STRATEGIC ASSESSMENT OF ALTERNATIVE NATIONAL POLICIES TO REDUCE TRANSPORT EXTERNALITIES

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Abstract

In the last years attention has being increasingly paid on negative social and environmental effects of transport. Measuring such undesired effects – the so-called *externalities* – is then important to get a comprehensive picture of cost and benefits of transport development. The ASTRA-Italia strategic transport model simulates the complex interaction – and the feedback effects - of passenger and freight mobility with economy, land-use and environment systems and provides an estimate of the development of transport externalities in the next years.

The model has been used to simulate two alternative policies aimed at reducing the external costs of transport. The two policies share the same set of instruments, that is the use of economic leverages (tolls, taxes, subsidies), and have a common objective: the reduction of the impact of transport on the society and the environment, without endangering the passenger and freight mobility development. The first policy is focused on the technological side and consists in the taxation of conventional fuels (gasoline and diesel) to raise funds for providing subsidies to households and firms to purchase innovative vehicle. The second policy is focused on modal shift and involves an extensive use of road pricing to collect money used to improve competitiveness of public transport and non-road freight modes.

The outcome of the simulations allows the comparison of the effects of the two strategies with reference to transport (modal split, average distances, etc.), economy (expenditure, revenues, GDP, etc.), environment (emissions, etc.) and welfare (external costs) in comparison with a baseline scenario. Although the simulations required several assumptions to deal with uncertainty on technological developments and the aggregate nature of the model, the outcome is certainly interesting as both policies are effective, although the size of externality reduction is not huge.

Keywords: Strategic assessment; System dynamics; Externalities
Topic Area: E3 Valuation of Internal and External Benefits / Costs

1. Introduction

Negative social and environmental effects of transport are being posed at the centre of the scientific and institutional debate. Consequently, the measure of such effects – called *externalities* – is crucial to better assess costs and benefits of transport development. The ASTRA-Italia strategic transport model simulates the complex interaction – and the feedback effects - of passenger and freight mobility with economy, land-use and environment systems and provides an estimate of the development of transport externalities at national level.

In Italy, people mobility gives rise to about 900 billions pass-km per year (75% by car) while domestic goods transport provokes some 290 billion tons-km per year (75% by trucks which account for 90% of land modes transport). According to the estimation of the ASTRA-Italia model, this volume of traffic is responsible for external costs of 67.5 billions Euro, of which about 89% due to road vehicles. The externality figures take into account polluting emissions and greenhouse gases (38.6 billions Euro), noise (3.3 billions Euro), accidents (22.6 billions Euro) and congestion (3.0 billions Euro). Such estimations are in line with the international literature (e.g. Infras-IWW, 2000), while other studies provide even higher values for Italy: for instance Amici della Terra (2002), which adopt a slightly different methodology, estimates a total amount of 100 billions Euro.

This paper presents the assessment of two different policies aimed at the reduction of transport externalities in Italy. The first policy is focused on the technological side and consists in the taxation of conventional fuels (gasoline and diesel) to raise funds for providing subsidies to households and firms to purchase innovative vehicle. The second policy is focused on modal shift and involves an extensive use of road pricing to collect money used to improve competitiveness of public transport and non-road freight modes. It seems important to underline two major characteristics of the policies:

– their common aim is to reduce substantially the damages of mobility and thus the pricing/taxation leverages are used as ways to raise money to fund alternative solutions, without any reference to economic theories such as Social Marginal Cost Pricing or externalities internalisation;
– they assume the mobility development as a given element and therefore are alternative with respect to an approach which aims at reducing the negative effects of mobility by reducing the mobility itself (for instance through land-use policies, tele-working support, etc).

The paper is organised as follows. In section 1 the ASTRA-Italia model is introduced. In section 2, the two policies are discussed in terms of their rationales and features and the way how they are implemented in ASTRA is also described. In section 3 the modelling results are shown and commented. Finally, section 4 provides the main conclusions which can be drawn from the model application.

2. The ASTRA-Italia model

The ASTRA-Italia model is a System Dynamics model focused on the study of national transport demand and its links to economy and environment at an aggregate level. The System Dynamics Modelling approach has four theoretical foundations: the information-feedback-theory, the decision theory, experimental computer simulation and the processes of mental problem solving. It can be defined as a computer-oriented method to analyse the behaviour of a complex system and its development in time. System dynamics models assume that the behaviour of systems is primary determined by its feedback mechanisms.

ASTRA-Italia is one member of the ASTRA family of models, which was originated by a European Commission co-funded research project in the Fourth Framework Programme (ASTRA, 2000). Since then, the European scale model has been further developed and extended and now the ASTRA family includes ASTRA-T model, developed in the TIPMAC project (TIPMAC, 2002), ASTRA-LOTSE model which has been enlarged to EU accession countries plus Switzerland and Norway (IWW, 2003), ASTRA-Italia and a few other applications.

In the following paragraph a brief description of the main features of the ASTRA-Italia model is provided (more details on the model can be found in Centro Studi Federtrasporto, 2002 and in Fiorello et al., 2002).

2.1. Structure of the ASTRA-Italia model

In ASTRA-Italia the system under analysis is the transport sector, including its connections with the economic sector and the environment. Thus the model encompasses different contexts and five main sub-models strictly connected among each other can be identified: the macroeconomics sub-model (MAC), the generation sub-model (GEN), the transport sub-model (TRA), the vehicle fleet sub-model (FLV) and the environmental sub-model (ENV).

