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M. Berrittella, A. Certa, M. Enea and P. Zito

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M. Berrittella, *Centro Interdipartimentale di Ricerca per la Programmazione Informatica dell'Economia e Tecnologia (CIRPIET), Università di Palermo*
A. Certa, *Dipartimento di Tecnologia Meccanica, Produzione e Ingegneria Gestionale (DTMPIG), Università di Palermo and Dipartimento di Scienze Economiche, Aziendali e Finanziarie, Università di Palermo*
M. Enea, *Dipartimento di Tecnologia Meccanica, Produzione e Ingegneria Gestionale (DTMPIG), Università di Palermo*
P. Zito, *Dipartimento di Ingegneria dei Trasporti (DITRA), Università di Palermo*

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Summary

Transport is the sector with the fastest growth of greenhouse gases emissions, both in developed and in developing countries, leading to adverse climate change impacts. As the experts disagree on the occurrence of these impacts, by applying the analytic hierarchy process (AHP), we have faced the question on how to form transport policies when the experts have different opinions and beliefs. The opinions of experts have been investigated by a means of a survey questionnaire. The results show that tax schemes aiming at promoting environmental-friendly transport mode are the best policy. This incentives public and environmental-friendly transport modes, such as car sharing and car pooling.

Keywords: Analytic Hierarchy Process, Transport Policies, Climate Change

JEL Classification: C90, Q54, R48

Address for correspondence:

Maria Berrittella
Università di Palermo
Viale delle Scienze (Edificio 8)
90128 Palermo
Italy
Phone: +39 091 238412
Fax: +39 091 423105
E-mail : maria.berrittella@unipa.it

1. Introduction

The transport system has mutual interactions and multi-dimensional effects on environment (i.e. in terms of urban air pollution, climate change and land use), economic development (i.e. in terms of GDP) and social equity (i.e. in terms of accessibility, human health, life quality of cities and metropolitan areas).

Amongst the industries, transport is the sector with the fastest growth of greenhouse gases emissions, both in developed and in developing countries. In developed countries this problem is intensified with the substantial growth in transport volumes. For example, in Italy passenger and freight traffic have risen, respectively of 29.5% and 22.75%, in the period 1990-2000. These traffic flows are expected to grow in the next future. Furthermore, the intermodal transport, which is more environmentally friend, attracts marginal shares of the whole freight and passenger transport demand, respectively, 23% and 2.5% (Mazzarino, 2000). This behaviour increases the greenhouse gas emissions. At the national level, the Italian government has developed the new Master Plan, which deals with the Kyoto Protocol on Climate Change of 1997. On the basis of this Protocol, the transport sector is committed to contribute to 15% reduction (with respect to the 1990 levels) of its own CO_2 emissions. This is equivalent to reduce the CO_2 emissions by about 30 millions tons per year (t/yr). Developing countries rely heavily on energy consumption for its daily mobility. For example, in Singapore the rapid economic development has led to increased demand for land transportation, which is presently heavily dependent on oil. Various measures and recommendation were announced and documented in the Singapore Green Plan to reduce the greenhouse gas emissions (Poh et al., 1999).

The aim of the different plans to reduce the greenhouse gas emissions and, hence, the adverse climate change impacts, can usually be achieved by different transport policies, each characterized by quantitatively and qualitatively different effects on the transportation system itself, as well as on the natural environment and economic and social context.

The environmental implications of transport policies can be assessed by the Environmental Impact Assessment (EIA), which is an intrinsically complex multi-dimensional process. The EIA involves scoping, that is, to define which components are to be included in the EIA and alternatives to be considered, studying baseline conditions, namely the benchmark by which the future conditions of project alternatives are compared, identifying potential impacts, predicting significant impacts and evaluating them (Shepard, 2005). EIA can be solved by different decision support techniques, such as Cost Benefit Analysis (Zhang *et al.*, 2006), Multi-Criteria Analysis (Sayers *et al.*, 2003; Tzeng *et al.*, 2005) and Life Cycle Analysis (Bristow *et al.*, 2000; Stavros *et al.*, 2004). Furthermore, uncertainty in EIA has been modelled by using the fuzzy logic approach (Silvert, 1997; Buckley *et al.*, 1999; Enea *et al.*, 2001; Ayag *et al.*, 2006; Boclin, 2006).

In order to choose the optimal policy action to reduce the adverse climate change impacts due to the transport sector, we have applied the analytic hierarchy process (AHP), developed by Saaty (1980), which decomposes the decisional process in a hierarchy of criteria, subcriteria, attributes and alternatives through a set of weights that reflect the relative importance of alternatives. The AHP has become a significant methodology in EIA due to its capability for facilitating multi-criteria decision-making (Ramanathan, 2001). In facts, the AHP has been widely applied to numerous complex environmental and economic problems (Alphonce, 1997; Tiwary et al., 1999; Duke et al., 2002; Ferrari, 2003).

