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Estimating External Costs of Transportation in Regional Areas[1]

La stima dei costi esterni di trasporto a scala regionale

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In questa nota si propongono delle metodologie semplificate per la stima dei costi esterni prodotti dai sistemi di trasporto in ambito regionale, che possono essere utilizzate basandosi sui dati statistici disponibili per le diverse regioni italiane, senza la necessità di predisporre apposite indagini.
Queste metodologie consentono di ottenere una stima preliminare dei costi esterni principali, utile per valutare piani, politiche e progetti di sistemi di trasporto.
Nella nota, dopo un esame dello stato dell'arte delle metodologie per la stima dei costi esterni proposte in ambito internazionale e degli studi sviluppati sull'argomento, si stimano i costi esterni principali (emissioni di gas serra, inquinamento atmosferico, inquinamento acustico, incidentalità e congestione) prodotti dai sistemi di trasporto in Regione Campania.
In particolare sono stati stimati i costi esterni prodotti non solo dal traffico stradale, che comunque risulta essere il principale "colpevole", ma anche dal trasporto ferroviario ed aereo.
I risultati ottenuti nell'ambito della Regione Campania hanno mostrato come l'entità dei costi esterni non sia trascurabile in rapporto al PIL regionale e come i costi esterni di maggiore entità risultino essere quelli ambientali: inquinamento acustico, inquinamento atmosferico ed emissioni di gas serra.
I risultati ottenuti hanno mostrato la rilevante incidenza dei costi esterni e la necessità che essi siano correttamente ed opportunamente valutati ogniqualvolta si investono soldi pubblici in progetti di miglioramento dei sistemi di trasporto.

Introduction

Transportation system costs are generally classified in three main groups: the service production costs, the user costs and the external costs.
The service production costs are borne by public bodies, (state-owned or private) enterprises or local authorities as regards the maintenance and construction of infrastructures (roads, highways, railways, stations, airports, etc.), and by (state-owned or private) transit companies as regards the purchase and maintenance of transit vehicles (buses, trains, airplanes, etc.) and as regards the management of transit systems (employees, fuel, overheads, taxes, insurance costs, other running costs, etc.).
The costs borne by users of transit systems are mainly private car purchasing, maintenance costs, fuel, highway fares, transit fares, parking fares, etc.
The external costs, instead, even if are produced by running and use of transportation systems, are borne by the whole community; indeed, also who does not use the transportation system bears these costs.
It is important to note that also a (great) part of the service production costs (e.g. infrastructure maintenance and construction costs of public roads and public subsidies to transit systems) are borne by the whole community; these costs are already (totally or in part) internalised in the transportation system since it can be assumed that they are covered by the taxes on fuel (excises) and on vehicles (road taxes) that are paid by the users. If these taxes cover more than the amount of these costs, the difference can be seen as a partial internalisation of external costs; vice versa, if these taxes cover less than the amount of these costs the difference should be summed to external costs. The external costs usually considered are sometime called social costs, since they impact on the society and represent the externalities of the transportation system.

The externality concept assumes an important role inside the classic microeconomic theory and it has been widely discussed in the literature since 1920 (Pigou 1920; Scitovsky 1954; Buchanan and Stubblebine 1962; Baumol and Oates 1988). Some specific studies about transportation externalities are the ones by Verhoef (1996) and Green et al. (1997).

The externalities produced by transportation systems can be negative (e.g. air and noise pollution) or positive (e.g. a new metro line that improves the value of buildings in its influence areas); in the following the paper will focus on the main negative externalities of transportation systems.

Examining the different definitions, it can be summarised that a negative externality is a cost that is produced by subject A and is borne by subject B; moreover, subject A does not consider the effects of his/her behaviour on subject B and does not compensate subject B for the costs that this last one is forced to bear.

In the field of transportation systems, in general, subject A represents the users and subject B represents the whole collectivity.

Beginning from '90 the interest for the external cost evaluation produced by transportation systems is really increased, mainly for the numerous studies on the effects produced by greenhouse gas emissions on climate changes. The importance of evaluation of external costs has been highlighted in several documents of international and communitarian policy (European Commission 2001; United Nations 2005). In particular, the European Union has promoted and financed several research projects in this field (EXTERNE 2005; COPERT 2005; UNITE 2005). The Kyoto Protocol, to which the European Community countries agreed, indicates the greenhouse gases reduction objectives; in this context, transportation systems are one of economic sectors with the higher impact on emissions.

Therefore, estimating external costs assumes an important role inside the evaluation of transportation projects, plans and policies.

The aim of this paper is to propose some simplified procedures for estimating the main transportation external costs in regional areas, using available national and/or regional statistical data, without the need of specific surveys, and the results of other specific studies on external costs developed in Italy and in Europe.

The proposed procedures are applied to the region of Campania (Italy), but they can be applied without difficulties to other regions in Italy and, if the data are available, also to regions of other European Countries. Since the proposed procedures are based on some simplifying assumptions, that are not removable without specific (expensive) surveys, the obtained results should be seen as an approximate estimation of external costs useful in preliminary studies. This paper will focus only on the methods for estimating the main external costs without examining how part of them are eventually already internalised (if there is a positive difference between taxes paid by users and service production costs); this problem will be object of further researches.

The outline of the paper is the following: section 2 focuses on definitions and literature review, identifying the main and the secondary transportation external costs, the kinds of external costs (total, medium or marginal) and some studies about their estimation; in section 3 methods for estimating the main total external costs (greenhouse gas emissions, air pollution, noise, accidents and congestion) using the statistical data available for Italian Regions are proposed and are applied to the case of the region of Campania; section 4 discusses the obtained results; section 5 summarises conclusion and research perspectives.

Definitions and literature review

The external costs produced by transportation systems can be classified in two groups: main costs and secondary costs. The main costs are the ones that are quantitatively prominent and that have been studied in the literature more or less widely. The secondary ones are the costs that produce less important and/or not easily quantifiable effects; in general, they have not been studied systematically.