The macroeconomic sub-model (MAC) provides the overall economic trend in term of GDP, employment, income, etc. and models in explicit terms the links between economy, demographic variables (e.g. population) and transport variables (e.g. cost of transport modes). Thus, the economy is a major determinant of transport demand and, at the same time, changes on the transport side can affect the level of the economic activity.

The role of the generation sub-model (GEN) is to provide an operating framework to model the transport demand generation and its distribution among possible destinations. Passenger demand, as modelled in the GEN, is derived through a combination of demographic cohorts based on age and economic position, car ownership and labour force models with feedback with the MAC (employment) and FLV (vehicle fleet), identifying twelve homogenous demand segments (e.g. employed adults with no car, unemployed/ inactive adults with a car, etc). Trip rates by purpose (business & commuting, personal and tourism) are then applied. Freight demand is based on industrial production in fifteen economic sectors, which are then converted to tonnes lifted using value-to-volume ratios and aggregated into three freight categories (solid and liquid bulk, semi-bulk and unitised freight).

The transport sub-model (TRA) deals with the modal split (based on a Logit algorithm) of demand by origin/destination pair and with computation of generalised times and costs, also used by GEN as input for the distribution of generated trips. The outcome of TRA, in terms of vehicle-km by mode of transport, is also a major input for the computation of externalities in the environmental sub-model (ENV).

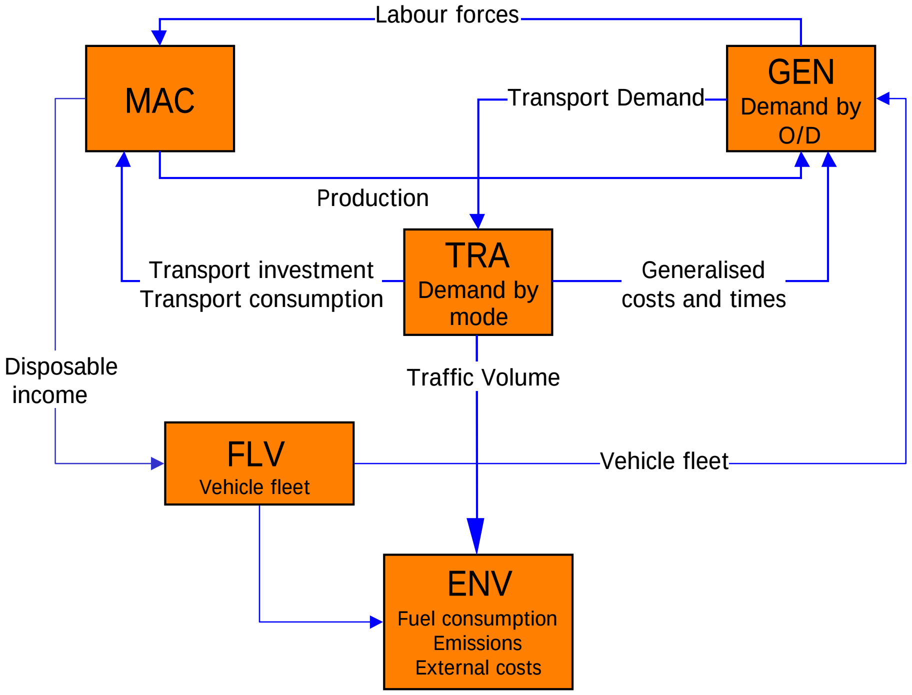

Figure 1. Main links among the ASTRA-Italia sub-modules

As most of environmental effects are dependent on the vehicle fleet, the vehicle fleet sub-model (FLV) is devoted to simulate the evolution and composition of this element and to feed this information into the environmental sub-model (ENV).

The environmental sub-model (ENV) computes the main impacts of traffic in terms of emissions, noise and accidents. Specific speed-dependent emission functions are therefore applied to the traffic volumes by mode provided by TRA in order to compute the total emissions of pollutants and greenhouse gas: CO_2, NO_x, CO, SO_2, VOC e PM. Marginal costs are used to appraise the value of the external costs associated to emissions, accidents and noise.

The model simulation period is of 40 years, from 1990 to 2030, where years from 1990 to 2000 are used for calibration. Results are provided on a yearly basis. The model produces a reference scenario, which includes a projection of past and current trends of key variables like GDP growth, population development, transport costs, etc. and alternative policy scenarios can be easily built by the modellers.

2.2. Geographical scope and the modelling of spatial dimension

The geographical scope of the model is Italy, which is split into three macro-regions: North, Centre and South. Each macro-region is defined as an aggregation of Regions and is further classified into three functional zones, clusters of Provinces on the basis of urban settlement typologies: Metropolitan Areas, High Density Areas and Low Density Areas.

