at the results for the Area C congestion charge, the effective reduction is obviously related to mobility toward the city centre (-27%), while the impact at municipality level is a reduction of about 4%. As expected, the scenarios applied to the whole municipality area with a ‘flat’ charge obtain stronger results: even with a reduced charge (Mc2) may produce a decrease of private mobility in the municipality area of about 13%. The scenario differentiated according to public transport services comes up with a lower reduction (about -8%), but the impact at municipality level is still higher than in the Area C scenario.

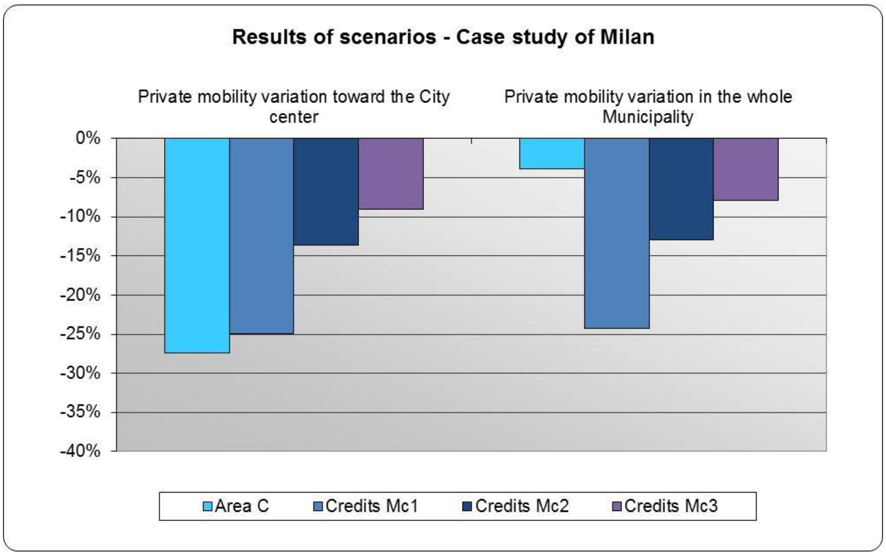

Figure 16 – Private mobility variation - Source: TRT

Therefore, the scenarios where the charge is applied to the whole municipality area show reactions and impacts which look more effective and efficient with respect to a scenario with a small area of application even in scenario Mc1 where the charge assumed is well below the current Area C charge. Furthermore the effect on traffic is better distributed than when charge is applied just to a small portion of the city. The application on a wide area would also provide an increased and more perceivable level of equity among the citizens.

The reduction of private mobility resulting from the application of the mobility credits is related to the reactions of individuals affected by the policy; as a result, changes in terms of mode split can be observed. Looking at the results, the area C scenario basically does not modify the mode choice significantly (except on the specific OD directly involved), while the mobility credits scenarios applied on a wider area do impact more effectively on both internal and interchange mobility. As reported in the following figure, scenarios Mc1 and Mc2 produce a mode shift from car to public transport on internal mobility (+5% and +2.5%), which is even more accentuated on the interchange mobility (+14% and +8%). In scenario Mc3 the impact on internal mobility is in line with the Area C test, while it is slightly higher concerning incoming mobility.

It should be noted that, whenever a consistent shift to public transport is produced, a remarkable improvement in the services might be required (of course, revenues from the policy application should reasonably be invested for improvements of the public transport services).