In our knowledge this paper is the first which concerns with the evaluation of the best transport policy at global level. In facts, although various studies have been carried out on the design and the evaluation of transport strategies (Colorni *et al.* 1999, May *et al.*, 2000; Vold, 2005; Zhang, et. al., 2006), essentially, all these works analyses the optimal transport strategy in urban areas or at local level. Furthermore, as there is uncertainty on the occurrence of the climate change impacts and there is lack of consensus among experts about them (Woodward *et al.*, 1997), we have faced here the question on how to form transport policies when the experts disagree. For this, we have investigated the opinions of experts by a means of a survey questionnaire. The surveyed experts were chosen as individuals with an in-depth understanding of the transport policies and their effects on climate change. Experts did not have to agree on the relative importance of the criteria or the rankings of the alternatives, but each expert enters his judgements and makes a distinct, identifiable contribution to the issue. The experts had to compare six policy options[1].

Firstly, *voluntary agreements among industries to improve the ecological efficiency of new vehicles*, which concern the agreements on standard of emissions produced by vehicles. Environmental agreements in the transport sector are difficulty to take place. However, in 1998, a voluntary agreement between the European Union and European car industries has been signed in 1998 to reduce CO_2 emissions by 25% (per vehicle/km) by 2008 (Mazzarino, 2000; Quinet *et al.*, 2001).

Secondly, *incentives for turnover of car fleet renewal*, which can produce two opposite effects on the environment. The positive effect regards the reduction of the pollution emissions caused by the substitution of the old polluting vehicles with the news, which are cleaner. The negative effect regards the shorter average car's life and, therefore, if the incentives are permanent or repeated over time, they increase the amount of energy and materials used, and emissions caused by all the processes involved in car construction, dismantling, scrapping and recycling. The positive effect is likely to prevail for most of the schemes implemented. New vehicles are also more durable and maintain design emissions levels over greater mileages than the old vehicles (ECMT, 99).

Thirdly, *tax schemes aiming at promoting environmental-friendly transport modes*, which use the price mechanism to reduce road traffic congestion, mainly, in urban areas. The economic theory let us know that if prices are not correctly adjusted to costs, distortions will rise in the resulting choices, which reduce economic efficiency and overall welfare. Current travel patterns are the results of the perceptions and choices of individuals of the opportunities offered to them and the cost implications of those choices. The introduction of pricing

[1] Readers can find rigorous discussion of the different transport policy options in Button *et al.*(2001).

schemes influences the costs of transport for certain modes, networks and/or time periods by means of taxes or fares, and involve all dimensions of travel choices: generation (choosing to make a trip); distribution (destination choice); mode choice (choosing the mode of transport); choice of day for travel and route choice. The use of pricing, combined with regulation of parking paces available, is now very widespread in urban areas. The combination of parking control and pricing is a very powerful tool for influencing the number of vehicles attracted by an area, enhancing in the same time the public transit, with rapid effects on reducing traffic and thus environmental pressure where desired (Paulley, 2002).

Fourthly, *better integration between transport planning and land uses*, which regards both the transport demand management and the control of development. The former has to address issues of meeting environmental standards, identifying pollution hotspots, and setting and achieving traffic reduction targets, but at the same time ensuring that all people have appropriate levels of accessibility to jobs, services and facilities. The latter has to control the development of activities and within existing public transport corridors (preferably with integrated public transport systems by time scheduling, space coordination and fare integration) and making the city structure more dense easily accessible, improving living conditions and decentralizing business and services activities. Actual trend is a multidisciplinary approach for transport planning and land use to reduce road traffic, pollution issues and to improve the life quality of citizens. The key role of planning is to promote the sustainable development by economic, environmental and social policy objectives in the achieving of targets, in order to reduce global warming, to reduce dependence on non renewable energy sources, and to minimize the local pollution and adverse social impacts (Banister, 2001).

Fifthly, *new and better transport infrastructures*. Many transport systems work close to the capacity of the infrastructure, and further increases of transport demand can not be absorbed without that the delay and congestion rise. The rapid growth in transport demand and the consequent congestion on transport infrastructures (port, airport, highways, rail stations) can require either new constructions or transport demand management policies. Environmental and social costs involved in the construction of new infrastructures make this solution unacceptable and only temporary effective, because expected growth demand will be able to cause still worse congestion levels. On the other hand, transport demand management policies, on the transport supply side, can increase the capacity of infrastructures through information provision. Nevertheless, in all cities road construction is still seen as an important measure, as well as the construction of pedestrian areas. Construction of public transport infrastructure depends on the present public transport system and on the size of the city. Bus and/or tram lanes are used or planned and light rail systems are in use in many cities. Park and Ride facilities are built in the larger cities and off street parking facilities in smaller cities. Traffic calming infrastructure and cycle paths have been planned in many cities (Lakshmanan, *et al.*, 2001; May *et al.*, 2003).