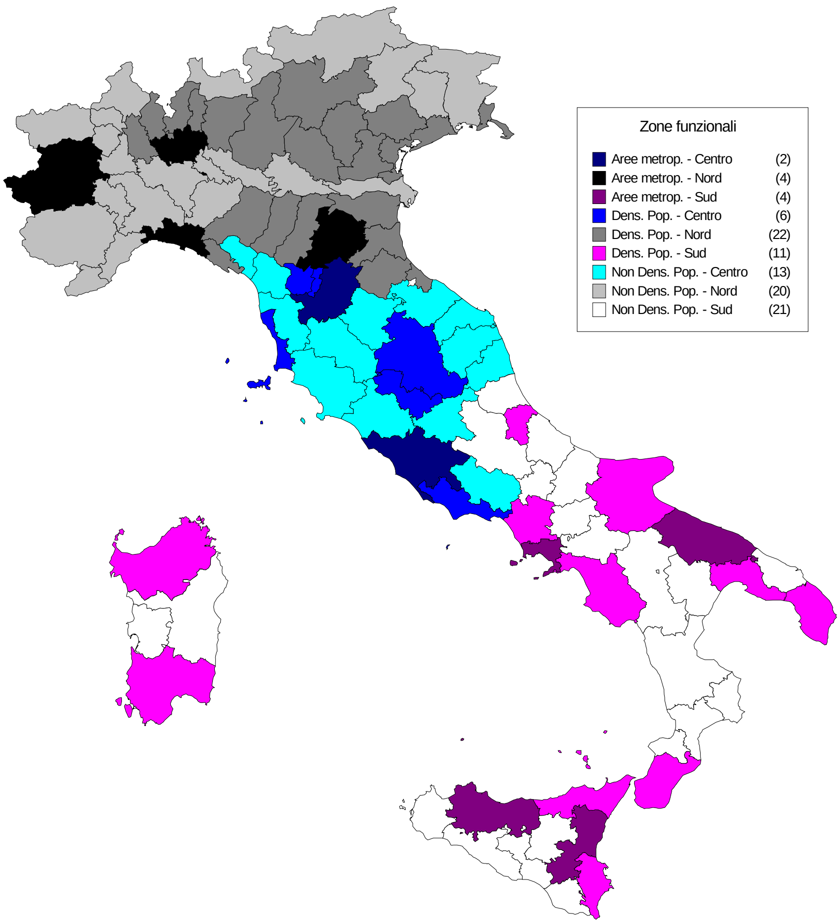

Figure 2 Italian macroregions and functional zones

Functional zones associate areas that – even if geographically far away from each other - share common settlement developments, transport supply levels, mobility patterns, etc. Given their definition, the functional zones have not a geographical meaning. However, modelling transport demand requires distinguishing short trips from long trips, at least because of different modal alternatives. For instance, slow modes are feasible alternatives if the distance of the trip is limited whereas, on the other side, air is not competitive under a threshold of hundreds kilometres. The concept of distance band is used to define a separate set of available modes for different distance class. In the distribution phase trips generated in a given zone (functional zone within a macro-region) are split among the available destinations defined as a zone in a distance band (e.g. trips from metropolitan areas of Northern Italy can be directed to high density areas within a distance band of 8-40 km or within a distance band of 40-160 km or over 160 km). Different distance bands are used for passenger trips (where very short distances are relevant) and for freight trips (where average distances are higher)

2.3. Modelling of transport supply

With reference to the modelling of transport supply constraints, and consequently of congestion, a synthetic representation was adopted by "collapsing" the links of the ideal detailed network in a single variable for each macro-region, where the capacities of such links were summed. At the same time, the traffic performed on the links was summed as well in order to have a comparable variable. The interaction between flow and capacity was therefore modelled by means of a single aggregate speed-flow curve for each macro-region.

The speed-flow curves adopted were then fine-tuned during the model calibration, as their form was necessarily different from those of curves used on single links. As the overall traffic of a region was involved, the average level of congestion was simulated. When the flow exceeds the capacity, the decrement of the average area speed is not as significant as it usually occurs when a single link is considered[1]

2.4. The fleet module

The fleet module simulates the composition of the various fleets (cars, motorcycles, Light Duty Vehicles, Heavy Duty Vehicles, buses). Vehicles are classified according to various elements: fuel type, cubic capacity, EURO standard. Other than in various groups, vehicles are divided by age. The model simulates a sort of conveyor where vehicles are transferred year by year from to an age class to the subsequent one and, after a maximum period of 20 years, are dropped out. Not all vehicles are used for the whole period of 20 years and a share of vehicles of is scrapped each year from each age class. In the car fleet module, which is the most sophisticated one, both the purchase rates and the scrapping rates are dependent on various elements: property tax, fuel price, income, etc.

The split of new vehicles among fuel type and cubic capacity classes is managed by means of fixed proportion calibrated on observed data. All vehicles purchased are assigned to the EURO standard in force for that year, for instance, all cars purchased from 2001 to 2005 are assigned to EURO III, from 2006 on all vehicles are assigned to EURO IV. One of the vehicle classes is dedicated to innovative vehicles. Within this category different technologies can fall, e.g. vehicles using methane or fuel cells vehicles. In the baseline scenario, it is assumed that in the earliest next years such innovative vehicles will be mainly based on the currently available

[1] This for the understandable reason that one link can easily subjected to congestion phenomena when traffic is almost stopped whereas a whole network cannot be congested in the same way

technology for mass production, e.g. methane vehicles, whereas fuel cells cars will start to enter the market later (from 2020 on). Such assumptions can be modified though the user interface for the construction of different scenarios.

2.5. The user interface and the policy tests

Several indicators are computed by the model to assess the effect of policies: transport volumes, modal split by purpose and distance classes, fuel consumption, vehicle fleet development, polluting emissions, external costs (on the basis of emissions, accidents, noise and congestion), etc. Indicators of the aggregated effect on economic variables are also produced.

A user-friendly interface allows to set up the alternative policy scenarios, run simulations and browse the results and to compare these with the model reference scenario. Alternative policy scenarios can be designed by activating different policy leverages for tariffs/taxes and subsidies.

- -Tariffs and/or taxes can be applied in terms of road pricing, park pricing, fuel taxes, car property taxes, airport and port taxes.
- -Subsidies can be used to reduce the user cost of various modes, to improve the level of service of urban public modes, to increase the market competitiveness of innovative road vehicles, to improve the logistics of freight transport.