The main external costs are due to:

– *greenhouse gas emissions*; the greenhouse gases (CO_2, CH_4, H_2O, N_2O, O_3, etc.) are naturally present in the atmosphere and, therefore, are not assumed as pollutants from a technical point of view. The high concentration of these gases (mainly the CO_2) increases the greenhouse effect, producing an increase in the average temperature of the planet, with serious climatic consequences.

– *air pollution*; transportation engines emit in the atmosphere some pollutants (SO_2, NO_x, PM10, CO, etc.). An high concentration of these gases cause damages to human health, buildings and cultivations.

– *noise*; transportation systems are noise sources. Besides disturbance, the noise produces health damages to residents in the more exposed zones.

– *accidents*; transportation accidents, mainly caused by road systems, are an important social problem. The costs produced by accidents are almost totally assumed as external, because the users do not perceive the accident risk and because the accident costs fall prevalently on collectivity (e.g. pain and suffering imposed to others).

– *congestion*; the increment of transportation costs due to congestion is not captured by the price system so the congestion costs are assumed as external, even if they are borne by users; they can be estimated by quantifying the users' lost time.

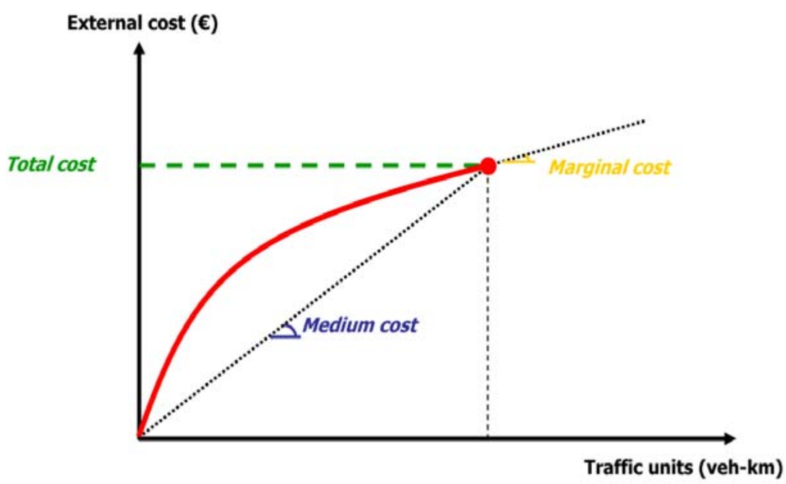
The secondary external costs are numerous; the most important are: water and soil pollution; landscape and nature damages; upstream and downstream effects; visual intrusion; separation effects; soil occupancy. In this paper only the main external costs will be examined.

Depending on the aim of the study, the externalities can be calculated as total, medium or marginal costs. The total cost is the total amount of externalities produced by the transportation system, the medium cost represents the external cost per traffic unit (veh-km, pass-km, t-km) and the marginal cost is the external cost due to a unitary increment of traffic unit in the system; the second one is the ratio between total cost and total traffic units, while the third one is the derivative of total cost function with respect to traffic unit. The figure above depicts the differences among the three kinds of cost. This paper will focus on the calculation of total costs.

In the literature several studies deal with the estimation of external costs. The Green Paper of European Commission (1995) reports in the Annex 2 a brief exam of approaches that has been proposed for valuating the external costs in monetary terms.

Some studies do not propose analytical methods but only some suggestions for estimate the external costs (EMT 1998; Nash 1999). Other studies refer to national (Proost and Van Dender 1999) or European corridor (Nash 2000) case studies. Marginal cost estimation is studied in the European research projects RECORDIT (2005), as regards the freight transportation, and UNITE (2005) in more general terms; the marginal external costs in urban areas are studied in the paper by Mayeres et al. (1996). Estimation of external medium costs is studied by Dings (1991), for the air transport, and by Maibach and Schneider (2002) for the main transport modes.

Total, medium and marginal costs.



A recent study (INFRAS/IWW 2004) estimates the total external costs of transportation systems in 17 European countries (15 European Union countries plus Norway and Switzerland). This study considers, besides the main 5 costs before mentioned, also the nature and landscape costs, the upstream and downstream costs and the urban effects due to the barrier effect for pedestrians and cyclists. The estimated total amount of these costs overcomes 650 billion € per year, equal to the 7.3 % of European GDP. The road system is the main guilty (83.7 %), followed by air system (14.0 %), rail system (1.9 %) and maritime system (0.4 %). This study gives also some results about medium and marginal costs.

Quinet (2004) compared different studies proposed in the literature, using the meta-analysis, and highlighted the wide dispersion of results, due to specific differences among the different contexts (economics, social, etc.), to the different kinds of costs considered, to the different assumptions introduced in the estimation mathematical models and to the unitary values given to some important parameters (value of life, value of time, etc.).

External cost estimation

In this section the main total external costs due to transportation systems are estimated for the region of Campania, using simplified methods based on available statistical data and on the results of national and European studies; all costs are estimated at year 2003. The proposed methods can be easily used for estimating the external costs also for other Italian regions and, if all data are available, for regions of other European countries.

In general, the external costs produced by road, rail and air transportation are estimated. For accidents and congestion only the external costs due to road transportation are examined; indeed, this mode causes the greater part of these costs.

In the estimation of air pollution costs only the effects on human health are considered, neglecting the effects on buildings and cultivations.

The outline of the section is the following: subsection 3.1 gives some information about the region of Campania; in subsection 3.2 some important parameters that influence the external cost estimation are examined (value of time and value of life) and a method for estimating the veh-kms is proposed and applied to the region of Campania; subsections 3.3, 3.4, 3.5, 3.6 and 3.7 propose simplified methods for estimating external costs due to greenhouse gas emissions, air pollution, noise, accidents and congestion respectively, and report the results obtained for the region of Campania; the results are summarised in section 3.8.