Finally, *development of intelligent transport systems (ITS) and information technologies* are now emerging as a set of key tools for improving the management and operations of the transportation network. Intelligent transport systems offer new tools for a number of different aspects of the management and operations of transportation. These must be considered in the context of travel demand management, because the new and emerging technologies allow of improving the modal split of travel. There are a number of possible ways to affect peoples' choice as to which mode of travel to select in space and in time, in broad terms, these are:

i. reduce the reliance or attractiveness of private transport through measure such as private vehicle access control;
ii. increase the attractiveness of more environmentally and sustainable forms of transport (such as public transport, car pooling);
iii. use new telematics means to reduce the reliance on travel into congested business areas and city centres by trip substitution in the form of teleworking/telecommuting.

In terms of integrated transport and demand management, a key requirement is to facilitate the interchange between the private and public transport. Whilst the information provision, both on trip and pre trip, provide the mechanism by which the traveller makes an informed decision on mode, time and route. For public transport, dedicated bus lanes and other bus priority measures are a key to providing a service with more reliable travel times and a quicker route through the congested road network. The provision of information is key to the success of transport integration and interchange. ITS offers many new routes to the provision of that information both before the user begins his or her trip as well as dynamically providing information to users, on trip, through in vehicle delivery of information, roadside mounted VMS, personal information devices (SMS mobile phone) as well as the internet, kiosks and information boards at interchange facilities (Taylor, 2001; Chowdhury *et al.*, 2003).

Amongst the alternative policies, the *tax schemes aiming at promoting environmental-friendly transport modes* (such as: the road price and the park price) have been assessed as the best transport policy to reduce the adverse climate change impacts. This result finds reasons in the fact that taxation is able to influence the behaviour of users through effective price and/or fare tools, increasing the perceived costs of private transport, and promoting public and environmental-friendly transport modes, such as car sharing and car pooling, non motorized modes.

2. The methodology

The Analytic Hierarchy Process (AHP) is a method of measurement for formulating and analyzing decisions. Saaty (1980) provided a theoretical foundation for the AHP, that is a decision support tool which can be used to solve complex decision problems taking into account tangible and intangible aspects. Therefore, it supports decision makers to make decisions involving their experience, knowledge and intuition.

The AHP decomposes the decision problem into elements, according to their common characteristics, and levels, which correspond to the common characteristic of the elements. The topmost level is the “focus” of the problem or ultimate goal; the intermediate levels correspond to criteria and sub-criteria, while the lowest level contains the “decision alternatives”. If each element of each level depends on all the elements of the upper level, then the hierarchy is complete; otherwise, it is defined incomplete. The elements of each level are compared pairwise with respect to a specific element in the immediate upper level.

Table 1 reports the pairwise comparison scale used in the AHP developed by Saaty (1977). It allows to convert the qualitative judgments into a numerical values, also with intangible attributes.

For computing the priorities of the elements, a judgmental matrix is assumed as follows:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (1)$$

where a_{ij} represents the pairwise comparison rating between the element i and element j of a level with respect to the upper level. The entries a_{ij} are governed by the following rules: $a_{ij} > 0$; $a_{ij} = 1/a_{ji}$; $a_{ii} = 1 \ \forall i$.

Following Saaty (1980, 2000), the priorities of the elements can be estimated by finding the principal eigenvector w of the matrix A, that is:

$$AW = \lambda_{\max} W \quad (2)$$

When the vector W is normalized, it becomes the vector of priorities of elements of one level with respect to the upper level. λ_{max} is the largest eigenvalue of the matrix A.

In cases where the pairwise comparison matrix satisfies transitivity for all pairwise comparisons it is said to be consistent and it verifies the following relation :

$$a_{ij} = a_{ik} a_{kj} \qquad \forall i,j,k \quad (3)$$

Table 1. The AHP pairwise comparison scale

Numerical values	Verbal scale	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favour one element over another
5	Strong importance of one element over another	An element is strongly favoured
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favoured by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments

Saaty (1980) has shown that to maintain reasonable consistency when deriving priorities from paired comparisons, the number of factors being considered must be less or equal to nine. AHP allows inconsistency, but provides a measure of the inconsistency in each set of judgments. The consistency of the judgmental matrix can be determined by a measure called the consistency ratio (CR), defined as:

$$CR = \frac{CI}{RI} \tag{4}$$

where CI is called the consistency index and RI is the Random Index.

Furthermore, Saaty (1980, 2000) provided average consistencies (RI values) of randomly generated matrices (table 2). CI for a matrix of order n is defined as:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{5}$$

In general, a consistency ratio of 0.1 or less is considered acceptable, this threshold is 0.08 for matrices of size four and 0.05 for matrices of size three. If the value is higher, the judgments may not be reliable and should be elicited again.

Table 2. The average consistencies of random matrices (RI values))

Size	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Once the local priorities of elements of different levels are available, in order to obtain final priorities of the alternatives a_i, the priorities are aggregated as follows:

$$S(a_i) = \sum_k w_k S_k(a_i) \tag{6}$$

where w_k is the local priority of the element k and $S_k(a_i)$ is the priority of alternative a_i with respect to element k of the upper level.