3. The policy tests: technology development vs modal shift

The ASTRA-Italia model has been used to simulate two alternative policies aimed at reducing the external costs of transport. The two policies share the same set of instruments, that is the use of economic leverages (tolls, taxes, subsidies), and have a common objective: the reduction of the impact of transport on the society and the environment, without contrasting the passenger and freight mobility development. Tolls and taxes are applied to raise funds for the policies implementation and do not make reference to economic theories like the Social Marginal Cost Pricing or external costs internalisation.

The approach behind the two policies is different, as these reflect two alternative ways to manage the transport development: the first policy is pivoted around the role of technology progress, as the most promising mean of abating the undesired effects of transport without modifying the current individual habits; the second policy addresses a different model of mobility, where public modes of transport play a much more significant role than today.

In principle, there are no reasons to see these two ways of reducing the external effects of transport as alternative rather than complementary, but we believe that such two extremely different approaches could provide useful insights about the most effective strategy to be eventually adopted. Of course, it is hard to pretend to provide an exhaustive comparison, especially because of the considerable amount of uncertainty that currently exists concerning some key variables of technical development.

As for most of the modellers dealing with these subjects, explicit or implicit assumptions were indeed required about a set of issues like: the price of an innovative vehicle available on the market if a mass-production were started next year, how many vehicles could be reasonable produced, the cost of building a distribution network for innovative fuel, the cost for improving the capacity and the quality of public transport at the extent that it can actually attract the demand diverted from private road modes.

A different reason for taking with caution the outcome of the simulation is that the analysis is carried out at a strategic level while in local specific circumstances different conclusions could be drawn, for instance because the model does not take into account effects like the visual impacts of cars in the urban environment, or the need for wide spaces dedicated to parking areas.

In spite of these caveats, the main effects of policies are accounted for in the model and therefore the response of the simulation can be considered representative. It should be also noticed that the model can be readily updated to receive more founded assumptions and thus results could be further enhanced.

3.1. Description of the baseline scenario

The baseline scenario of the ASTRA-Italia model provides forecasts concerning the future level of transport demand and, therefore, of external costs in a "business as usual" approach. In other words, the baseline scenario is not an attempt of providing the more likely future level of the variables, but rather a picture of the development of the system under the assumption that its main driving variables evolve consistently to the trend observed in the recent past. In this respect the baseline scenario is a benchmark to compare alternative scenarios.

The baseline trend of transport demand is heavily dependent on economic growth and population change (see table 1). The growth of GDP is around of 0.6% per year, which might be regarded as rather conservative although it is consistent to the more recent pace of economic growth. Total population at 2030 is forecast to be about 3% lower than in 2005[2], nevertheless passenger demand will increase and will be 17% higher at 2030; freight demand growth is lower (+8%), thus reflecting the role of immaterial productions in GDP development.

Table 1. Key variables trend in the baseline scenario

	2005	**2010**	**2020**	**2030**	**Var. 2005-2030**	**Var. per year**
Socioeconomic variables						
Population (Millions)	58.5	58.8	58.4	56.9	-2.8%	-0.1%
GDP (Billions Euro)	1071.6	1107.4	1172.9	1253.9	17.0%	0.6%
Transport demand						
Passenger demand (Billions pkm)	887.7	925.3	988.5	1041.3	17.3%	0.6%
share of private modes (%)	79.7%	79.8%	80.2%	80.6%		
Freight demand (Billions tkm)	286.28	293.11	300.04	309.13	8.0%	0.3%
Share of road modes (%)	74.3%	74.0%	73.6%	73.4%		

Source: ASTRA-Italia model

Technology development of the vehicle fleet is assumed and therefore emission levels are expected to fall (see table 2), with the exception of SO_2 (which is exclusively due to non-road vehicles). It's worth to note that PM is abated by 67% with respect to 2005 level, and in urban areas the effect is even higher. However, even if technology can help in reducing externalities of transport, the growth of demand has negative effects in particular on accidents and noise. Table 3 shows the development of the main sources of externalities in the baseline scenario: the monetary value of emissions costs is almost halved at the horizon of 2030, but the cost of accidents rises of 30% (thus becoming the major source of external costs) and also costs of noise at 2030 is 15%

[2] The model does not deal with migration, which could be a major determinant of a different trend

higher than at 2005. The increment of costs is especially relevant for cars used for interurban trips.

Table 2 Evolution of transport emission in the baseline scenario (Tons*1000)

Total	**2005**	**2010**	**2020**	**2030**	**Var. 2005-2030**	**Var. per year**
CO_2	120,063	129,893	121,122	104,195	-40%	-2.0%
CO	3,774	3,051	2,403	2,258	-13%	-0.6%
NO_x	677	500	377	329	-51%	-2.8%
PM	22	13	8	7	-67%	-4.3%
SO_2	88	93	100	107	22%	0.8%
VOC	758	574	424	418	-45%	-2.4%
Urban						
CO_2	2,679	2,190	1,810	1,796	-33%	-1.6%
CO	42,497	46,057	40,652	33,959	-20%	-0.9%
NO_x	192	152	104	91	-52%	-2.9%
PM	9	4	2	2	-80%	-6.2%
SO_2	1	1	1	1	9%	0.3%
VOC	592	471	370	373	-37%	-1.8%

Source: ASTRA-Italia model

Table 3 Development of externalities components in the baseline scenario (Millions Euro/year)

