COST-BENEFIT ASSESSMENT OF SELECTED ROAD SAFETY MEASURES IN GREECE

George Yannis	Eleonora Papadimitriou	Petros Evgenikos
Ass. Professor	Civil Engineer	Civil Enigneer

Department of Transportation Planning and Engineering
National Technical University of Athens
5, Iroon Polytechniou st., GR-157 73 Zografou, Athens, Greece
Phone: +30 210 7721326 Fax: +30 210 7721454 E-mail: geyannis@central.ntua.gr

ABSTRACT

The objective of this research is to investigate cost-benefit assessment techniques for road safety measures, including methodological issues, data availability and data quality, through three case-studies in Greece. The first part of the paper concerns a review of the available methods for calculating the efficiency of road safety measures, in terms of safety effect (accidents and casualties reduction) as well as other related effects (traffic, environmental etc.). Additionally, a detailed description of the calculation process of the various components of generalized and human accidents costs in Greece is presented. The second part of the paper reports the results of cost-benefit analysis application in three case studies in Greece; one on the implementation of traffic calming measures at municipal level, one on the upgrading of selected sections of the National Road network into motorways, and one on the nationwide intensification of speed and alcohol enforcement. Conclusions concern both the efficiency of the measures and the assessment process. Furthermore, the main difficulties encountered in the above case studies and the alternatives for dealing with them are discussed.

1 INTRODUCTION

Budgets for road safety policies and activities are not infinite, thus politicians have to decide about the best possible use of these budgets. The criteria used, when deciding about policies and budgets, are mainly suitability, lawfulness, and/or legitimacy. However, in the recent years, efficiency is often mentioned as a criterion for a good policy. The efficiency of an intended policy is determined by the use of efficiency assessment tools (EATs), which enable decision making and choice of the policy with the highest return in monetary terms. Cost Benefit Analyses (CBAs) and Cost Effectiveness Analyses (CEAs) are the widely used efficiency assessment tools. CBA mainly investigates the social output of a measure or a policy, while CEA is used for partial efficiency questions and investigates the casualties saved. In this study the Cost Benefit Analysis (CBA) will be implemented to assess Cost Effectiveness of road safety measures. Generally, CBA provides a logical framework for evaluating alternative courses of action when a number of factors are highly conjectural in nature. Essentially, it takes into account all the factors which influence either the benefits or the cost of a project, even if monetary value can not be easily assigned. (*Smith, 1998*).

However, it should be noted that there are certain barriers regarding the use of efficiency assessment tools in road safety policy. These barriers are mainly divided into three categories: fundamental (rejecting principles of welfare economics, rejecting efficiency as the most relevant criterion for priority setting, etc.), institutional (lack of consensus on relevant policy objectives, costs of CBA, etc.) and technical barriers (lack of knowledge of relevant impacts, inadequate monetary valuation of relevant impacts, etc.).

The main goal of this paper is to investigate several issues related to cost-benefit evaluation techniques for road safety measures, including methodological issues, data availability and data quality, through three case-studies in Greece. The developed methodology used to estimate the safety effect of road safety measures and road accidents cost in Greece is presented, while three case-studies are examined and the respective results are analysed.

2 METHODOLOGY

2.1 Estimation of the safety effect of road safety measures

In order to assess the cost-effectiveness of a road safety measure two basic elements are required: an estimate of the effectiveness of the safety measure in terms of the number of accidents or casualties (injuries, fatalities) that can be prevented and an estimate of the measure's implementation cost. Usually, the safety effect of a treatment is defined as the expected reduction in target accidents/casualties following the implementation of the treatment and is given in the form of a percentage (*Elvik et al, 1997, Ogden, 1996*).

The main source of evidence on safety effects is the observational before-and-after studies (*Hauer, 1997*). However, due to the diverse nature of road safety measures and the limitations of empirical studies, other methods for quantifying safety effects are also used. Those, provide mainly theoretical values of the effects based on the relationships between risk factors and the effects. More specifically, there are confounding factors, which influence the number of road accidents/casualties and, therefore, should be accounted for in the estimation of a real safety effect of the treatment. To properly quantify the effects of a treatment, a simple before/after comparison is not sufficient, as it is necessary to compare the situation with the treatment ("after") with the situation that would have existed if the treatment was not applied. The latter presents a corrected value of a previously observed ("before") situation.

Determining what would have occurred in a site without the treatment is a critical part of the entire process and is performed in two steps: determination of the correct "before" value (of the effect), which accounts for the selection bias and determination of the correct "after" value without the treatment, accounting for the uncontrolled environment. The Empirical Bayes method constitutes an effective instrument for the first step. A correction of "before" safety effects is performed with the help of reference group statistics, for each site in the treatment group. As for the second step (corrected value of effects without the treatment), two basic approaches are possible:

1. Using a comparison group, assuming that changes in the safety effect in the comparison group forecast accurately the changes that would have occurred at the treatment sites in the absence of treatment. The evaluation of the treatment effect is performed by means of the Odds-ratio, where for the "before" period the "corrected" effects numbers (from the first evaluation step) are applied (*Elvik, 1997, Gitelman, Hakkert et al, 2001*).

2. Using multivariate models, which supply the expected number effects as a function of a series of physical and traffic parameters of the treatment sites and of general trends. The technique of generalized linear models (GLMs), with a Poisson or Negative Binomial distribution for the frequency of examined effects, is the most widely accepted today for this purpose and several methods for the development of such models are available.