The region of Campania

The region of Campania is sited in the south of Italy and is the second Italian region (after Lombardia) as regards the population (5,701,931 inhabitants); it is the Italian region with the high population density (419 inhabitants/km^2) since it has a surface of 13,595 km^2. The chief town is Naples that has 1,004,500 inhabitants (the third in Italy as regards the population after Rome and Milan) with a very high population density equal to 8,566 inhabitants/km^2.
The road network of the Campania region is constituted by 445 km of motorways, 2,660 km of national roads, 6,927 km of provincial roads and 41,739 km of municipal roads (of whom 19,119 km are extra-urban). The regional rail network is constituted by 1,210 km of railway lines (of whom 528 km of double tracks); other 153 km of railway lines are under construction.
The railway extra-urban services are about 18 million train-km per year; the MetroCampania project will provide at 2010 an increment of services until 31 million train-km per year (Regione Campania 2002). The public bus services produce 343 million bus-km per year. Napoli Capodichino international airport manages about 2.3 million passengers per year (ENAC 2005). The GDP (Gross Domestic Product) of Campania region is 87,817.1 millions € at year 2003.

Value of Life, Value of Time and road veh-km estimation

The methods for estimating the external costs require, among other things, the following important input data: the Value of Life, the Value of Time and road veh-km/year (total road traffic). The entity of the Value of Life (VOL) influences highly the external cost estimates due to air pollution, noise and accidents. In the literature several authors studied the problem of estimating the VOL; a recent literature review (de Blaeij et al. 2003) shows as the values adopted in different studies are very disperse: from 113,000 € to 24,000,000 €.
In this paper, it is adopted as reference value the one proposed by two recent studies developed in Europe (INFRAS/IWW 2004; UNITE 2005); they proposed to adopt, for the year 2000, the value of 1,500,000 €, to adapt to the specific socio-economic condition using the pro-capita GDP. The value adopted in this paper, therefore, it is calculated taking account that the average pro-capita GDP in Campania is the 71.9 % of the average one in Europe and that it has been incremented between 2000 and 2003 (at current prices) by 15.2 % (ISTAT, 2005a). So, the adopted VOL is 1,242,545 €. The formula used for estimating the regional VOL is the following:

$$VOL_R = 1{,}500{,}000€ \times (GDPPC_R^{2000} / GDPPC_E^{2000}) \times (GDPPC_R^{2003} / GDPPC_R^{2000})$$

where
VOL_R is the regional Value of Life (€);
$GDPPC_R^{2000}$ is the regional Gross Domestic Product Pro Capita (€/inhabitant) at year 2000;
$GDPPC_E^{2000}$ is the european Gross Domestic Product Pro Capita (€/inhabitant) at year 2000;
$GDPPC_R^{2003}$ is the regional Gross Domestic Product Pro Capita (€/inhabitant) at year 2003.

The VOL can be seen as a shade-variable that represents policy choices; so, in the evaluation of transportation plans or policies can be chosen higher (or lower) values in function of the importance that policy makers would give to transportation safety and environment. The Value of Time (VOT) generally it is assumed different for each trip reason; in this paper we adopt the values proposed in a research developed in Italy (ENEA 2003) that fixes 7.74 €/h for job/study trips and 1.93 €/h for other trips. Obviously, for each country or region it should be adopted the value that represents in the best way the specific socio-economic conditions. The estimation of external costs due to greenhouse gas emissions, air pollution and congestion requires the road veh-kms/year as input data; the veh-kms/year have to be subdivided for different vehicle category and for different kinds of roads. These data are not directly available from national statistical sources at regional level for Italy, except for (urban and extra-urban) buses, which data are available by contracts between public transit firms and local authorities. Therefore, it is necessary to provide a method for estimating these values, using other available statistical data. For estimating the veh-kms/year in Campania, the ACI (2005a) database was used; this database reports for each Italian region the circulating vehicles subdivided by the COPERT (2005) classification. Therefore, it is possible to know the number of vehicles by kind of vehicle (motorcycles, cars, trucks, etc.), by kind of fuel (petrol, diesel, gas, etc.), by kind of piston displacement (under 1.4 litres, between 1.4 and 2.0 litres, over 2.0 litres) and by kind of European antipollution regulations (ECE, EURO I, EURO II, etc.).
This database does not contain data on scooters and motor bicycles (under 0.05 litres), since they are not registered in Italy; the number of these vehicles is estimated using the data estimated by ACI and ISTAT (2004) for Italy: 5,076,413 motor bicycles at year 2003. Assuming that the percentage of motor bicycles in Campania in comparison

with the total in Italy is equal to the corresponding percentage of motorcycles (obtaining by ACI data), it is possible to estimate 453,739 motor bicycles. The next table summarises data on circulating vehicles aggregated by kind of vehicle and kind of fuel. The buses are not considered since their veh-kms are deducible by contracts between transit firms and local administrations. A research developed by APAT (2005a) reports an estimation of average yearly distances covered in Italy by each kind of vehicle and the percentage of these distances on urban roads, extra-urban roads and motorways; these has been estimated for being used inside the COPERT model. Since the yearly distances covered are average values for Italy, in order to improve the estimation's precision, they have been corrected taking in account the yearly average fuel (petrol, diesel and gas) consumption per vehicle in Italy and the same value in Campania (data available by ACI, 2005b). This correction leads to reduce the average distances covered by petrol vehicles of 20 % and by diesel vehicles of 22 %, and to increase them of 22 % for gas vehicles. Therefore, the formula adopted for estimating veh-kms/year in a region is the following:

$$VKM^R_j = VEH^R_j \times ADC^{IT}_j \times ACON^R_j / ACON^{IT}_j$$

where

VKM^R_j indicates the estimated veh-kms/year in the region for the kind of vehicle j;

VEH^R_j indicates the number of circulating vehicles of kind j in the region;

ADC^{IT}_j is the average yearly distances covered by vehicles of kind j in Italy;

$ACON^R_j$ is the average yearly fuel consumption per vehicle of kind j in the region;

$ACON^R_j$ is the average yearly fuel consumption per vehicle of kind j in Italy;

It is necessary to specify that the veh-kms so estimated are the ones produced by Campania vehicles even if a part of them is performed outside the region; moreover, some veh-kms on the Campania's roads are generated by outside vehicles. These errors can be considered acceptable because in part they compensate each other and in part because the external costs regard the whole society (also the inhabitants of other regions). The previou table summarises the results of the veh-kms estimation.