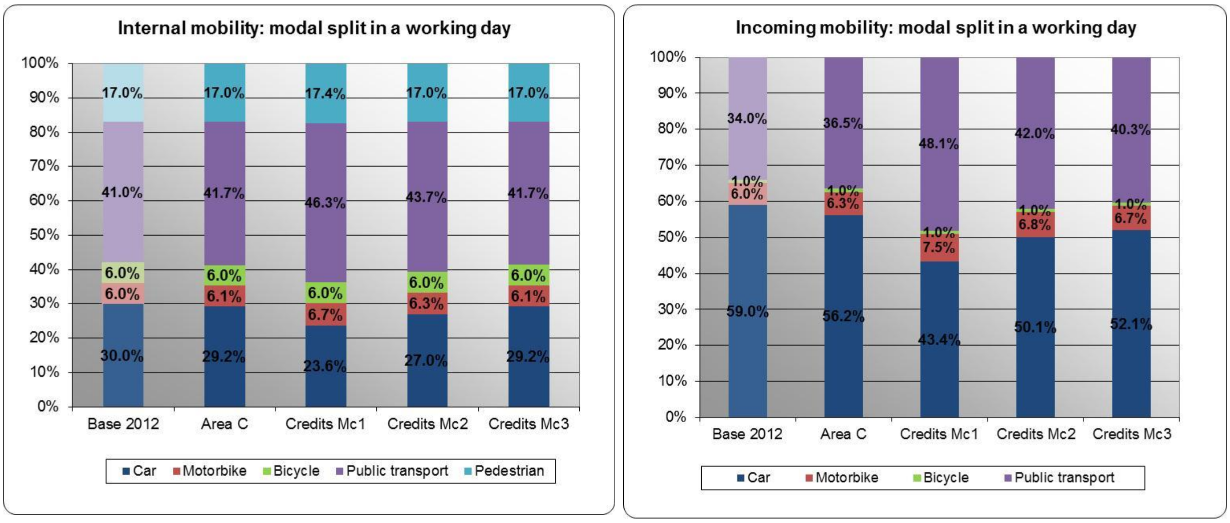

Figure 17 – Internal mobility and incoming mobility: impact on modal split - Source: TRT data and elaboration on Campus data

The amount of revenues for the Local Authority (and therefore the expenditure for the individuals) depends on many aspects: the mobility behaviour of individuals and their willingness to pay, the cost for purchasing Extra-credits and the Total Amount of credits distributed in the area. Depending on the combination of the elements mentioned above, the pricing policy may produce revenues about 7 million Euro in a quarter (as in the current area C congestion charge), or even 4 to 8 time larger (as in some of the mobility credits scenarios applied to the whole municipality). In scenario Mc3, revenues are increased only by 70% with respect to Area C test, mainly due to the reduced charge applied to the OD where an efficient public transport service is not available.

Table 3– Index of the economic results of scenarios simulated

	Area C	Credits Mc1	Credits Mc2	Credits Mc3
Average expenditure per person resident in the Municipality	**100**	**851**	**432**	**90**
Average expenditure per person not resident in the area	**100**	**749**	**352**	**192**
Revenues of the local Administration	**100**	**800**	**386**	**171**

Source: TRT

From the point of view of the users, in the test replicating the Area C congestion charge the average quarterly expenditure per individual (weighted on the whole population travelling by car) is about 3 to 8 Euro (except those living in the city centre). In the scenarios applied to the whole Municipality the average quarterly expenditure per individual might be up to 8 time larger the actual one, i.e. in scenario Mc1: in fact, since the price is the same (5 euro) but a larger part of mobility is involved in the policy with respect to the Area C test, individuals have to face a strong increase of their cost for mobility. In this case, the benefit in terms of mobility reduction at municipality level (-24%) is obtained at the cost of increased expenditure for the citizens. Looking at scenario Mc2 it can be observed that a consistent benefit in terms of mobility reduction (-13%) could be obtained with an economic burden 4-time larger than in the Area C scenario. Finally, in scenario Mc3, with the same average expenditure for individuals residents in Milan, an increased and more diffuse mobility reduction is obtained (-8%): this is mainly due to the distribution of the budget of free credits, as confirmed by the increase of the average expenditure for individuals not resident in Milan.

CONCLUSIONS

In this paper we have reported the experiences of the municipality of Milan regarding urban road charging. The first application based on the “polluter pays” principle (Ecopass) demonstrated that, without a regular update of the charged groups, the effectiveness of the policy tends to run out as the technological renewal of the fleet comes in.

The shift to a “congestion charge” principle (Area C) proved more effective results, despite its introduction is still young and any conclusions can only be provisional. This scheme however is applied only to a small part of the municipality area and therefore benefits are very concentrated. If the road charging is extended to the whole city benefits could be larger and better distributed also spatially.

The flexibility of the mobility credits approach provides many leverages to internalise urban mobility cost and control the distribution of the burden: differentiated tolls, differentiated amounts of free trips and so on. Given this flexibility there is also more room for a transparent and explicit communication to citizens of the reasons and benefits of the restrictions (or rather permissions) than in conventional pricing policies.

In any case, it can be expected a high level of initial opposition or at least uncertainty to a measure that might be seen as an extra burden on car drivers: therefore, a key factor is to convince users and citizens of being part of an overall sustainable urban concept, instead of urging or penalizing them for private car use.

As negative points, the mobility credits approach does not enable to fully collect cost internalization payments into the public budget and it implies some additional administration costs related to the allocation and accounting of credits to users (especially when applied to a wide area). Finally, some issues might concern the privacy of individuals, raised in terms of release of their ‘protected data’ related to the use of technological equipment to track private vehicle trips.

