# THE EXTERNAL COSTS OF TRANSPORT IN ITALY: A QUANTITATIVE APPROACH

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## Abstract

This paper presents the methodological approach and the results of a modelling application in the field of estimated external and social costs of transport in Italy.
A simplified model has been developed to support general evaluations of the traffic management policies impact in urban and non urban areas. The model simulates the impacts on *environment* (changes in emissions and energy consumption) and *mobility* (changes in costs and journey times) caused by the policies implemented and compares the values of environmental and transport parameters given in the base scenario (*ante policy*) to the ones in the *post policy* scenario.

## INTRODUCTION

This paper presents the methodological approach and the results of a modelling application in the field of estimated external and social costs of transport in Italy, an issue of rising interest at national and international level. The item is linked to the critical points reached by the main urban areas in terms of congestion levels, lowering of safety levels, depletion of environmental conditions. The simplified model of transport external costs was set up by TRT Trasporti e Territorio within the study on "External Costs of Transport in Italy" (ISFORT/TRT, 1996).
The computing procedure has been developed to support general evaluations of the traffic management policies impacts upon urban and non urban areas. The model simulates the impacts on *environmental changes* in emissions and energy consumption and *mobility* (changes in costs and journey times) caused by the policy implemented and compares the values of environmental and transport parameters given in the base scenario (*ante policy*) to the ones in the *post policy* scenario. The model has been applied to three case studies: one urban area of approximately 100.000 inhabitants, one metropolitan area with about 3 million inhabitants, and a motorway link. The monetary values of the environmental costs used through the study has been derived from existing literature, therefore the study does not give particular contribution on this issue.
Section 1 of the paper contains a brief review of external costs in Italy, quantifying the monetary level of both emission and social costs in urban and non urban areas. The methodological aspects of the model are presented in Section 2. Section 3 presents the simplified model designed and implemented to estimate external and social costs in urban and non urban areas. Section 4 discusses the evaluation process implemented to test the efficiency of transport policies (pricing vs. regulation) in urban and non urban areas, and its results for the three case studies. Finally, Section 5, presents the possible research developments.

## SOME METHODOLOGICAL ASPECTS OF THE EXTERNAL COSTS IN ITALY

The external costs of transport considered are:
1. The environmental costs in Italy. The monetary values of the environmental costs in Italy have been derived from the study carried out by Kågeson (1993). The approach followed by Kågeson was the avoidance cost one, that is by defining the marginal cost of reducing emissions by certain shares. The emissions taken into account are CO, $NO_x$, VOC, $CO_2$ and noise.

**Table 1 - External costs in Italy**

| Emissions | ECU 1993(1000 pax*km) | ECU 1993 (1000 t*km) |
|---|---|---|
| Air pollution (except $CO_2$) | 14.6 | 5.6 |
| $CO_2$ | 4.5 | 3.5 |
| Noise | 0.9 | 0.5 |
| Total | 20.0 | 9.6 |

Source: TRT processing of data contained in Kågeson (1993)

2. The social costs of transport accidents. These are the main costs that are not perceived by the road users. The social costs of transport accidents include several cost items, some of which are already borne by the transport users (i.e. they are internal), some not: i) damage to property (vehicles, buildings, etc.), ii) medical costs, police, emergency and legal costs, iii) lost production, iv) and loss of human value (grief, pain and sorrow) (Kageson, 1993; Rothengatter, 1998).

The costs related to points i) to iii) are generally covered by the vehicle owner's liability insurance or personal assumption of risk, in other words they are internal costs of the road users (club). The main problem is related to the last one (loss of human values). In this study, following Rothengatter (Rothengatter, 1998) all costs which are covered by the party responsible for the occurrence of an accident, including insurance are considered internal, while the costs which are diverted to other parties as for instance the victim, etc., are obviously external.