Vehicle	Veh-km/year (Urban)	Veh-km/year (Extra-Urb.)	Veh-km/year (Motorways)	Veh-km/year (Total)
Petrol cars	7,047,620,872	8,382,280,084	951,420,454	16,381,321,410
Diesel cars	1,552,923,762	5,956,232,646	3,499,115,802	11,008,272,210
Gas cars	1,153,698,649	1,538,264,865	1,153,698,649	3,845,662,162
Not identified cars	970,243	1,325,535	619,399	2,915,177
Total	*9,755,213,526*	*15,878,103,129*	*5,604,854,304*	*31,238,170,959*
Petrol light trucks (under 3.5 t)	59,646,100	131,221,420	47,716,880	238,584,400
Diesel light trucks (under 3.5 t)	597,820,698	1,315,205,535	478,256,558	2,391,282,790
Petrol heavy trucks (over 3.5 t)	1,117,120	3,351,360	1,089,192	5,557,672
Diesel heavy trucks (over 3.5 t)	361,953,813	1,172,682,537	1,441,247,730	2,975,884,080
Not identified trucks	66,055,509	184,646,489	140,368,892	391,070,890
Total	*1,086,593,239*	*2,807,107,341*	*2,108,679,252*	*6,002,379,832*
Motorcycles	1,421,626,530	829,282,143	118,468,878	2,369,377,550
Motor bicycles	1,429,277,563	612,547,527	0	2,041,825,090
Total	*3,463,451,620*	*1,441,829,669*	*118,468,878*	*4,411,202,640*
Buses *(contracts 2003)*	107,168,422	236,272,317	0	343,440,740
Total	*107,168,422*	*236,272,317*	*0*	*343,440,740*

Estimation of veh-km/year in Campania.

Circulating vehicles in Campania (elaboration of data by ACI, 2005a).

Vehicle	Number
Petrol cars	2,312,050
Diesel cars	740,670
Gas cars	165,865
Not identified cars	428
Total	*3,219,013*
Petrol light trucks (under 3.5 t)	25,111
Diesel light trucks (under 3.5 t)	171,149
Petrol heavy trucks (over 3.5 t)	1,142
Diesel heavy trucks (over 3.5 t)	89,664
Not identified trucks	19,624
Total	*306,690*
Motorcycles	391,130
Motor bicycles *(estimation)*	453,739
Total	*844,869*

Greenhouse gas emissions

Earth's atmosphere is composed of several gases; the more important are oxygen (O), carbon dioxide (CO_2) and water steam (H_2O). Other gases present in the atmosphere are methane (CH_4), nitrogen protoxide (N_2O) and ozone (O_3) that are produced by natural sources, and other artificial compounds. The carbon dioxide and the water steam are the gases that produce the greenhouse effect, that makes it possible that the sun energy, which arrives on the Earth, is not entirely dispersed towards the space, allowing that the average temperature of the planet is about 34° C. Without the greenhouse effect the life should not be possible on the Earth. In last decades, the excessive production of carbon dioxide by industries, combustion engine vehicles, thermoelectric power stations and houses (heating) have been increased the CO_2 concentration in the atmosphere, causing the well-known global warming (increase of the average temperature of the planet). This

Vehicle	Urban roads [g/veh-km]			Extra-urban roads [g/veh-km]			Motorways [g/veh-km]		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Petrol cars	279.435	0.278	0.030	141.703	0.032	0.012	175.674	0.019	0.027
Diesel cars	262.170	0.009	0.027	150.297	0.005	0.027	188.823	0.013	0.027
Gas cars	230.325	0.109	0.015	134.863	0.033	0.015	173.037	0.023	0.015
Not identified cars	270.878	0.215	0.028	144.264	0.022	0.018	183.341	0.016	0.025
Petrol light trucks (under 3.5 t)	470.821	0.291	0.024	201.115	0.034	0.010	200.860	0.020	0.017
Diesel light trucks (under 3.5 t)	355.668	0.010	0.017	197.794	0.005	0.017	262.248	0.005	0.017
Petrol heavy trucks (over 3.5 t)	699.645	0.140	0.006	466.430	0.110	0.006	513.073	0.070	0.006
Diesel heavy trucks (over 3.5 t)	975.521	0.126	0.030	604.087	0.051	0.030	689.209	0.053	0.030
Not identified trucks	582.618	0.068	0.022	379.985	0.027	0.022	573.530	0.041	0.027
Buses	975.521	0.126	0.030	604.087	0.051	0.030	-	-	-
Motor bicycles	99.388	0.203	0.001	99.388	0.203	0.001	-	-	-
Motorcycles	92.537	0.200	0.002	84.202	0.200	0.002	111.576	0.200	0.002

Specific road traffic greenhouse gas emissions (source: APAT 2005a).

temperature increase can produce catastrophic climate changes. In order to tackle this situation, the Kyoto Protocol commits the industrialised countries to reduce the yearly CO_2 emissions before the 2010 respect to the emissions at year 1990. The estimation of external costs due to greenhouse gases generally is obtained (INFRAS/IWW 2004; UNITE 2005) estimating the total emissions of equivalent CO_2 and multiplying these quantities by a unitary cost; this last one represents a shadow value of a CO_2 ton that, in most cases, is assumed as the average cost that the country should bear for reducing the emissions, in order to respect the Kyoto Protocol.

The definition of the shadow value is not univocal and not simple to fix; the values proposed in the literature vary from 20 €/t to 135 €/t (INFRAS/IWW 2004). In particular, the minimum value (20 €/t), that it is adopted in this paper for estimating the external costs for the region of Campania, represents the lowest limit for the costs that are necessary for complying with the Kyoto Protocol and it is the value assumed in the Italian case study by the european project UNITE (2005).

The greenhouse gases considered in the estimates are carbon dioxide (CO_2), methane (CH_4) and nitrogen protoxide (N_2O); the emissions of the last two ones are converted in CO_2 equivalent ton by the following conversion rates: 1 t CH_4 = 21 t CO_2 eq.; 1 t N_2O = 310 t CO_2 eq. The estimation of the greenhouse gas emissions due to road transportation is obtained by the specific emissions per veh-km, deducible by the APAT (2005a) inventory (see previous), and by veh-km/year in Campania (see table pg. 79 on the right). The results are summarised in the next table.