3. Assessment of alternative transport policies

In order to evaluate alternative transport policies to reduce the adverse climate change impacts, we have investigated the opinions of nine experts on transport policies and economics by a means of a survey questionnaire. Consulting more experts avoid bias that may be present when the judgements are considered from a single expert. Experts did not have to agree on the relative importance of the criteria or the rankings of the alternatives. Each expert entered his judgement and gave a distinct, identifiable contribution to the issue.

For the case study, a three-level analytic hierarchy process has been applied, as shown in figure 1. The first level is composed of the final goal one wishes to attain in carrying out the project: reduction of the adverse climate change impacts due to the transport sector. The second level represents the criteria on the basis of which the projects are to be evaluated:

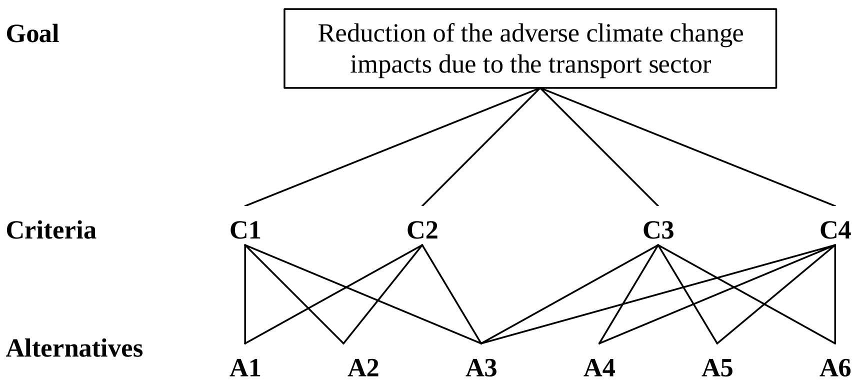
- adoption of fuels with reduced carbon content (C1);
- technological improvements in the ecological efficiency of vehicles (C2);

- increase in the public and multi-modal transport market share (C3);
- improvements due to better mobility management systems (C4).

The third level presents the policy options, which are:

- voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1);
- incentives for turnover of car fleet renewal (A2);
- tax schemes aiming at promoting environmental-friendly transport modes (A3);
- better integration between transport planning and land uses (A4);
- new and better transport infrastructures (A5);
- development of intelligent transport system (ITS) technologies (A6).

Figure 1
Analytic hierarchy structure



C1 adoption of fuels with reduced carbon content
C2 technological improvements in the ecological efficiency of vehicles
C3 increase in the public and multi-modal transport market share
C4 improvements due to better mobility management systems

A1 voluntary agreements amongst industries to improve the ecological efficiency of new vehicles
A2 incentives for turnover of car fleet renewal
A3 tax schemes aiming at promoting environmental-friendly transport modes
A4 better integration between transport planning and land uses
A5 new and better transport infrastructures
A6 development of intelligent transport system (ITS) technologies

The criteria C1 and C2 involve the alternatives A1,A2 and A3. Essentially, A1 and A2 regard the factors directly responsible of the vehicle emissions by fixed standards on fuels and vehicles. The alternative A3 indirectly produces environmental benefits through the disincentive of private car use, increasing the perceived costs of private transport, and promoting the public transport and non motorized modes (by cycle and walking). Moreover, the criteria C3 and C4 involve the alternatives from A3 to A6, since their environmental benefits are correlated to the traffic reduction produced by transport demand management policies either transport demand side or transport supply side.

Experts were asked to compare pair-wise the relative importance of the elements for each level on the basis of the Saaty scale (table 1). The questionnaire submitted to the experts is reported in the Appendix. From the pair-wise comparisons, a judgmental matrix was formed for each expert. This matrix was used for computing the priorities and the consistency index was carried out. The priorities expressed by experts have been combined using the geometric mean method (Ramanathan *et al.*, 1994; Saaty, 2000).

4. Results

By applying the procedure previously outlined, the results indicate the highest importance to the criteria C2 “technological improvements in the ecological efficiency of vehicles” (35.1%); the other three criteria have almost equal priority (about 20%), as results from the eigenvector of the criteria comparison matrix, reported in table 3, whose components provide an estimate of the weights of the criteria. The principal eigenvalue of this matrix is λ_{max}= 4.027, with a consistency ratio CR=0.0098<0.08. Thus, the results are consistent.