Total	**2005**	**2010**	**2020**	**2030**	**Var. 2005-2030**	**Var. per year**
Emissions	32,645	25,021	19,650	17,056	-48%	-2.6%
Accidents	23,681	24,752	27,568	30,703	30%	1.0%
Noise	3,565	3,708	3,939	4,116	15%	0.6%
Total	59,891	53,481	51,157	51,874	-13%	-0.6%
Inter-urban passenger car	**2005**	**2010**	**2020**	**2030**	**Var. 2005-2030**	**Var. per year**
Emissions	8,022	5,945	4,626	3,904	-51%	-2.8%
Accidents	14,085	14,928	17,140	19,714	40%	1.4%
Noise	403	434	496	561	39%	1.3%
Total	22,510	21,307	22,262	24,179	7%	0.3%

Source: ASTRA-Italia model

3.2. Policy 1: introduction of innovative vehicles

The choice adopted in the first policy is to reduce transport externalities by boosting vehicle technology advancements, with special reference to road modes (cars, buses, duty vehicles, etc.). The policy is a mix of taxes and subsidies aimed at penalising the use of traditional road vehicles and improving the competitiveness of the innovative ones. Additional taxes are levied on conventional fuels, gasoline and diesel, while subsidies are used to allow to purchase and use innovative vehicles at a competitive cost (i.e. not higher than conventional vehicles'). The additional tax per litre has been proportioned to the overall fuel consumption in Italy, with the objective to collect the amount of money requested to subsidise households for purchasing innovative vehicles, given the price difference with respect to conventional ones. In other words, under the working assumption that an innovative vehicle costs 50% more than the average price of a conventional one, the amount of money required to subsidy this difference for, say, 10,000 new vehicles (cars, buses, light duty vehicles, heavy duty vehicles) per year has been computed.

In the context of this policy, innovative vehicles are considered as ZEV (Zero Emissions Vehicles, like fuel cells vehicles or equivalent technology). The assumptions concerning the price of the different type of vehicles at 2005, first year of policy application, are summarised in table 4. Such prices are assumed to decrease over time as the result of economy of scale, so that these will be halved at 2030.

Table 4 Assumed costs of conventional and innovative vehicles

Vehicle type	**Price of conventional vehicle (Euro)**	**Price of innovative vehicle (Euro)**
Car	9,500 – 36,500[1]	125,000
Van	25,000	150,000
Bus	125,000	1,125,000
Truck	150,000	1,450,000

The model simulates different conventional car types, the lowest and the highest price are reported

Prices of conventional vehicles have been drawn from price lists of various producers. Prices of innovative (fuel cells) vehicles have been assumed on the basis of available information: interviews with researchers and relevant literature including Arthur D Little (2001), Bennet (2003), Breakthrough Technologies Institute (2001), ICCEPT and UNEP (2002), James at al. (2002). As estimates were available for cars and buses only, the price of duty vehicles has been assumed taking the same price proportion between duty and passenger existing for conventional vehicles (vans vs. cars and trucks vs. buses).

It is apparent that price of innovative heavy vehicles looks very high, even though it should be considered that fuel cells technology is still at a very experimental stage and the efforts are focused on cars. Producing fuel cells duty vehicles and buses is even a more complex task, especially for the requirement of long fuel distance coupled with availability of load space. For this reason, the difference of price between conventional and innovative vehicles can be very high.

An additional element had to be considered before to estimate the size of the fuel tax required to subsidy the purchase of a given number of innovative vehicles. Bridging the price gap between innovative and conventional vehicles cannot allow in itself that the former are purchased. For the time being, innovative vehicles are not much more than prototypes and a mass-production to satisfy a significant demand could not be guaranteed. At the same time, the use of innovative vehicles requires, among other things, the availability of a fuel network to supply the innovative fuel. Such elements have been taken into account in an indirect way in the ASTRA-Italia model, assuming that even if the money raised by a given fuel tax would allow to subside the purchase of *n* vehicles, just *m* (lower than *n*) can be actually bought. The limit, i.e. the difference between *n* and *m*, is progressively reduced over the simulation period in order to represent the adaptation on the supply side. Resources raised by the fuel tax were divided in two tranches: part to subsidy households, firms and bus companies to purchase ZEVs and part to subsidy a) the national automotive industry to convert/add plants for mass-production of innovative vehicles and b) the fuel distribution network to convert/add stations for distributing innovative fuels.

Therefore, an additional tax of 0.12 Euro/litre has been set (the same tax applies to gasoline and diesel). Given that the total yearly vehicle fuel consumption in Italy (calculated in the model baseline for the first year of the application of the policy) is about 45 billion litres, a total approximate sum of 5 billions Euro can be raised (taking into account a reduction of fuel consumption, due to price elasticity of passenger demand). The number of innovative vehicles assumed as available for the purchase at the first year of application is reported in table 5 together with the subsidy per vehicle and the total subsidy. The difference between tax revenues and total subsidy, it is accounted (implicitly) as contribution for boosting the mass-production of innovative cars and implementing a fuel distribution network.

Table 5 Subsidies for innovative car at the beginning year (2005)

Vehicle type	Subsidy per vehicle (Euro)	Available vehicles at first year	Total subsidy (Millions Euro)
Car	100,000	15,000	1,500
Van	125,000	1,200	150
Bus	1,000,000	125	125
Truck	1,300,000	30	39

The fuel tax, and therefore the overall amount of subsidies, is endogenously reduced during the simulation to take into account that innovative vehicles enter in the market and therefore fuel consumption and external costs of transport decrease. Figure 3 shows the result of policy 1 simulation with reference to the fuel tax revenues. The effect on the fleet composition of the subsidies is shown in figure 4. Public transport companies are the most promising customers of innovative vehicles. The forecast is that at 2030, about 70% of bus fleet is made of innovative vehicles. Also for the car fleet the renewal rate is significant: almost one half of the fleet is forecast to be composed of innovative vehicles at 2030. For commercial vehicles, and above all Heavy Duty Vehicles, the introduction of fuel cells vehicles in the fleet takes place at a slower pace. This is reasonable as the technical challenge towards mass-production of fuel cells trucks is even more demanding than for cars.