For rail transportation the total emissions due to electric traction have been estimated multiplying the kWhs consumed by rail public transportation firms in Campania (data given by the firms) by the estimated CO_2 eq. specific emission, equal to 489 g/kWh; this value (ENEA 2003) was estimated on the basis of data provided by the national energy operator (GRTN), by ENEL (Italian electricity distributor) and by other public electric energy producers. The first of the tables below shows the results for the rail system.

For the air transportation, only the emissions produced in the phases of landing and taking-off (LTO-cycles) have been considered; more precisely, only the flights of the Napoli Capodichino airport have been referred to, differentiated in national and international flights. The air traffic data are obtained from ENAC (2005) for the year 2003. The specific emissions are obtained by APAT (2005a) inventory and are summarised in the second able. The third table reports the estimation of total greenhouse gas emissions due to air traffic of Napoli Capodichino airport; the LTO cycles are the half of the movements reported on the stats: indeed, the movements are the sum of landing and take-off operations.

Estimation of total CO_2 eq. road traffic emission in Campania.

Greenhouse gas	Urban roads [t/year]	Extra-urban roads [t/year]	Motorways [t/year]	Total [t/year]
CO_2	3,653,690	3,630,739	2,250,210	9,534,639
CH_4	2,761	727	199	3,687
N_2O	302	357	194	853
CO_2 equiv.	*3,805,313*	*3,756,645*	*2,314,420*	*9,876,378*

Estimation of total CO_2 eq. rail emission in Campania.

Transit firm	kWh/year	Specific CO_2 eq. [g/kWh]	Yearly emission [t/year]
A.N.M.	5,500,000		2,690
Circumvesuviana	33,195,000		16,232
MetroCampania N.E.	2,800,000		1,369
Metronapoli	30,000,000	489	14,670
SEPSA	12,240,000		5,985
Total	*83,735,000*		*40,946*

Specific greenhouse gas emissions from air traffic (source: APAT 2005a).

Flight	Greenhouse gas [g/LTO]		
	CO_2	CH_4	N_2O
National	2,147.21	169.99	100.00
International	2,804.07	355.39	300.00

Estimation of total CO_2 eq. air traffic emission in Campania.

	National flights	International flights	Total
LTO/year	19,101	9,340	*28,441*
CO_2 [t/year]	41	26	67
CH_4 [t/year]	3	3	7
N_2O [t/year]	2	3	5
CO_2 equiv. [t/year]	*701*	*965*	*1,666*

Estimation of greenhouse gas external costs in Campania.

Mode	Yearly emission [t CO_2 eq /year]	Specific external cost [€/t CO_2 eq.]	Total external cost [€/year]
Road transportation	9,876,378		197,527,560
Rail transportation	40,946		818,920
Air transportation	1,666	20	33,317
Totale	*9,918,990*		*198,379,797*

	SO_x	NO_x	PM10	CO	NMVOC
	Urban roads				
Petrol cars	0.011	1.063	0.034	24.458	3.733
Diesel cars	0.047	0.949	0.275	1.089	0.267
Gas cars	0.000	1.343	0.045	8.935	1.697
Not identified cars	0.015	1.078	0.074	18.902	2.940
Petrol light trucks (under 3.5 t)	0.019	1.792	0.047	48.740	6.276
Diesel light trucks (under 3.5 t)	0.064	2.399	0.366	1.383	0.274
Petrol heavy trucks (over 3.5 t)	0.028	4.353	0.488	66.313	6.567
Diesel heavy trucks (over 3.5 t)	0.176	12.027	0.890	3.891	2.119
Not identified trucks	0.101	5.780	0.533	5.111	1.286
Buses	0.176	12.027	0.890	3.891	2.119
Motor bicycles	0.004	0.029	0.127	13.296	8.102
Motorcycles	0.004	0.122	0.042	19.996	2.255
	Extra-urban roads				
Petrol cars	0.006	0.837	0.025	3.548	0.534
Diesel cars	0.027	0.554	0.120	0.368	0.092
Gas cars	0.000	1.877	0.038	1.659	0.497
Not identified cars	0.013	0.832	0.062	2.172	0.365
Petrol light trucks (under 3.5 t)	0.008	1.995	0.047	4.557	0.621
Diesel light trucks (under 3.5 t)	0.036	0.918	0.217	0.677	0.099
Petrol heavy trucks (over 3.5 t)	0.019	7.255	0.488	52.103	5.159
Diesel heavy trucks (over 3.5 t)	0.109	6.308	0.502	1.941	0.970
Not identified trucks	0.067	3.390	0.336	1.502	0.521
Buses	0.109	6.308	0.502	1.941	0.970
Motor bicycles	0.004	0.029	0.127	13.296	8.102
Motorcycles	0.003	0.240	0.042	19.642	0.885
	Motorways				
Petrol cars	0.007	1.162	0.023	3.988	0.448
Diesel cars	0.034	0.829	0.169	0.331	0.032
Gas cars	0.000	2.237	0.035	14.819	0.318
Not identified cars	0.022	1.175	0.117	3.934	0.162
Petrol light trucks (under 3.5 t)	0.008	2.340	0.047	8.983	0.662
Diesel light trucks (under 3.5 t)	0.047	1.199	0.264	0.885	0.094
Petrol heavy trucks (over 3.5 t)	0.021	7.255	0.488	42.103	3.283
Diesel heavy trucks (over 3.5 t)	0.124	6.772	0.464	1.650	0.776
Not identified trucks	0.102	5.311	0.405	1.664	0.609
Buses	-	-	-	-	-
Motor bicycles	-	-	-	-	-
Motorcycles	0.005	0.383	0.042	29.614	1.928

Specific road traffic pollutant emissions in g/veh-km (source: APAT 2005a).

The last table of previous page summarises the estimated external costs due to greenhouse gas emissions in Campania, that amount almost to 200 million euros per year and are nearly totally due to road transportation.