3. Congestion costs. From the standpoint of the external costs apportionment, there are two main methodological approaches for defining and estimating congestion costs. The first considers the problem of congestion internal to the users of a congested infrastructure, but external to individual agents: congestion is a damaging activity internal to the infrastructure users, but the marginal cost caused to the other users by one additional motorist entering a congested area is in principle external (Kågeson, 1993; Rothengatter, 1997). For the second one, which has been followed in this study, congestion generates costs not only to road users, but to the whole community in terms of additional costs for: 1) the car system (have higher consumption, higher polluting and noise emissions because of irregular driving cycles); 2) the public transport system (lower commercial speed, irregular service, higher production costs, etc.); 3) the urban system (longer journey times and lower quality of life) (Quinet, 1995; CEC, 1995c).

4. The different external costs between urban and non urban areas. In very densely populated regions the external cost per passenger kilometre is higher (Ecoplan/Infras, 1992) than in non urban areas. This is reasonable, if we consider that up to total car*kms driven in Western European countries, 30% to 50% is driven in urban areas, and 30% of car traffic is related to the city centre (Himanen *et al*, 1992). In Italy, 37% of domestic journeys take place in urban areas, where car density is more than five times the average national value (98 cars / sq km at national level, rather than 563 cars / sq km in cities - Conto Nazionale Trasporti, 1995).

5. The estimation of generated costs has taken into account the current taxation levels of road users in Italy (OICA, 1995). The study takes into account only taxation levels of consumption (excise duties for fuels). This assumption is consistent with two options:

- the first is to estimate external costs per vehicle km, that is in function of the consumption level; this is to say, of the incremental costs and not of the average costs;
- the second is to align with the aims of the study, intended to define a <u>simplified</u> model for evaluating the impacts of different policies on the environmental and the transport systems; a "<u>complete</u>" model intended to evaluate the long-term costs and benefits, would provide a very high complexity level and would have to do with the macroeconomic dimensions of the environmental phenomena and policies, going far away from the current analysis.

## External costs in urban and non urban areas

In the study, the estimation of the external costs generated by road users has been carried out as a balance between the tax level on energy consumption (excise duty) and the costs generated by road transport in the three cases analysed: urban, metropolitan and non urban areas. For the urban and metropolitan areas the monetary values reported are related only to passenger traffic (light vehicles), (see Tab. 2), while for the non urban case study (see Tab. 3) also freight has been considered.

In distinguishing between the urban and metropolitan areas and the non urban ones the following factors have been considered: i) the size of the population exposed; ii) the concentration of pollutants. Keeping account of the Italian urban areas features of population density (the average urban density is five times higher than the national average) and emissions level (the average level is twice the level in rural areas), an estimation of the reduction costs for the environmental damage in urban areas takes to evaluate the environmental external costs ten times the value for rural areas.

**Table 2 - Comparison between taxes and costs in metropolitan and urban areas (ECU/1000 veh*km), 1996**

| | Metropolitan Area (ECU/1000 veh*km) | Urban Area (ECU/1000 veh*km) |
|---|---|---|
| Excise (petrol/diesel fuel) | 53.2 | 53.2 |
| Generated costs | | |
| Environmental | 138.0 | 138.0 |
| Congestion costs | 337.0 | 52.9 |
| Maintenance | 6.1 | 6.1 |
| Total generated costs | 481.1 | 197.0 |

Source: TRT, 1996

The estimation has been carried out taking into account the following items:
- share of fuel taxes on average consumption per traffic unit;
- environmental costs in urban areas as estimated by Kågeson (1993), discounted back to 1996[1];
- congestion costs estimated by the modelling application in the metropolitan and urban areas;
- maintenance costs of the road network estimated on the basis of monetary values reported by European Commission (1995c) and discounted back to 1996.