REFERENCES

AMAT - Agenzia Mobilità Ambiente e Territorio. (2012). Area C - C is Change - Area C: Clearness, Cleanness, Change. Guangzhou International Award for Urban Innovation 2012.

AMAT - Agenzia Mobilità Ambiente e Territorio. (2012). AREA C Tabella Bilancio Economico.

Bedogni, M., S. Moroni, D. Nuccio and L. Tosi. (2012). Area C - Sintesi della valutazione dei risultati conseguiti nei primi 6 mesi di applicazione del provvedimento ed effetti della sospensiva disposta a seguito dell'ordinanza del Consiglio di Stato. AMAT- Agenzia Mobilità Ambiente e Territorio.

Bedogni, M. (2012). Area C – Emissioni atmosferiche da traffico stradale in AREA C nel periodo Gennaio – Settembre 2012. AMAT- Agenzia Mobilità Ambiente e Territorio.

Bedogni, M. (2012). Area C – Emissioni atmosferiche da traffico stradale in AREA C nel periodo Gennaio – Dicembre 2012. AMAT- Agenzia Mobilità Ambiente e Territorio.

Bedogni, M., A. Pulpito, L. Tosi. (2011). Valutazione nuovi scenari di regolamentazione degli accessi alla ZTL Cerchia dei Bastioni. AMAT- Agenzia Mobilità Ambiente e Territorio.

Borjesson M., J. Eliasson, M. B. Hugosson, K. Brundell-Freij. (2012) The Stockholm congestion charges – 5 years on. Effects, acceptability and lessons learnt. Elsevier, Transport Policy, 20, 1-12.

Campus P., et al. (2012) The city of the future – Intelligent cities in the post Kyoto era – Smart ways to move people – The future of cars and the idea of the flexible congestion rights (FCR), London – The House of Lords, 16 October 2012.

Coase, R. (1960). The Problem of Social Cost. Journal of Law and Economics, 3, 1-44.

Colombi C., M. Lazzarini, et al. (2012). Rapporto Annuale sulla Qualità dell'Aria – Anno 2011. ARPA Lombardia.

Danielis R., L. Rotaris, et al. (2011). An economic, environmental and transport evaluation of the Ecopass scheme in Milan: three years later. University of Trieste, University of Roma 3, University of Ca' Foscari, Venice.

Department for Transport (DfT). (2004). The Future of Transport - a network for 2030. London, HMSO.

Eliasson, J., M. Lundberg. (2002). Road pricing in urban areas. T&E - Europe's voice for sustainable transport and Vagverket – Svedish National Road Administration

Evidenze (2006). Il Modello dei Crediti di Mobilità - Progetto Crediti di Mobilità per Genova. Milano.

Ieromonachou P., S. Potter and J.P. Warren. (2006). A Strategic Niche Analysis of Urban Road Pricing in the UK and Norway. The Open University, U.K.

ISFORT (2011). AUDIMOB – osservatorio sui comportamenti di mobilità degli italiani - La domanda di mobilità degli italiani. Fondazione BNC

Nuccio, D. et al. (2012). Monitoraggio Area C - Sintesi risultati al 30 Settembre 2012 - Traffico e composizione del parco veicolare. AMAT – Agenzia Mobilità Ambiente e Territorio
Nuccio, D. (2012). Monitoraggio Area C - Sintesi risultati al 31 Dicembre 2012 - Traffico e composizione del parco veicolare. AMAT – Agenzia Mobilità Ambiente e Territorio

Raux, C. (2008). How Should Transport Emissions Be Reduced? Potential for emission trading Systems. JRC Discussion Paper No 2008-1, OECD-ITF.

Transport Research Knowledge Centre. (2010). Financing, pricing and taxation. Thematic Research Summary.

Ministero dello Sviluppo Economico, Dipartimento per l'Impresa e l'Internazionalizzazione Direzione Generale per il Mercato, la Concorrenza, il Consumatore, la Vigilanza e la Normativa Tecnica - Div. V "Monitoraggio dei prezzi" (2013). Evoluzione dei prezzi dei prodotti petroliferi per autotrazione - anno 2008-2013

Centre for Climate and Energy Solutions (C2ES). (2010). What is Black Carbon?. Arlington, Virginia, U.S.A.

Viegas, J. (2001). Making Urban Road Pricing Acceptable and Effective: Searching for Quality and Equity in Urban Mobility. Transport Policy 8 (2001), pp. 289-294.

WEB REFERENCES

www.comune.milano.it
http://osservaprezzi.sviluppoeconomico.gov.it/