Air pollution

The air pollution is one of the main reasons of quality of life reduction in the great cities; it damages people's health, cultivations and buildings. Accurate descriptions of pollutants, of their damages and of the influence of transportation on total pollution can be found in the wide literature.
An estimation of air pollution external costs produced in Italy by road transportation is reported in Danielis and Chiabai (1998).
In this paper the estimation of air pollution external costs produced by transportation systems in Campania is obtained in function of the total emissions of the main pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter (PM10), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOC).
The specific emissions, as well as for greenhouse gases, are deduced by the APAT (2005a) inventory, for the different vehicle categories (see the table in the previous page). Total emissions are obtained by multiplying the veh-km/year of each kind of vehicle (see table pg. 79 on the right) by the corresponding specific emission, in the different contexts (Urban, Extraurban, Motorway).
Table 10 summarises the obtained results. Similar results can be obtained by using the COPERT (2005) software to the region of Campania; indeed, the APAT inventory data are based on the COPERT model.
Total emissions of rail transportation have been estimated in function of kWhs consumed every year from the rail firms in Campania (see table 5) and of the unitary pollution emissions per kWh (see table 11); these last ones are deduced by the study by ENEA (2003). In table 11 are summarised also the total emission in Campania due to rail transportation. Similarly to the procedure adopted for greenhouse gas emissions, air pollution emissions due to air transportation are estimated in function of LTO cycles of Capodichino airport (ENAC 2005) and of the specific emissions (APAT 2005a) reported in table 12. Table 13 summarises the results for air transportation.

Estimation of total pollutant emissions due to road traffic in Campania (t/year).

	SO_x	NO_x	PM10	CO	NMVOC
Urban roads	291	18,300	1,635	237,790	45,094
Extra-urban roads	430	24,428	2,158	63,596	13,178
Motorways	342	17,832	1,513	29,069	2,418
Total	*1,063*	*60,560*	*5,306*	*330,455*	*60,690*

Unitary (source: ENEA 2003) and total (in Campania) emissions due to rail transportation.

Pollutant	Unitary emission [g/kWh]	Total emissions [t/year]
SO_2	2.0020	167.64
NO_x	0.7136	59.75
PM10	0.0793	6.64
CO	0.0679	5.69
NMVOC	0.0136	1.14

Specific air transportation pollutant emissions (source: APAT 2005a).

Pollutant	Unitary emission (national flights) [kg/LTO]	Unitary emission (international flights) [kg/LTO]
SO_2	0.674	0.879
NO_x	8.252	10.854
PM10	0.384	0.462
CO	7.331	11.637
NMVOC	1.601	3.347

Estimation of total emissions due to air transportation in Campania.

Pollutant	National flight emissions [t/year]	International flight emissions [t/year]	Total emissions [t/year]
SO_2	12.87	8.21	21.08
NO_x	157.62	101.38	259.00
PM10	7.33	4.32	11.65
CO	140.03	108.69	248.72
NMVOC	30.58	31.26	61.84

Pollutant	Urban ambit [€/t]	Extra-urban ambit [€/t]
SO_2	14,818.22	3,899.06
NO_x	5,063.52	3,538.31
PM10	748,695.19	4,619.47
CO	9.42	1.09
NMVOC	1,260.81	376.32

Unitary damage costs due to pollutant emissions (elaboration on ENEA 2003, data).

The estimation of external costs due to air pollution can be obtained multiplying total emissions by a unitary damage cost (€/t), different for every pollutant and for urban and extra-urban areas. As unitary damage costs can be adopted the ones proposed in the study developed by ENEA (2003); these values have been estimated on the basis of results of the European project EXTERNE (2005), on the exposed population and on the effects on the health due to pollutants. The unitary damage costs reported in the ENEA study are estimated assuming a Value of Life (VOL) equal to 3,700,558 €. For adopting these estimates in this paper making comparable the results of air pollution with the other external costs that are based on VOL value (noise and accidents), it has been necessary to reduce the unitary damage costs in function of the value previously estimated (1,242,545 €). The monetary unitary damage costs so obtained are reported in the previous table.

For calculating the total external costs the following hypotheses are assumed:

- the emissions due to road transportation on extra-urban roads and on motorways are produced in extra-urban ambit, the other ones in urban ambit;
- the emissions due to rail transportation are produced in extra-urban ambit (since the thermoelectric power stations are generally sited outside urban areas);
- the emissions due to air transportation are produced in urban ambit, since the Capodichino airport is located inside Naples urban area.

The estimated results are summarised in table 15; they overcome 1.5 billion € per year.

Noise

The noise caused by transportation systems generally is assumed as a real source of pollution that has effects on human health and on quality of life. The calculation of external costs due to noise is not simple, particularly for lack of data; indeed, several studies in the literature (INFRAS/IWW 2004; UNITE 2005) are based on the number of people exposed to different noise levels. They used data on the people exposed to several noise levels in the cities with more than 10,000 inhabitants, disaggregated for transportation mode. Since specific data for the Campania Region are not available, it is necessary to assume that the exposition rate in Campania is equal to the Italian average. Table 16 reports people exposed to different noise levels in Campania's cities with a population over 10,000 inhabitants.

Generally, it is possible to calculate the external costs due to noise considering the following items:

– willingness to pay for reducing the noise;
– costs related to heart disease risk;
– medical treatment costs.

The first item represents how much is the willing to pay for reducing the noise level under the threshold of 65 dB(A) by day and of 55 dB(A) by night.

The estimation of this willingness to pay should require a specific Stated Preference survey. In this paper we use the values reported in the INFRAS/IWW (2004) study, adapted to the Campania's pro-capita GDP. The table 17 reports these values for different transportation modes and different noise levels.

Using these values for the willingness to pay, the corresponding item of external cost should amount to 476,528,003 €/year.

The second item is related to the increment of death risk due to noise; Babish et al. (1994) showed that the increment of acute myocardial infarction is 20 % for people that are exposed to a noise level between 65 and 75 dB(A) and 70 % if the noise level is over 75 dB(A).

For estimating the deaths due to noise can be adopted the following formula:

Estimation of external costs due to air pollution in Campania.