**Table 3 - Comparison between taxes and costs: non urban area (ECU/1000 veh*km, 1996)**

| | Freight (ECU/1000 veh*km) | Passengers (ECU /1000 veh*km) |
|---|---|---|
| Excise (petrol /diesel fuel) | 170.0 | 45.4 |
| Motorway toll | 83.9 | 41.9 |
| Total | 253. 9 | 87.3 |
| Generated costs | | |
| Environmental | 215.7 | 17.3 |
| Congestion | 150.7 | 60.3 |
| Maintenance | 17.7 | 0.0 |
| Total generated costs | 384.1 | 77.6 |

Source: TRT, 1996

The estimation has been carried out taking into account the following items:
- share of fuel taxes on average consumption per passenger and freight traffic unit;
- motorway toll: passenger and freight;
- freight environmental costs: the value drawn from Kågeson (1993) has been reported to the traffic unit in function of the average load of heavy goods vehicles (20 tons) and discounted back to 1996;
- passenger environmental costs: the value drawn from Kågeson (1993) has been reported to the traffic unit (car*km) and discounted back to1996;
- the congestion costs have been estimated in the modelling application on a sample motorway stretch separately for light and heavy vehicles;
- the maintenance costs of the infrastructure have only been ascertained to heavy vehicles, because of the relation between maintenance costs and axle weight; the estimation assumes the monetary values from European Commission (1995c) discounted back to 1996.

*Some considerations on the estimates proposed*

The estimates reported for urban and non urban areas are not intended to provide an exhaustive and analytical comparison between taxes and costs generated by road transport users, yet have the merit to draw the attention onto three relevant issues.

1. The level of external costs generated by freight transport on motorways. Both environmental and congestion costs are very significant when comparison is made between freight and passenger transport. For instance the ratio of heavy goods vehicles fuel consumption up to "light" vehicles is 1:5[2]. The reader should remember that for every diesel fuel litre, $NO_X$ emissions are 31.5 g for heavy goods vehicles (1993) against 10 g emitted by light vehicles (Kågeson, 1993).
2. The weight of congestion costs on motorways. The computing method applied in modelling allows one to define the optimum toll as a proxies of the toll that internalise congestion costs on motorway. This data gives a clear suggestion for a policy aiming at introducing efficient tolls on the basis of the infrastructure use.
3. The different weight of congestion costs in urban and metropolitan areas. The two values of congestion costs estimated for the urban and the metropolitan case studies show how the phenomenon changes in relation to urban size[3]. The main factor being the dispersion/concentration of economic and residential activities and, all things considered, the interaction between land pattern and mobility system.

## THE MODEL OF EXTERNAL COSTS

The simplified model of external costs of transport is composed of three submodels:

1) **estimation of external costs in urban areas**, implemented in the urban case studies;
2) **estimation of external costs in non urban areas**, calibrated on the Italian motorway corridors; the policy tests have been carried out on a motorway stretch;
3) **evaluation of the polluting and climate-change (green-house effect) emissions;** the submodel can estimate energy consumption and emissions on the basis of traffic volumes and types (light and heavy vehicles);

The software works under Windows™ (Excel) and operates by inserting data into the three submodels linked one to each other.

THE EXTERNAL COSTS MODEL

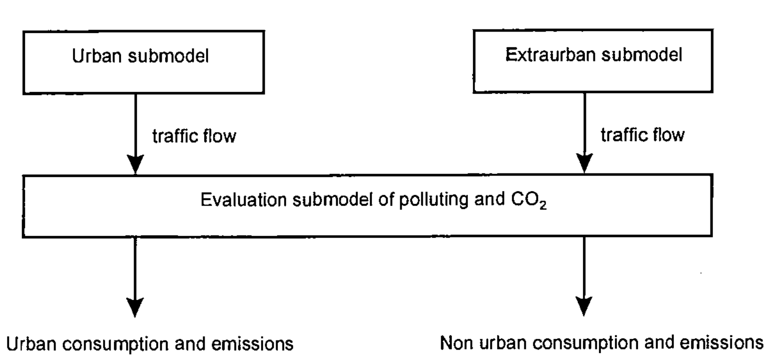


**Figure 1 - The external costs model**

## The urban submodel

The implemented urban sub model is simple to test and allows one to implement pricing and regulation policies. It has been set up to display the different types of physical functional features of the urban structures (road networks and land use). Furthermore, a "concentration index" of road capacity is used in order to define a series of speed-flow relations, which are derived from a sample of traffic surveys. In this way, the characteristics of "traffic capacity" of each zone and town can be broadly quantified.