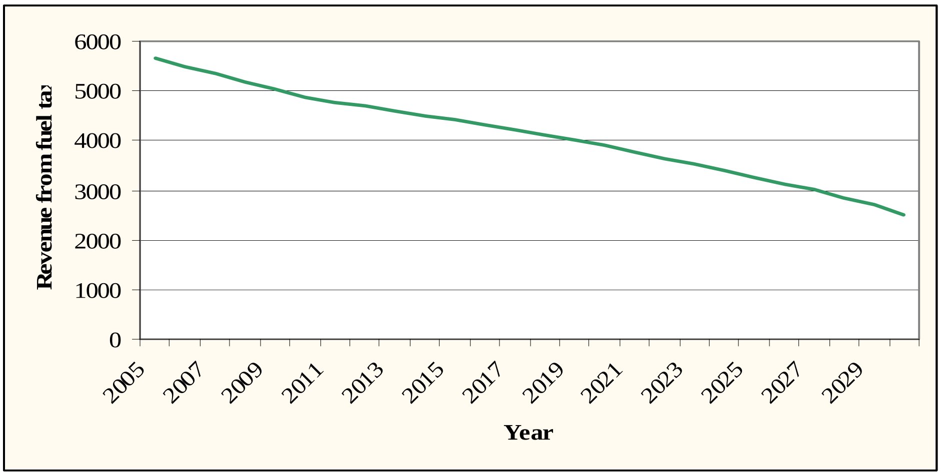

Figure 3 Trend of fuel tax revenues in policy 1

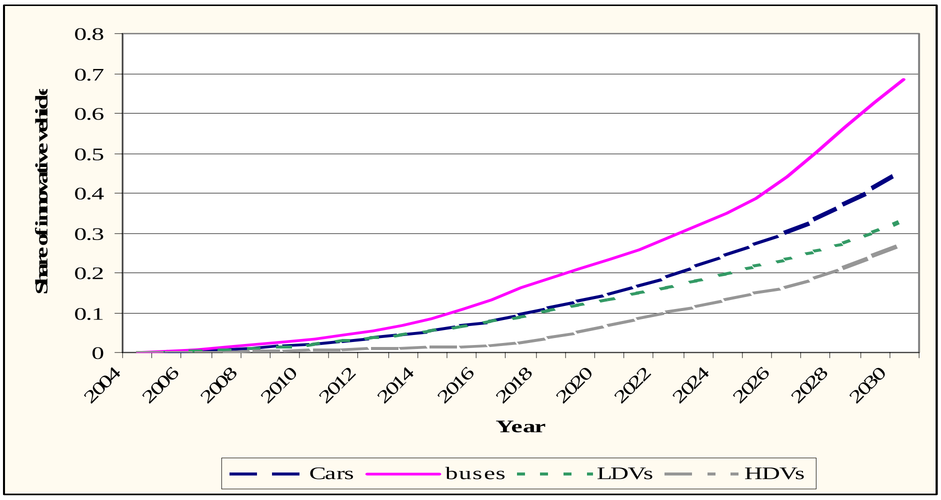

Figure 4 Share of innovative vehicles in the fleet

3.3. Policy 2: modal shift

The second policy simulated is focused on modal shift from road private modes to non-road and public modes (excluding air transport) to reduce the external effects of transport. A pricing policy is applied on interurban roads and resource are used to subsidies bus companies, railways, sea shipping in order to improve the level of service and attract demand from road modes of transport.

The major source of uncertainty in such a policy is how additional public resources could be used by public transport operators which are already heavily subsidised. Indeed, in Italy, like in many other countries, public transport and rail freight transport receive public money to cover their costs[3]. Thus the working assumption adopted was that part of the subsidy is used to reduce fares and another part is used for investments in organisation, infrastructures, rolling stock, services, etc. Furthermore, part of the revenues is to cover the costs of the tolling system that has to be extended to currently non-tolled roads.

ASTRA-Italia includes explicitly transport fares for all modes and therefore the effect of tariffs reduction has been readily translated in a model input. The basic idea is that for a given sum available as an additional subsidy, the tariff is reduced at the extent that the lower revenues are paid off by the subsidy[4]. The improvement of urban public transport quality is also modelled in terms of reducing trip times in urban areas. On the other side, the model does not simulate the internal organisation of public transport companies. As well, the detail of the model allows simulating the use of resources to increase supply only in implicit terms. Also implicit is the need for extending the tolling system. In brief, the mechanism is the same for policy one: even if with a given amount of revenues from the road pricing tariffs could be reduced of an amount x the reduction applied is y ($y < x$), the residual amount of resources is considered as used for enhancing public transport supply and for setting-up a tolling system.

In order to size the road pricing, it has been considered the target of an average reduction of 25% of non-road public modes plus the amount of money required to improve supply. Given the

[3] Over 18 billions Euro in 2001 (CNT, 2001)

[4] For instance, if the subsidy is 200 Millions Euro it is computed the fare reduction which would produce a revenue loss of 200 Millions Euro.

current fares and the current overall revenues of non-road modes the sum required to reduce fares by 25% has been computed in 5 Billions Euro per year. At the same time, as the current level of investments in non-road modes services and infrastructures (excluding airports) in Italy is of about 11 billions Euro (over 50% of this expense concerns rail), it has been assumed that, in order to provide a significant enhancement of supply, to improve the quality of service and to cover the cost of extending the tolling system to all the main inter-urban roads, an additional investment of 10 billions Euro was needed.