Table 3. Matrix of criteria comparison

Criteria	C1	C2	C3	C4	Weights vector
C1	1	0.584	0.921	1.421	0.228
C2	1.712	1	1.408	1.825	0.351
C3	1.086	0.710	1	0.956	0.226
C4	0.704	0.548	1.046	1	0.195

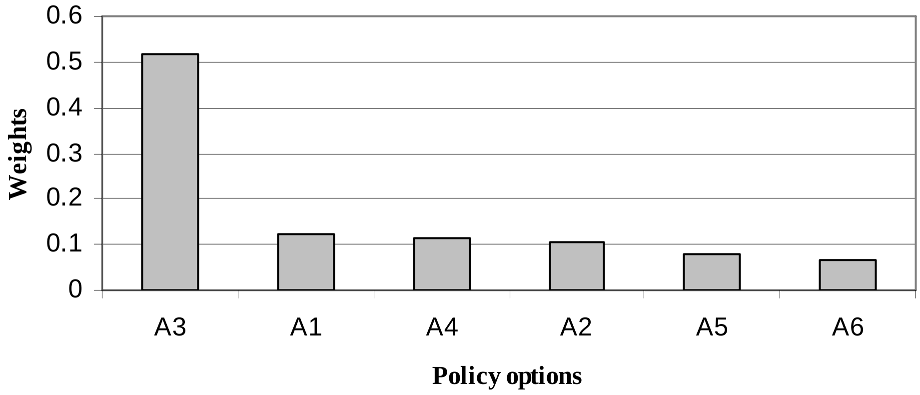
Table 4 reports the priorities of the policy options for each criteria. Tax schemes aiming at promoting environmental-friendly transport modes (A3) turns out to have the highest priority for any criteria. In particular, for the criteria C1 (adoption of fuels with reduced carbon content) and C2 (technological improvements in the ecological efficiency of vehicles), the priority of A3 is slightly higher than 60%, the remaining is shared almost equally by the other two alternatives: voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1) and incentives for turnover of car fleet renewal (A2). For criteria C3 and C4 the priority of A3, respectively, 40% and 36%, is lower than its weight for the other two criteria. A4 (better integration between transport planning and land use) is the second-best policy option for both criteria. A5 (new and better transport infrastructures) is slightly more important than A6 (development of ITS technologies) for criteria C3; whereas, A5 and A6 are almost equally important for criteria C4.

The ranking of the policy options with respect to the ultimate goal, shown in figure 2, is obtained multiplying the transpose matrix of priority of the alternative under each criteria (table 4) by the weights vector of the matrix of criteria comparison (table 3). The policy option A3 receives the highest importance (more than 50%); A1 is the second-best option (12%), but it is slightly more important than A4 and A2.

Table 4. Matrix of the priorities of the policy options per criteria

Policy options / **Criteria**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**
C1	0.199	0.177	0.624	0	0	0
C2	0.217	0.178	0.605	0	0	0
C3	0	0	0.407	0.243	0.209	0.141
C4	0	0	0.361	0.302	0.169	0.167

Figure 2
Analytical hierarchical process priorities for policy options



Furthermore, we run the sensitivity analysis to test under which conditions the ranking of alternatives may change. The method has involved specifying a certain number of experiments, which set different possible combinations of the criteria' weights (Harrison *et al.*, 1993). In particular, the weight of any criteria i, w_i, has been supposed to evolve according to the stochastic differential equation:

$$dw_i = \mu w_i dt + \sigma w_i dz \quad \forall i \tag{6}$$

This equation implies that w_i are changing according to a process of *geometric Brownian motion* (GBM). The term μdt is the mean or expected percentage change in w_i for the increment dt, and μ is called the *mean drift rate*. The term σdz introduces a random component to the drift, because $dz = \varepsilon(t)\sqrt{dt}$, where ε(t) is a normally distributed random variable with 0 mean and standard deviation of 1. A discrete approximation of (6) is given by the stochastic difference equation:

$$dw_{i,t+1} = (1+\mu)w_{i,t} + \sigma w_{i,t}\varepsilon_{t+1} \tag{7}$$

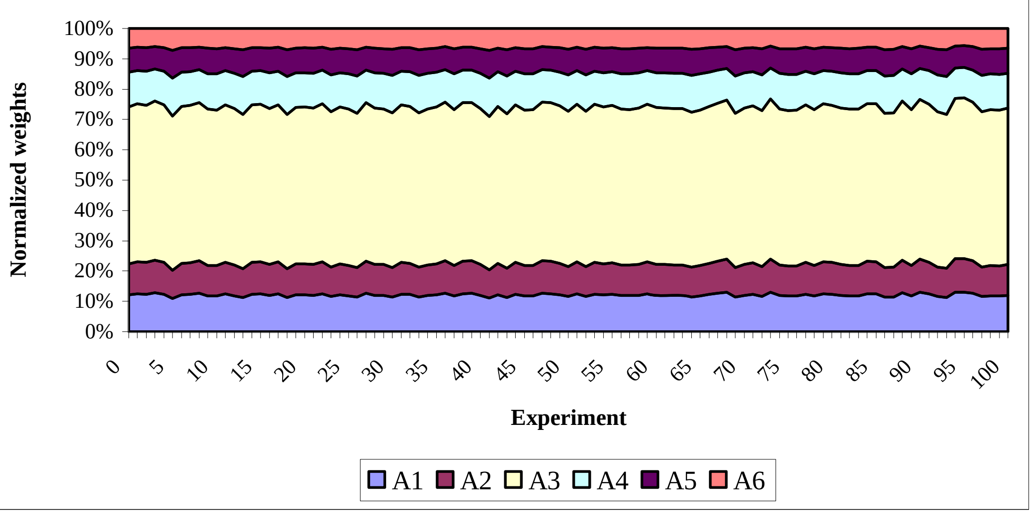
where the ε_{t+1} are the standard normal variates and the implied increment is dt=1.