The submodel of evaluation of external costs at urban scale requires the following stages:

1. generation-assignment: the module generates and assigns traffic flows (vehicle*km), divided in public and private ones, to each group of links and nodes of the network for every matrix cell (area characteristics / road network characteristics); it requires therefore the zoning of urban areas and the set-up of a matrix linking land use features of different city areas to the road network characteristics, on the basis of the following scheme (Tab. 4);

**Table 4 - Matrix: road network and land use**

| | Road network features | | |
|---|---|---|---|
| | **Winding/steep** | **Straight** | **Motorway-like** |
| *Land use features* | | | |
| Commercial | * | * | * |
| Residential central | * | * | * |
| Residential suburb | * | * | * |
| Industrial rural | * | * | * |

Source: TRT, 1996

2. congestion module: estimates journey times for public and private modes - for every matrix cell (crossing zone/road type), on the basis of the flow/capacity relation of the flow curve.

The scheme of the urban submodel is shown in the following figure.

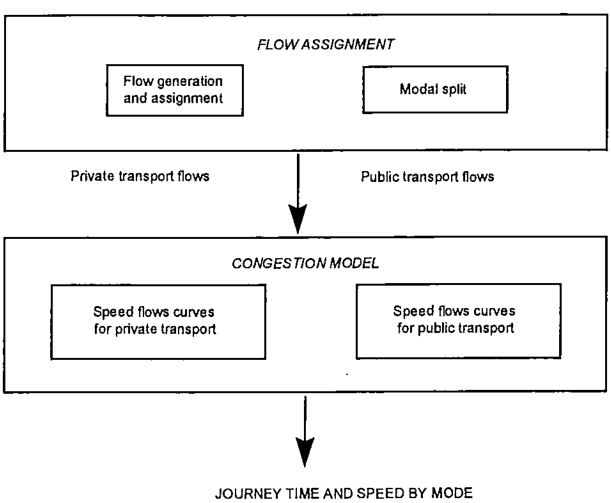


**Figure 2 - Scheme of the urban submodel**

Source: TRT, 1996

The quantitative data required by the urban submodel is: 1) population and economic features (employed per activity type) of the land use zones; 2) description of transport supply (graphs of the private and public network); 3) transport demand (origin and destination matrices per mode); 4) interaction between demand - supply (driving speed, traffic flows on graph links, etc.)[4]; 5) modal elasticities to monetary costs and to journey times.

## The non urban submodel

The non urban sub model is simpler than the urban one and has a similar methodology to measure speed-flow relations. The model is based on *aggregated flow curves* by road types and pattern of land use: this enables the user to represent the relationship between speed and traffic flows on a local basis.

The data required is: capacity of links, traffic flows (light and heavy vehicles), toll levels, modal elasticities to monetary costs and to journey times.

Emission levels are defined as a function of heavy and light traffic and average driving speed.

Modelling consists of the calibration of flow curve parameters, linking flows with capacity on the motorway stretches under study, reproducing with sufficient reliability the observed speed and consequently the times spent.

A relevant element in the motorway case study, because influences the traffic flow conditions and has an impact on the infrastructure operating costs, is the heavy traffic share onto the overall traffic composition. This is taken into account, in every single stretch, writing the flows in equivalent cars.