	SO_2	NO_x	PM10	CO	NMVOC
			Urban ambit		
Emissions					
Road transportation (t/year)	291	18,301	1,635	237,790	45,094
Air transportation (t/year)	21	259	12	249	62
Total (t/year)	*312*	*18,560*	*1,646*	*238,039*	*45,156*
Costs					
Unitary cost (€/t)	14,818.22	5,063.52	748,695.19	9.42	1,260.81
Total (€/year)	*4,618,537*	*93,976,805*	*1,232,679,439*	*2,241,643*	*56,933,357*
			Extra-urban ambit		
Emissions					
Road transportation (t/year)	773	42,260	3,671	92,665	15,595
Rail transportation (t/year)	168	60	7	6	1
Total (t/year)	*940*	*42,320*	*3,678*	*92,670*	*15,597*
Costs					
Unitary cost (€/t)	3,899.06	3,538,31	4,619.47	1.09	376.32
Total (€/year)	*3,666,533*	*149,739,936*	*16,990,501*	*100,695*	*5,869,326*
			Total costs		
Urban ambit (€/year)			1,390,449,782		
Extra-urban ambit (€/year)			176,366,991		
Total costs (€/year)			*1,566,816,773*		

Noise level [dB(A)]	Road transportation	Rail transportation	Air transportation
55-65	1,561,752	295,514	119,768
60-65	1,025,402	211,329	86,354
65-70	594,065	109,787	37,319
70-75	178,350	33,847	16,924
>75	50,771	8,245	9,981

Estimation of people exposed to different noise levels in Campania.

Leq dB(A)	55-65	60-65	65-70	70-75	>75
Road transportation	44	132	219	307	395
Rail transportation	0	44	132	219	307
Air transportation	44	132	219	307	395

Estimation of willingness to pay for reducing noise levels in Campania (€/person year).

$DIC_{NOISE} = (x_{65} - x_{NE})\ PC65 + (x_{75} - x_{NE})\ PC75$

where

DIC_{NOISE} represents the heart disease deaths in Campania due to noise;

x_{NE} is the heart disease risk per inhabitant exposed to noise under 65 dB(A);

x_{65} is the heart disease risk per inhabitant exposed to noise between 65 and 75 dB(A);

x_{75} is the heart disease risk per inhabitant exposed to noise over 75 dB(A);

PC65 is the Campania population exposed to noise between 65 and 75 dB(A), equal to 970,292 inhabitants (see table 16);

PC75 is the Campania population exposed to noise over 75 dB(A), equal to 68,997 inhabitants (see table 16).

The heart disease risks can be estimated solving the following equation system:

$DIC = x_{NE}\ PC75 + (x_{65} - x_{NE})\ PC65 + (x_{75} - x_{NE})\ PC75$

$x_{65} = 1.2\ x_{NE}$

$x_{75} = 1.7\ x_{NE}$

where *DIC* represents heart disease deaths in Campania, equal to 2,905 (ISTAT 2005b). Solving the equation system the heart disease risks are equal to:

$x_{NE} = 0.00048870$

$x_{65} = 0.00058645$

$x_{75} = 0.00083080$

With these values, the heart disease deaths in Campania due to noise can be estimated in 118 that, multiplied by the VOL (1,245,545 €), gives an estimated total cost equal to 147,167,747 €/year.

The third cost item is related to the medical treatment costs borne by society due to noise. The research MOSCA (2002) estimated for Germany that each person exposed to a noise level over 65 dB(A) bears an additional cost for medical treatments equal to 130 €/year. Assuming the same value, the medical treatment cost can be estimated equal to 135,107,150 €/year.

Summing the three cost items, the estimated total external cost produced by noise is equal to 758,803,320 €/year.

Accidents

Every year in European Union the road accidents cause over 40,000 fatalities and 1 million injuries; over the social problems, economic damages are caused. In a first estimate of European Union the damage amount about to 160 billion euros per year. One of the objectives declared by European Commission, as reported in the White Paper on transport policy (European Commission 2001), is to reduce the road accidents of 50 % between 2000 and 2010.

As regards Italy, the 2003 ISTAT data show 225,141 accidents, 6,015 fatalities and 318,961 injuries. In Campania the registered accidents are over 9,400 and they caused 347 fatalities and over 14,000 injuries. Table at the end of this page reports accident data subdivided by province.

The ISTAT specifies that the registered data are probably underestimated for several reasons: are registered only accidents that caused damage to people and only fatalities that occurred within 30 days by accident; many accidents

Accidents registered in Campania at 2003 (source: ISTAT, Incidenti stradali 2003, http://www.istat.it).

Province	Accidents	Fatalities	Injuries
Avellino	648	40	926
Benevento	448	15	756
Caserta	1,087	81	1,832
Napoli	4,604	128	6,869
Salerno	2,650	83	3,938
Campania	*9,437*	*347*	*14,321*

Car	Urban roads	Extra-urban roads	Motorways	Total
Petrol cars	187,903,146	132,719,606	29,587,615	*350,210,367*
Diesel cars	62,116,950	98,010,064	30,142,118	*190,269,132*
Gas cars	46,147,946	23,665,613	9,614,155	*79,427,715*
Not identified cars	38,810	21,351	5,417	*65,578*
Total	*296,206,852*	*254,416,634*	*69,349,306*	*619,972,792*

Estimation of hours spent in a year in car in Campania under the assumption that the average congestion is equal to the average Italian congestion.

with light injuries are not declared. Anyway, in this paper it has been preferred to use the official data, without amplifying those using uncertain corrective coefficients.
The external cost items due to road accidents estimated in this paper are:
- people damage;
- productivity and consumption losses;
- other costs (medical treatments, administrative and judiciary costs).