Given the base weights vector of the criteria in table 3 and the values for μ and σ, selected from the standard normal distribution defined for the 95% confidence interval, we have generated a sample paths of 100 random numbers for any criteria. The sensitivity results, reported in figure 3, confirm the ranking of the policy options in figure 2. Also table 5, which reports the mean percentage change in each alternative and the standard deviation across the 100 random samples, suggests that the results are relatively robust to different combinations of the weights' values. In fact, the mean percentage change is very low, as well as the standard deviation tend to be quite small. Moreover, analysing the sample probability of the ranking of alternatives, we have found that A3 is always the best option, and the change in the ranking of alternatives is due mainly to the fact that A4 becomes slightly more important than A1 (26% of cases) or less important than A2 (9% of cases).

Table 5
Sensitivity analysis of policy options

	Mean %	Standard deviation
A1	3.276	0.009
A2	3.362	0.007
A3	3.676	0.028
A4	4.430	0.007
A5	4.235	0.005
A6	4.408	0.004

Figure 3
Sensitivity analysis of policy options priority



5. Discussion and conclusions

Amongst the alternative policies, the *tax schemes aiming at promoting environmental-friendly transport modes* has been assessed as the best transport policy to reduce the adverse climate change impacts. This result finds reasons in the fact that it is able to influence the behaviour of users through effective price and/or fare tools, increasing the perceived costs of private transport, and promoting public and environmental-friendly transport modes, such as car sharing and car pooling, non motorized modes. In this context, a key role is played by the public transport system, which should be able to attract major shares of the transport demand by information diffusion (pre- and on- trip), improving the perceived quality of the service. This policy option produces immediate effects in terms of traffic reduction and, hence, environmental pressure in the interested area. The second best policy is the *voluntary agreements amongst industries to improve the ecological efficiency of new vehicles*. It produces slower effects, since its effectiveness depends on natural turn over of car fleet or by incentives, but it generates environmental benefits in the long term. Although growth of car ownership rate is not controlled and mobility needs are not regulated, in the next future the environmental benefits produced by new vehicles will be totally compensated by the increase of the number of vehicles running on the road network. For this reason, the efforts of planning should be addressed to modify the behaviour of users, rationalizing their trips (reducing number of kilometres run and eliminating unnecessary trips), and rebalancing their modal choices to reduce climate change impacts.

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APPENDIX

QUESTIONNAIRE

A MULTI-CRITERIA ANALYSIS FOR CHOOSING AMONG ALTERNATIVE TRANSPORT POLICIES TO REDUCE CLIMATE CHANGE IMPACTS IN ITALY

Dear participant,
in the following sheets we would like to elicit your opinion as expert on transportation research, policy and economics.

We investigate the opinions of experts by a means of a survey questionnaire. Experts do not have to agree on the relative importance of the criteria or the rankings of the alternatives. Each expert enters his judgements and makes a distinct, identifiable contribution to the issue.

YOUR PERSONAL DETAILS (optional)

Contact Name	
Address	
Town/City	
Country	
Organization	
Tel:	
Fax:	
e-mail:	

Background

The economic valuation of the climate change impacts requires knowledge of both natural and socio-economic processes. Climate change is due to the accumulation of greenhouse gases emissions and is, currently, considered a critical problem, because it may cause future damages, which are considered highly uncertain, possibly severe and likely to be irreversible. Amongst the industries, the transport sector significantly contributes to energy consumption and carbon dioxide emissions, considering also that transport sector is extremely dependent on petroleum. This calls for transportation projects, which aim to reduce the climate change damages.