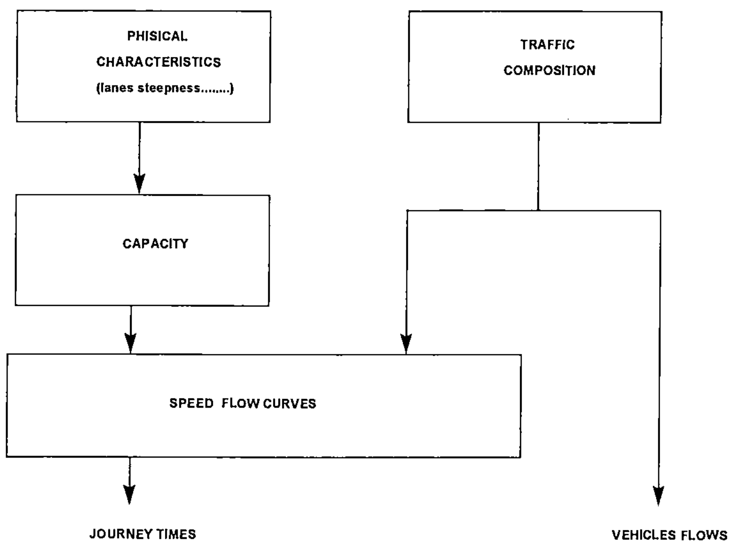


**Figure 3 - Scheme of non urban model**

Source: TRT, 1996

Data used to set up and to calibrate the model is demand data (loads per stretch and direction) and the physical characteristics of the single stretches (lane number, capacity, free-flow speed and $\beta$ parameter of the flow curve, etc.).

### Evaluation submodel of polluting and green-house effect emissions

The set-up of the evaluation model for polluting and green-house emissions from the environmental costs standpoint is based on the assumption of impact parameters for polluting atmospheric emissions (carbon monoxide and nitrogen oxides) and for $CO_2$ emissions.
The methodology used to set up the computing emissions module has been developed on the basis of CORINAIR emission factors, split by vehicle type and only for the group of private cars by power class and registration year (CEC, 1995c; CEC, 1991)[5]. The computation of total emissions in peak-hours in urban areas is based on emission factors specific for vehicle and measured in g/km driven and total kilometres driven by every vehicle type.
In detail, the computing methodology is split by the following steps:
1. defining the average composition of the car fleet;
2. computing of specific emission factors for the car fleet;
3. deriving from specific factors some computing continuous functions to be put into the model.

The definition of an average emission factor for the whole car fleet is supported by a computing software designed on this purpose (Istituto Ambiente Italia, 1996). The software works in Windows$^{TM}$ environment and allows the definition the parameters for the car fleet composition and for the operating characteristics to which atmospheric emissions and energy consumption are to be estimated. The consumption and emission unit factors are turned into polynomial continuous functions of the driving speed. The formulae thus obtained are put into the two estimation submodels of external costs for urban and non urban areas, allowing to immediately compute the total consumption and emission indexes for each measure scenario forecasted by the policies.

## TESTS OF THE TRANSPORT POLICIES

The policies have been chosen for their relevancy and ability to be an example, without pretending to constitute the rich tools framework set up by local governments. For defining the policies to be evaluated, the attention has been paid to the recent contributions by the European Commission (CEC, 1995b; CEC, 1995c) and to the set up of local-level tools based on a *bottom-up* decision process[6]. Central government action in fact takes shape through general policies and tools such as: the pollutants standards imposition or emission targets, accidents risk reduction measures, the set up of local planning guidelines. On the contrary, local government action has specific tools such as: traffic management, parking control, access control, public transport performance improvements, incentives for non polluting transport modes (cycle tracks) and so on.
In this section, the evaluation of the transport policies efficiency is presented as tested by the simplified model of external costs. The modelling has tested in particular:

- **pricing policies**, by the set up of an *extra toll*, that is the toll that internalises the environmental and congestion external costs; the pricing policies can be implemented as road or park pricing;
- **regulation policies**, tested through the set up of measures to increase the occupancy level of vehicles - i.e. car pooling; the test is aimed at giving indications on the possible environmental attributes changes (consumption, emissions) and mobility attributes (times, costs) caused by an increase in the vehicle occupancy rate; the car pooling policy well fits pricing measures (road and/or park pricing);
- **policies in favour of public transport**, tested through the set up of priority conditions for the collective transport system - i.e. bus priority; the measure takes shape by an increase in collective transport road capacity both in physical terms (reserved lanes) or virtual terms (traffic light priority).