To collect the overall sum of 15 billions Euro a specific toll has been defined for each road mode on the basis of the observed volume of traffic and of an elasticity of demand derived from a series of modelling test. Tolls are supposed to be levied on all motorways and trunk roads and are kept unchanged over the whole simulation period (table 6).

Table 6 Road tolls envisaged in policy 2

Road mode	**Toll (Euro/veh-km)**	**Expected revenue (Million Euro)[1]**
Cars	0.05	8,900
Duty vehicles	0.25	5,300
Buses	0.07	250
Motorcycles	0.02	200
Total		14,650

1 The expected revenue takes into account demand elasticity

For instance, if the subsidy is 200 Millions Euro it is computed the fare reduction which would produce a revenue loss of 200 Millions Euro.

Despite such an investment, the amount of demand diverted from road modes is quite limited (table 7): just 5.5 percentage points of modal shares for passenger and less than one percentage point for freight. This result seems to be a consequence of the transport demand rigidity.

Table 7 Development of road modes share in policy 2

Passengers	**2005**	**2010**	**2020**	**2030**
Baseline	79.8%	79.9%	80.2%	80.6%
Policy 1	79.8%	79.5%	80.4%	81.7%
Policy 2	74.4%	74.2%	74.5%	74.9%
Freight				
Baseline	47.3%	47.5%	48.0%	48.5%
Policy 1	47.3%	47.2%	47.7%	48.4%
Policy 2	46.6%	46.7%	47.2%	47.6%

4. The policies comparison

Both policies are of benefit with respect to the baseline, but with different paths, as can be seen in figure 5, where overall external costs are compared to the transport baseline. The external costs include air pollution, climate change, accidents and noise.

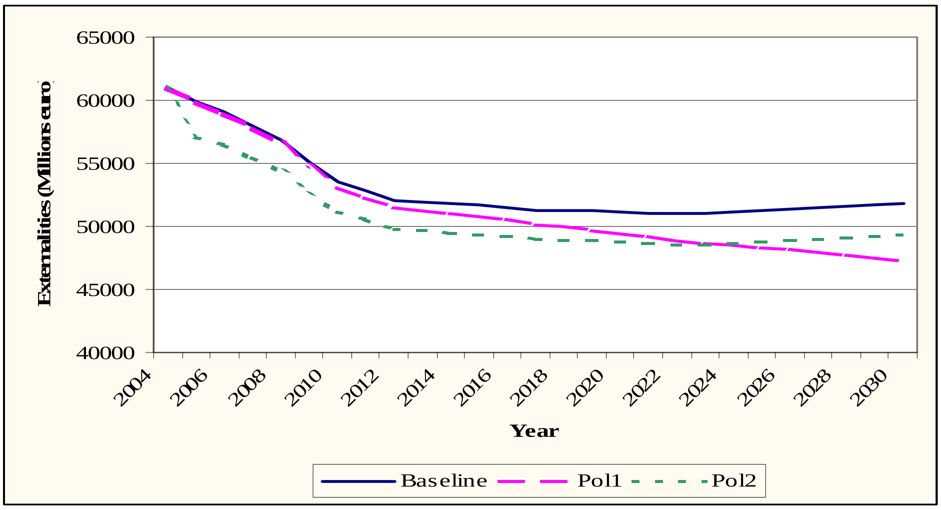

Figure 5 Total external costs in the alternative scenarios

In the baseline it is forecast a decrement external costs due to the automatic renewal of the road vehicle fleet. This effect ends in mid ’20s and afterwards external costs tend to grow again. Policy 1 has little or no effect for the first 5 years. From 2010 on the growing share of fuel cells vehicles on the fleets begins to give rise to a significant reduction of the external costs. At the end of the simulation period (2030) the difference amounts to about 4.5 Billions Euro. Policy 2 is more effective in the shorter terms: at 2005 total external costs are lowered by about 2.8 Billions Euro. However, this advantage is not further improved in the following years, instead it remains more or less constant.

As the assumptions concerning the initial price of innovative vehicles – as well as the speed of reduction of such a price once mass production of innovative vehicle is started – is a crucial input of policy 1, in the course of the simulation the sensitivity of the results to different assumptions has been tested. The outcome of such tests is that the overall results in term of externality reduction are quite robust. For instance, if the price of innovative vehicles decreased 50% faster than originally assumed, the amount of externalities at 2030 would differ by 2.5% with respect to the values documented here.

Table 8 summarises the development of the different components of external costs in the three scenarios. External costs due to emissions are further reduced by policy 1 with respect to baseline: emissions external costs at 2030 are almost one third of 2005. Policy 2 is much less effective in this respect.

Costs of accidents increase due to the increment of demand in all scenarios. Policy 2, shifting demand from road modes to non-road modes, allows a reduction of such costs (about 7% less). Instead, policy 1 has a slightly negative effect on accidents. Indeed, using zero-emissions vehicles does not allow to avoid road casualties. Furthermore, subsidies to new vehicles have the effect of increasing the motorization rate and therefore overall road transport demand is slightly higher and so are the accidents.

Noise does not change significantly in the three scenarios. Actually, this is a drawback of the model as innovative vehicles should be much less noisy than conventional one and therefore we should see a decrement of noise costs in the policy 1 scenario.