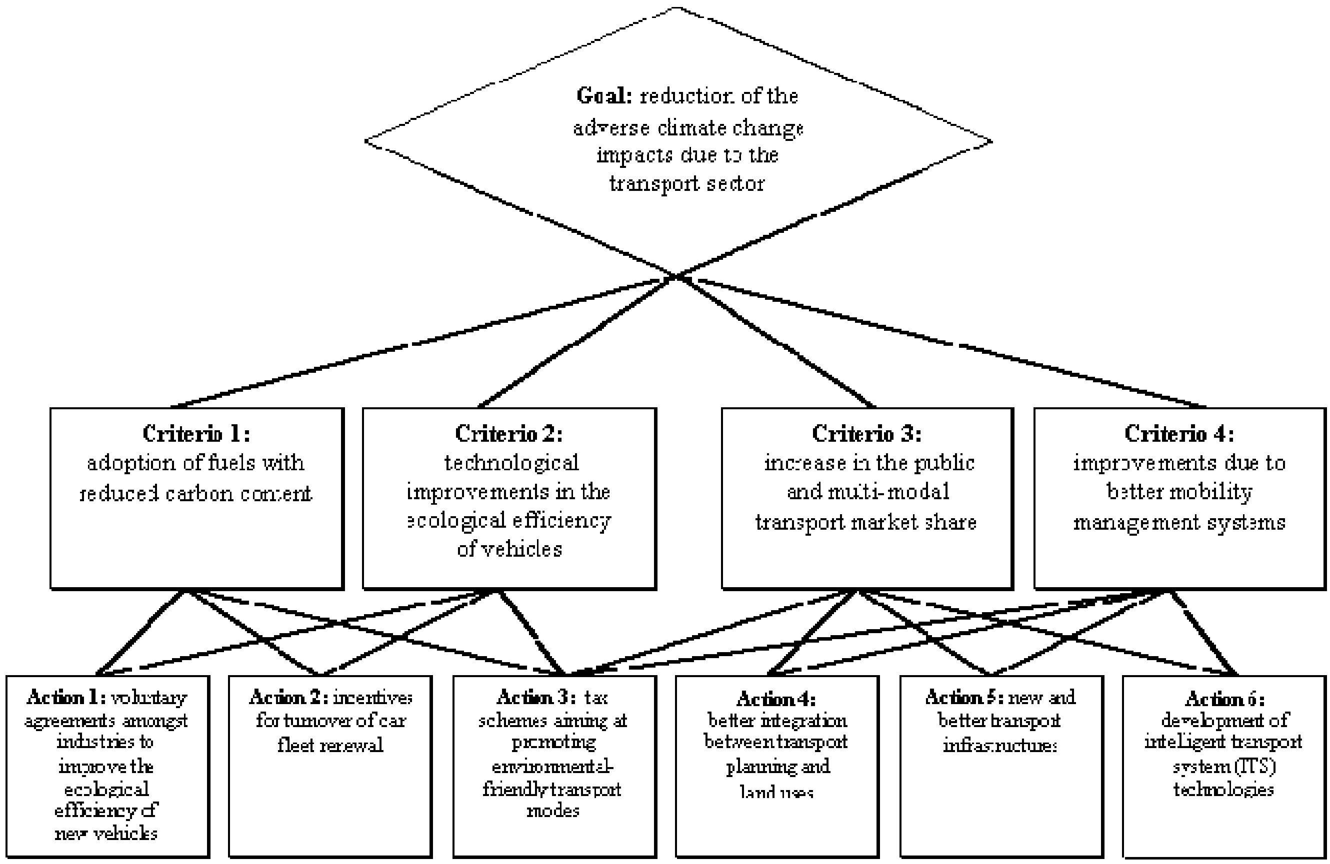
At the national level, the Italian government has developed the new Master Plan, which deals with the Kyoto Protocol on Climate Change of 1997. On the basis of this Protocol, the transport sector is committed to contribute to 15% reduction (with respect to the 1990 levels) of its own CO_2 emissions. This is equivalent to reduce the CO_2 emissions by about 30 millions tons per year (t/yr).

In this context, we aim to apply a multi-criteria analysis, specifically, by a three-level analytic hierarchy process, to choose the optimal policy action in order to reduce the adverse climate change impacts due to the transport sector. The first level is composed of the final goal one wishes to attain in carrying out the project; the second level represents the criteria on the basis of which the projects are to be evaluated and, finally, the third level presents the policy options (*figure 1*).

In more details, the whole yearly reduction may be achieved on the basis of the following criteria:
- adoption of fuels with reduced carbon content (C1);
- technological improvements in the ecological efficiency of vehicles (C2);
- increase in the public and multi-modal transport market share (C3);
- improvements due to better mobility management systems (C4).

In order to satisfy these criteria, the following policy measures are currently under discussion and refinement at the government level:
- voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1);
- incentives for turnover of car fleet renewal (A2);
- tax schemes aiming at promoting environmental-friendly transport modes (A3);
- better integration between transport planning and land uses (A4);
- new and better transport infrastructures (A5);
- development of intelligent transport system (ITS) technologies (A6).

Figure 1: **Three-level analytic hierarchy structure**



In the following sheets, we would like to elicit your opinion as expert in order to select amongst the alternatives. The pairwise comparison scale by Saaty, reported in Table 1, can be used to express the importance of one element over another.

Table 1. Saaty Scale

Numerical values	Verbal scale	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favour one element over another
5	Strong importance of one element over another	An element is strongly favoured
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favoured by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments

A. Please write on the box (element 1) the criteria code that you assess more or equal important than other, with respect to the goal: "reduction of the adverse climate change impacts due to the transport sector" and express on the verbal scale the importance of the more or equal important criteria (element 1) over the other.