## Results of the test policies for urban case studies

The two cities option (urban and metropolitan area) has been brought about, beside the basic information availability required by the model, by the choice to represent two extremely relevant Italian urban areas. On one side, the middle-sized town (100,000 inhabitants) represents an urban context widely spread in Italy: this urban context, because of environmental and traffic emergencies, underlines the need to set up sector policies and measures. On the other side, the metropolitan area (3 million inhabitants) represents the main complex, critical points typical for metropolitan areas in Italy.
The policy test results are reported in the enclosed table (see Tab. 5 to 10), in which the public/private transport demand changes, the global journey times for modelled traffic flows, the energy consumption and emissions changes are estimated with respect to the reference solution, as well as the economic efficiency evaluation of cost internalising policies (pricing) against regulation policies.

*Pricing: road/park pricing*

The road pricing policy has been implemented in the central and commercial areas of the two cities, imposing an access fare that internalises environmental costs (atmospheric pollution and noise) after the current taxes and the congestion costs. The monetary values of the fare that internalises the external costs are the one reported at Tab. 2.
Summarising the results of the tests, the road pricing tariff set up in both urban areas brings about an 11% private car flow reduction and even a higher share, as well as a consequent increase in the demand share served by the public mode. This results in a relevant decrease in emissions and energy consumption in both urban contexts.

*Regulation: car pooling*

The car pooling policy has been modelled by increasing the average private vehicle occupancy rate from 1.3 to 1.75 passengers per vehicle, and by penalising the journey times in order to take into account the worsened level of service consequent to a collective use of cars. This has been done by changing the Level of Service, LOS, (Kirby *et al*, 1974), defined as the ratio between the global journey time needed to move from origin to destination and the car journey time. In case of a car trip, such a ratio is equal to one. Using the information on journey times by car and by public transport, the LOS for car pooling has been increase up to 1.5. Results of the car pooling policy show consistent variations of mobility and environmental parameters for the whole urban area both in terms of modal split and in consequent emissions and consumption changes. In detail, the energy consumption decrease varies between -25% and -31% of the current values and a similar CO, $NO_x$, $CO_2$ emissions.

*Bus priority: reserved lanes*

The implementation of the bus priority policy has been carried out assuming:
- a reservation on road capacity for public transport mode (reserved lanes);
- a substantial increase of road public transport speed because public flows are separated from private ones.

The attractiveness of public transport mode, with increasing performance, is well represented in the model in terms of provided demand and of contemporary decrease in consumption and emissions with respect to the reference solution. As a negative effect, higher journey times for the private mode have been observed.

### Results of the tests policies for the motorway case study

The policy tested in the motorway case study is the estimation of the "optimum toll", defined as the toll that internalise the environmental and the marginal congestion costs (see Fig. 4). The test has been carried out assuming as exemplum a standard stretch representative of the Northern Italy motorway network. In short, the infrastructure route spreads over 93 km and three lanes per direction. The modelling representation allows the definition of the tariff optimising the use of the infrastructure under congestion conditions in peak hours, that is the highest trafficked periods of the day for the motorway.

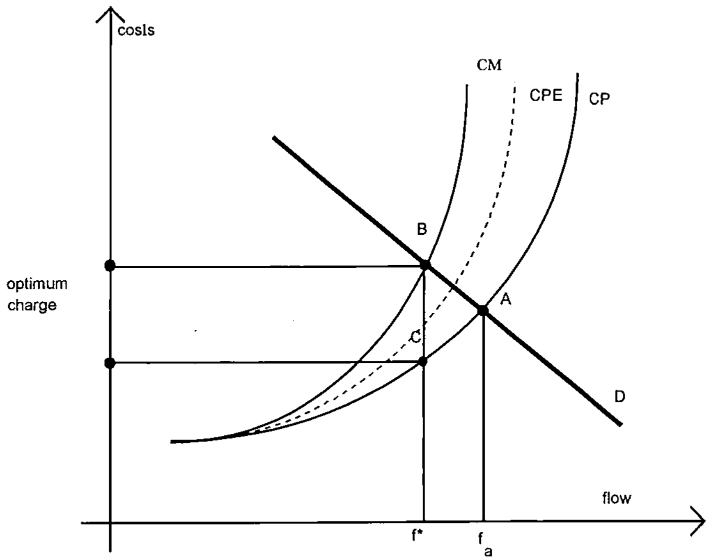


**Figure 4 - Optimum toll**

Source: TRT, 1996

where:

CP = perceived cost curve
CPE = perceived costs plus environmental costs
CM = marginal cost curve
D = demand curve
$f_a$ = current flow equilibrium
f* = optimal flow
BC = charge internalising congestion and environmental costs

The estimated value of the peak-hour optimum toll is 60.3 ECU per 1000 equivalent veh*km (114% of the current average toll), which represents a 50% increase in the perceived monetary cost (from 121.1 to 181.4 per1000 equivalent veh*km).
The introduction of the congestion toll in peak-hours brings about:

- a driving speed increase in peak-hours from the current 63 km/h to 96 km/h, with a 6,000-hour global time saving (-50.2% with respect to current times), coming from the relevant traffic flows decrease (-2,600 equivalent vehicles, corresponding in relative terms to -24%);

- as a consequence of the speed increase, a reduction of the energy consumption (-16%) and the polluting emissions of CO (-16%) and $CO_2$ (-15%), while for $NO_x$ emissions the decrease is scarce (3%).

The implementation of the congestion pricing shows an outstanding policy indication for the set up of efficient prices for the infrastructure use, as aforementioned. Yet the congestion optimal toll estimation, as developed by the simplified model for external costs, does not deal with the problems and costs linked to safety. Such underestimation of the external costs results in an extremely critical element because of the positive correlation between, on one side, accidents number and seriousness, and on the other driving speed and the speed increases deriving from the flow optimisation.

**Table 5 -Urban area - Results of the policy tests: changes in vehicle*km**

| Policies | Trips (Veh*km) | | | | | |
|---|---|---|---|---|---|---|
| | private | % | public | % | total | % |
| Reference solution | 53.770 | | 14.690 | | 68.460 | |
| Road Pricing | -5.893 | -11% | 5.897 | 40% | 4 | 0% |
| Bus Priority | -2.562 | -5% | 3.909 | 27% | 1.347 | 2% |
| Car Pooling | -4.912 | -9% | 5.005 | 34% | 93 | 0% |

**Tab. 6 Urban area - Results of the policy tests: changes in journey times**

| Policies | Journey times (hours) | | | | | |
|---|---|---|---|---|---|---|
| | private | % | public | % | total | % |
| Reference solution | 11.904 | | 3.543 | | 15.447 | |
| Road Pricing | -1.196 | -10% | 1.379 | 39% | 183 | 1% |
| Bus Priority | 84 | 1% | -10 | 0% | 74 | |
| Car Pooling | -1.612 | -14% | 964 | 27% | -648 | -4% |

**Table 7 - Urban area - Results of the policy tests: changes in consumptions and emissions**

| Policies | Energy consumption (kgtep) | | Emissions (in kg) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | % | CO | % | NOx | % | $CO_2$ | % |
| Reference solution | 19.963 | | 4.420 | | 398 | | 54.253 | |
| Road Pricing | -1.246 | -6% | -313 | -7% | -20 | -5% | -3.378 | -6% |
| Bus Priority | -481 | -2% | -121 | -3% | -7 | -2% | -1.304 | -2% |
| Car Pooling | -6.092 | -31% | -1.348 | -30% | -121 | -30% | -16.558 | -31% |

**Table 8 - Metropolitan area - Results of the policy tests: changes in vehicle*km**

| Policies | Trips | | | | | |
|---|---|---|---|---|---|---|
| . | private | % | public | % | total | |
| Reference solution | 263.158 | | 85.792 | | 348.950 | |
| Road Pricing | -122.941 | -47% | 45.027 | 52% | -77.914 | -22% |
| Bus Priority | -12.918 | -5% | 15.150 | 18% | 2.232 | 1% |
| Car Pooling | -11.139 | -4% | 8.799 | 10% | -2.340 | -1% |