Table 8 Development of externalities components in the alternative scenarios (Millions Euro/year)

Externality component	**Scenario**	**2005**	**2010**	**2020**	**2030**	**Var. 2005-2030**	**Var. per year**
	Baseline	32,645	25,021	19,650	17,056	-48%	-2.6%
Emissions	Policy1	32,627	24,630	17,785	11,577	-65%	-4.1%
	Policy2	31,529	24,441	19,200	16,751	-47%	-2.5%
	Baseline	23,681	24,752	27,568	30,703	30%	1.0%
Accidents	Policy1	23,683	24,688	27,742	31,499	33% 30%	1.1%
	Policy2	22,018	23,073	25,683	28,559		1.0%
	Baseline	3,565	3,708	3,939	4,116	15%	0.6%
Noise	Policy1	3,565	3,700	3,939	4,141	16% 16%	0.6%
	Policy2	3,481	3,641	3,862	4,027		0.6%
	Baseline	59,892	53,481	51,157	51,874	-13%	-0.6%
Total	Policy1	59,875	53,018	49,466	47,217	-21% -	-0.9% -
	Policy2	57,028	51,155	48,745	49,337	13%	0.6%

Table 9 Evolution of overall transport emission in the alternative scenario (Tons*1000)

Pollutant	**2005**	**2010**	**2020**	**2030**	**Var. 2005-2030**	**Var. per year**
	3,774	3,051	2,403	2,258	-40%	-2.0%
CO	3,771	3,023	2,147	1,338	-65%	-4.1%
	3,599	2,916	2,307	2,170	-40%	-2.0%
	120,063	129,893	121,122	104,195	-13%	-0.6%
CO_2	119,941	127,216	109,317	68,671	-43%	-2.2%
	114,876	124,741	116,116	100,262	-13%	-0.5%
	677	500	377	329	-51%	-2.8%
NO_x	677	497	354	253	-63%	-3.9%
	648	491	377	333	-49%	-2.6%
	22	13	8	7	-67%	-4.3%
PM	22	12	8	5	-75%	-5.4%
	21	13	8	7	-65%	-4.1%
	88	93	100	107	22%	0.8%
SO_2	88	95	102	107	21%	0.8%
	95	102	109	117	23%	0.8%
	758	574	424	418	-45%	-2.4%
VOC	757	570	380	260	-66%	-4.2%
	731	557	413	407	-44%	-2.3%

So, policy 1 is the most promising in the long term mainly thanks to the reduction of external costs of emissions. Table 9 shows the trend of emissions in the different scenarios. The most significant contribution of fuel cells vehicles concern CO and CO_2, which are almost halved in policy 2 with respect to the baseline. SO_2, which depend entirely on non-road vehicles is not reduced in policy 1 and it is even increased in policy 2 as the share of non road modes grows.

It should be considered that we assumed the current level of emissions of non-road modes over the whole simulation period. If significant improvements on this side could be achieved, the benefit of policy 2 would be higher.

Eventually, it is useful to have a look at the different impact of the two policies on the Gross Domestic Product (table 10): as it could be expected, the impact is small, but both policies show a positive effect on GDP, due to the stimulated investments in the vehicle building sector or in the non-road transport services. Specifically, in the policy 1 scenario, GDP at 2030 is 2.7% higher than in the baseline scenario. In the policy 2 scenario GDP is higher by 1.3%.

Table 10 Evolution of GDP in the alternative scenarios (Billions Euro)

Scenario	2005	2010	2020	2030	Var. 2005-2030	Var. per year
Baseline	1,071.6	1,107.4	1,172.9	1,253.9	17%	0.6%
Policy 1	1,071.7	1,112.0	1,185.1	1,288.1	20%	0.7%
Policy 2	1,074.9	1,122.3	1,190.3	1,271.5	18%	0.7%

5. Conclusions

This paper presents the application of the ASTRA-Italia model to test two alternative policies aimed at reducing the impact of transport externalities using economic leverages to pursue their objective.

Although the simulations required several assumptions to deal with uncertainty on technological developments and the aggregate nature of the model, the outcome is of some interest.

Both policies are effective, although the size of externality reduction is not huge. Policy 1, who stakes on technology, provides the best results in the longer terms: at 2030 externalities are reduced by 9% (4.5 Billions Euro) with respect to the baseline. Policy 2, which aims at shifting demand on non-road modes, is able to produce a 5% reduction at the same year even though it results is more effective in the shorter terms.

The simulations suggest that a relatively small tax added to the fuel price (a policy instrument which has the advantage of not having cost for its administration) can raise enough money to support a radical renewing of road vehicle fleet with increasing advantages in terms of external costs. Additionally, the outcome of the simulation suggests that the aim of reducing externalities by means of a modal shift has to tackle against the rigidity of road demand. In principle a higher level of road pricing (or coupling road pricing to a fuel tax) could generate a more relevant result, however in the test we wanted to simulate a socially acceptable threshold of taxing; unbelievable levels of tolls would undermine the sense of the test. Furthermore it should be considered that policy 2 should have much higher costs of implementation.

On the other side it should also be said that the results of the simulation do not take into account some sources of external cost like congestion and visual intrusion, which would not be reduced by policy 1. However, as the modal shift obtained by policy 2 is small, it should not be expected that it could contribute significantly to reduce this kind of external costs.

Summing up, from the comparison of the two policies by using the ASTRA-Italia model, the most promising alternative to smooth transport externalities without reducing mobility seems to be the technological one.

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