The material damage are not assumed as external costs since they are fully covered by insurances that are paid by users.
For estimating the people damage costs, it is necessary to establish a unitary cost for fatality, for serious injury and for light injury. As regards the fatality cost, the value previously estimated is adopted (1,242,545 €); INFRAS/IWW (2004) proposes a medium value equal to 200,000 € for serious injury and equal to 15,000 € for light injury. Adapting these values to pro-capita GDP of Campania's inhabitants, the values of 165,673 € per serious injury and of 12,425 € per light injury are obtained.
ISTAT estimates that the 80 % of injuries can be assumed light and the 20 % can be assumed serious; under this assumption in Campania in the year 2003 there were been 2,864 serious injuries and 11,457 light injuries.
The estimated people damage cost in the Campania Region amounts to 1,048,038,315 €/year.
Following the suggestions of UNITE (2005) project, the productivity and consumption losses can be estimated assuming 10 inactivity days for light injuries and 25 inactivity days for serious injuries.
For Campania Region the daily production loss is equal to 89.36 € per employed person, while the consumption loss is equal to 21.74 € per unemployed person (both vales are estimated adapting UNITE values to pro-capita GDP in Campania). In Campania Region the percentage of employed people is 26%; assuming the same percentage among casualties, the costs due to productivity and consumption losses is 7,321,354 €/year.
From available ISTAT 2002 data it is possible to estimate the average medical treatment cost per accident equal to 2,796.33 €, inclusive of hospital, first aid and rehabilitation costs. Using this value the total medical treatment cost amounts to 26,388,966 €/year.
From the same ISTAT data it is possible to estimate the administrative and judiciary costs per accident as 8,830.51 €; the total cost due to these items is equal to 83,333,474 €/year.
Therefore, the total external cost due to road accidents is estimated equal to 1,165,082,109 €/year.
This cost is partially already internalised by insurances (paid by users); indeed, in Italy a part of insurance premium is devolved directly to National Health Service. Another part of premium indemnities material damage (that are not considered external costs) and people damage; a study for estimating the part of accident costs already internalised will be object of further research.

Congestion

The congestion affects mainly the road transportation, especially in urban areas. The evaluation of externalities due to congestion can be obtained by estimating the time lost by users in the congested system respect the case of absence of congestion.
Other more effective methods can be based on the users' surplus evaluation, but they should require studies on the demand elasticity.
In this paper the congestion costs will be estimated only for road transportation.
For estimating the external costs due to congestion, the total travel time that should be spent by car users in Campania if the congestion level is equal to the average in Italy has been estimated. This estimate is obtained by the veh-kms/year for each car category and by the average yearly speeds desumed by APAT (2005a), for each ambit (see table in this page).
The ISFORT (2005) survey shows that the average speed in Campania is equal to the 89.9 % of the average Italian value; the same survey shows that the 48.8 % of trips are made for job/study purposes.
Applying the ratio between average Italian speed and average Campania speed to the total hours of table 19, it is possible to obtain a total number of hours equal to 690,491,024; therefore the lost hours for congestion can be assumed equal to 70,518,232, of which the 48.8 % (34,412,897) for job/study trips.

Cost item	Total cost [€/year]	Cost per inhabitant [€/inhabitant-year]
Greenhouse gas emissions	198,379,809	34.79
Air pollution	1,566,816,773	274.79
Noise	758,803,320	133.08
Accidents	1,165,082,109	204.33
Congestion	436,850,858	76.61
Total	*4,125,932,870*	*723.60*

Estimation of external costs in Campania region.

These hours has to be multiplied by the average car occupancy factor, which can be assumed equal to 1.3; therefore, lost hours are 91,673,702, among which 44,736,767 for job/study trips and 46,936,935 for other trips.
The external cost can be estimated multiplying lost hours for VOT (€/h); as seen in subsection 3.2, ENEA (2003) proposed 7.74 €/h for job/study trips and 1.93 €/h for other purpose trips. With these values the estimated congestion cost amounts to 436,850,858 €/year.
It is necessary to specify that the external cost so estimated is minimal, since the average Italian conditions cannot assumed uncongested and that the effects on freight transportation has been neglected.

Cost summary

The previous table and the figure below summarise external costs produced by transportation system in Campania. It can be noted that the largest costs are due to air pollution (38.0 %) and accidents (28.2 %); noise amounts to 18.4 %, while less importance is assumed by congestion (10.6 %) and greenhouse gas emissions (4.8 %). The total cost overcomes 4.1 billions euros per year, equal about to 4.7 % of regional GDP.
In particular, the environmental costs (air pollution, noise and greenhouse gas emissions) are over the 60 % of total external costs.

Conclusion

In this paper simplified methods for estimating the external costs due to transportation in regional areas are proposed. The advantages of proposed methods are related to the possibility to use input data easily available from official stats, without the necessity of providing specific surveys.
An approximate estimation of external costs is useful for evaluating transportation plans and policies, in particular if they are devoted to the reduction of environmental impacts.
The results obtained for the region of Campania show as the amount of external costs is equal about to 4.7 % of regional GDP and, in particular, as the environmental costs (greenhouse gas emissions, air pollution and noise) overcome the 60 % of total costs.
Further research will be addressed to improve the precision of proposed methods, mainly as regards the specific costs of air pollution and of greenhouse gas emissions.

Notes

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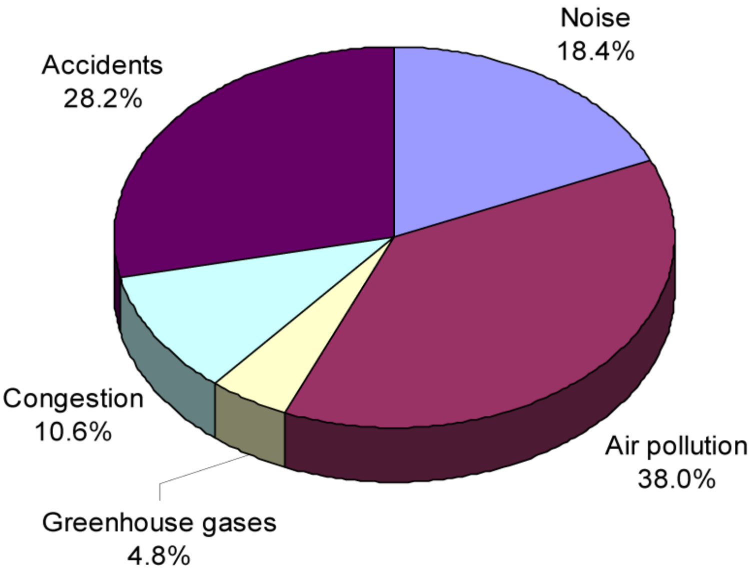
External costs in Campania region (percentages).



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L'immagine a pag. 59 è dell'autore.