1 = EQUAL	3 = MODERATE	5 = STRONG	7 = VERY STRONG	9 = EXTREME

Pairwise	Element 1									
- adoption of fuels with reduced carbon content (C1) - technological improvements in the ecological efficiency of vehicles (C2)		1	2	3	4	5	6	7	8	9
- adoption of fuels with reduced carbon content (C1) - increase in the public and multi-modal transport market share (C3)		1	2	3	4	5	6	7	8	9
- adoption of fuels with reduced carbon content (C1) - improvements due to better mobility management systems (C4)		1	2	3	4	5	6	7	8	9
- technological improvements in the ecological efficiency of vehicles (C2) - increase in the public and multi-modal transport market share (C3)		1	2	3	4	5	6	7	8	9
- technological improvements in the ecological efficiency of vehicles (C2) - improvements due to better mobility management systems (C4)		1	2	3	4	5	6	7	8	9
- increase in the public and multi-modal transport market share (C3) - improvements due to better mobility management systems (C4)		1	2	3	4	5	6	7	8	9

B1. Please write on the box (element 1) the policy action code that you assess more or equal important than other, with respect to the criteria 1: "adoption of fuels with reduced carbon content" and express on the verbal scale the importance of the more or equal important action (element 1) over the other.

1 = EQUAL	3 = MODERATE	5 = STRONG	7 = VERY STRONG	9 = EXTREME

Pairwise	Element 1									
- voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1) - incentives for turnover of car fleet renewal (A2)		1	2	3	4	5	6	7	8	9
- voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1) - tax schemes aiming at promoting environmental-friendly transport modes (A3)		1	2	3	4	5	6	7	8	9
- incentives for turnover of car fleet renewal (A2) - tax schemes aiming at promoting environmental-friendly transport modes (A3)		1	2	3	4	5	6	7	8	9

B2. Please write on the box (element 1) the policy action code that you assess more or equal important than other, with respect to the criteria 2: "technological improvements in the ecological efficiency of vehicles" and express on the verbal scale the importance of the more or equal important action (element 1) over the other.

1 = EQUAL	3 = MODERATE	5 = STRONG	7 = VERY STRONG	9 = EXTREME

Pairwise	Element 1									
- voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1) - incentives for turnover of car fleet renewal (A2)		1	2	3	4	5	6	7	8	9
- voluntary agreements amongst industries to improve the ecological efficiency of new vehicles (A1) - tax schemes aiming at promoting environmental-friendly transport modes (A3)		1	2	3	4	5	6	7	8	9
- incentives for turnover of car fleet renewal (A2) - tax schemes aiming at promoting environmental-friendly transport modes (A3)		1	2	3	4	5	6	7	8	9

B3. Please write on the box (element 1) the policy action code that you assess more or equal important than other, with respect to the criteria 3: "increase in the public and multi-modal transport market share" and express on the verbal scale the importance of the more or equal important action (element 1) over the other.

1 = EQUAL	3 = MODERATE	5 = STRONG	7 = VERY STRONG	9 = EXTREME

Pairwise	Element 1									
- tax schemes aiming at promoting environmental-friendly transport modes (A3) - better integration between transport planning and land uses (A4)		1	2	3	4	5	6	7	8	9
- tax schemes aiming at promoting environmental-friendly transport modes (A3) - new and better transport infrastructures (A5)		1	2	3	4	5	6	7	8	9
- tax schemes aiming at promoting environmental-friendly transport modes (A3) - development of intelligent transport system (ITS) technologies (A6)		1	2	3	4	5	6	7	8	9
- better integration between transport planning and land uses (A4) - new and better transport infrastructures (A5)		1	2	3	4	5	6	7	8	9
- better integration between transport planning and land uses (A4) - development of intelligent transport system (ITS) technologies (A6)		1	2	3	4	5	6	7	8	9
- new and better transport infrastructures (A5) - development of intelligent transport system (ITS) technologies (A6)		1	2	3	4	5	6	7	8	9

B4. Please write on the box (element 1) the policy action code that you assess more or equal important than other, with respect to the criteria 4: "improvements due to better mobility management systems" and express on the verbal scale the importance of the more or equal important action (element 1) over the other.

1 = EQUAL	3 = MODERATE	5 = STRONG	7 = VERY STRONG	9 = EXTREME

Pairwise	Element 1									
- tax schemes aiming at promoting environmental-friendly transport modes (A3) - better integration between transport planning and land uses (A4)		1	2	3	4	5	6	7	8	9
- tax schemes aiming at promoting environmental-friendly transport modes (A3) - new and better transport infrastructures (A5)		1	2	3	4	5	6	7	8	9
- tax schemes aiming at promoting environmental-friendly transport modes (A3) - development of intelligent transport system (ITS) technologies (A6)		1	2	3	4	5	6	7	8	9
- better integration between transport planning and land uses (A4) - new and better transport infrastructures (A5)		1	2	3	4	5	6	7	8	9
- better integration between transport planning and land uses (A4) - development of intelligent transport system (ITS) technologies (A6)		1	2	3	4	5	6	7	8	9
- new and better transport infrastructures (A5) - development of intelligent transport system (ITS) technologies (A6)		1	2	3	4	5	6	7	8	9

**** Please give us few more seconds by answering to the following questions in order to improve our analysis (optional):**

	yes	**no**
Did you find the questionnaire clear?		
Do you find the topic issues interesting?		

Please give us any additional comment (optional):

With many thanks for your effort and time.

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