**Table 9 - Metropolitan area - Results of the policy tests: changes in journey times**

| Policies | Journey times (hours) | | | | | |
|---|---|---|---|---|---|---|
| | private | % | public | % | total | % |
| Reference solution | 33.910 | | 16.680 | | 50.590 | |
| Road Pricing | -9.537 | -28% | 7.812 | 47% | -1.725 | -3% |
| Bus Priority | 1.178 | 3% | -806 | -5% | 372 | 1% |
| Car Pooling | -2.752 | -8% | 1.288 | 8% | -1.464 | -3% |

**Table 10 - Metropolitan area - Results of the policy tests: changes in consumptions and emissions**

| Policies | Energy consumption (kgtep) | | Emissions (in kg) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | % | CO | % | NOx | % | CO2 | % |
| Reference solution | 55.034 | | 12.851 | | 1.013 | | 150.268 | |
| Road Pricing | -11.194 | -20% | -2.800 | -22% | -181 | -18% | -30.435 | -20% |
| Bus Priority | -781 | -1% | -198 | -2% | -13 | -1% | -2118 | -1% |
| Car Pooling | -14.356 | -26% | -3.346 | -26% | -265 | -26% | -39.199 | -26% |

## RESEARCH DEVELOPMENTS

Two major items for further research development were identified. The first one is related to the quantification of the external (environmental and social) costs in urban and non urban areas. Costs tend to enormously vary from urban to non-urban contexts, i.e. for short and long-distance traffic: health damage depends, in a large proportion, on the spatial emissions concentration and on population exposure to this concentration. This implies a "more-than-linear" impact reduction from urban areas to rural areas, and in addition that long-distance traffic generates far less externalities than short-distance traffic per emission unit.

The second one concerns the estimate of a motorway optimal speed as a trade-off between accident costs and journey time savings, taking into account that: i) accidents are not related to traffic levels (but to human errors, mechanical failures, etc.), yet accident costs, whatever the cause, are related to speed (as confirmed by evidence of the deaths reduction, but not of accidents, as a consequence of increased congestion, i.e. decreased average speed); ii) drivers cannot fully and spontaneously balance the value of his/her time and the risk connected with speed: there is a non-perceived (or ill-perceived) statistical cost concerned with speed.

Using standard average accident statistics for a given speed limit, it was possible to observe the (linear) variation of journey time with speed, and the (quadratic) variation of accident costs, deriving a set of "optimal" speed limits linked with different accidents cost evaluation. The preliminary empirical results found on a sample of Italian motorways show the values of "optimal speeds" are in the 100 km/h magnitude order, that is the same order of American speed limits, and lower than the European average values.

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## FOOTNOTES

1 Keeping account of the Italian urban areas features of population density (five times higher then the national average) and emission levels (twice then in rural areas) the environmental costs in urban areas have been assumed to be ten times the average values, with the exception of CO2, due to the transboundary impact of the greenhouse emissions.

2 Estimates given by Kågeson (1993) on the basis of 1992 data by the Swedish Environment Protection Agency report a consumption level for diesel-engined light and heavy vehicles of a ratio 1:5. The data is virtually in line with Italian current estimates for heavy vehicles consumption (4,8 times higher than light vehicles; Armani, 1993).

3 Please compare the values estimated by Newbery (1995): congestion costs vary from about 0.63 ECU per veh*km in central urban areas in peak hours, to 0.11 ECU per veh*km in middle-sized cities (in peak hours as well).

4 The modelling application developed for the work ISFORT/TRT (1996) has been referred to the urban and metropolitan areas and has used the output of the transport territory interaction model MEPLAN.

5 For cars, the factors vary with speed, through adequate computing formulae; for commercial vehicles three speed classes are considered (urban, extra urban, motorway).
For petrol-engined cars, different emission factors per registration year have been proposed, to keep into account the emission limits progressively set up at Community level.

6 This process is opposite to a traditional *top-down* model, in which the policy is defined at central government level.