The safety effects observed in this study are weighted by means of Odds-ratio of the total number of road accidents in "before" and "after" treatment period. This results to the estimated effect:

Estimated effect $(\theta_i) = [X_a/X_m]/[C_a/C_b]$

where

X_a - the number of road accidents observed at the treatment area in the "after" period

X_m - the number of road accidents observed at the treatment area in the "before" period
C_a - the number of road accidents observed at the control group area in the "after" period
C_b - the number of road accidents observed at the control group area in the "before" period
The statistical weight of the estimate is:

$$w_i = \frac{1}{\frac{1}{A^i} + \frac{1}{B^i} + \frac{1}{C^i} + \frac{1}{D^i}}$$

Where A, B, C, D are the four numbers of the odds-ratio calculation.

The weighted mean effect is:

$$Weighted\ mean\ effect(WME) = \exp\left(\frac{\sum_i w_i \ln(\theta_i)}{\sum_i w_i}\right)$$

with 95% confidence interval for the weighed effect estimated as follows:

$$\left(WME \exp\left(\frac{z_{\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}} \right), WME \exp\left(\frac{z_{1-\frac{\alpha}{2}}}{\sqrt{\sum_i w_i}} \right) \right)$$

The applicable value of the safety effect, i.e. the best estimate of accident reduction associated with the treatment (in percents), is calculated as (1-WME)*100.

Furthermore, another methodology is used to estimate the safety effect, which is based on the Test X^2. The number of accidents occurring in the area examined is compared with the accidents occurring in the control group, according to the following equations:

$$X^2 = \frac{(\Psi - XA)^2}{(X + \Psi)A} \quad (1)$$

$$\text{where} \quad A = \frac{\Psi_E}{X_E} \quad (2)$$

Then, the estimated X^2 value is compared with the X^2_α value for a given probability standard α and for n=1 freedom standard (n = k – 1, where k = 2 are the observations, one before and one after the implementation of the measures). When the estimated X^2 value is higher than the X^2_α (for a predetermined probability standard α, the reduction in the number of accidents is considered statistically significant and in all likelihood is attributed to the implementation of speed humps and woonerfs. The predetermined probability standard (α) used in this research is 95%, which can be considered as conservative.

2.2 Road accidents cost in Greece

The estimation of average accidents cost was carried out on the basis of a recent study on accidents cost in Greece (*Liakopoulos, 2002*) and another recent study on willingness-to-pay for accidents reduction in Greece *(Yannis et al., 2005)*.

The first study concerned the estimation of the costs of various components of accidents cost (material damage costs, generalized costs, human costs) for fatal accidents, injury accidents and material damage accidents, including:

- Material damage costs
- Police costs
- Fire brigade costs
- Insurance companies cost

- Court costs
- Lost production output
- Pain and grief
- Rehabilitation costs
- Hospital treatment and rehabilitation
- First aid and transportation costs

The various costs were calculated by means of en exhaustive data collection process addressed to various organizations (National Statistical Service of Greece, National Police, Fire Service of Greece, Emergency Medical Service of Greece, hospitals, courts, insurance companies etc.). Additional parameters were adopted on the basis of estimations from experts in each field, as well as the existing international literature.

It should be noted, however, that the above study, did not adequately account for the human cost component, as the pain and grief parameters as reported in the Courts are not sufficiently representative of the human cost. On that purpose, a separate investigation for human cost in Greece was carried out in the framework of the present research. In particular, human cost was estimated according to the following formula:

VoSL = (NAEIS) / (LSE)
Where:
VoSL: Value of Statistical Life
NAEIS: National Annual Expenditure on Improving Safety
LSE: Expected lives Saved from this Expenditure annually

In particular, the calculations included parameters such as the percentage of the family annual income that each person is willing to pay in his/her entire life in order to reduce the probability of accident involvement of himself/herself or of any family person by 50%, the average members per family in Greece, the proportion of families with an economically active member, the average family annual income in Greece, the National Population, the life expectancy in Greece and the current and new accident risk.

As regards the percentage of the family annual income that each person is willing to pay in his/her entire life in order to reduce the probability of accident involvement by 50%, the results of the second study mentioned above (a recent "willingness-to-pay" survey) were exploited (*Yannis et al., 2005*). In this survey, respondents were asked the percentage of annual income they were willing to pay to reduce by 50% the probability of fatal accident, injury accident and material damage accident involvement. It should be noted that, in the willingness-to-pay survey, respondents were also asked to rate various types of accidents and injuries, in order to identify their perception on injury severity. On the basis of the results, in the present research, the value corresponding to injury accidents is considered to adequately represent serious injury accidents, whereas the value for material damage accidents is considered to adequately represent both slight injury and material damage accidents. In the following Table 1, the parameters concerning accident cost in Greece are summarized, on the basis of the previous research exploited and the additional calculations carried out:

Table 1: Breakdown of accident cost in Greece (1999)

Cost of Accident with:	**Killed**	**Seriously Injured**	**Slightly Injured**
Material Damage cost (€)	28.769	18.175	13.904
Generalised cost (€)	442.467	23.907	6.960
Human cost (€)	612.141	467.703	206.340
Total accident cost (€)	1.083.377	509.785	227.204

It is noted that the above costs concern costs of individual accidents. Any accident underreporting does not necessarily affect the results of the following cost-benefit assessment cases studies, as in each case, both figures compared (before and after) refer to the same underreporting ratio.

3 RESULTS OF COST-BENEFIT ANALYSES

3.1 Development of motorways in Greece

In the early nineties a multi-annual programme for the upgrade of the main national road axis Patras - Athens - Thessaloniki - Evzoni (~750 km) into a motorway started and several road segments were constructed since then. On this axis, two sections of 70 km each (Athens - Korinthos and Athens - Yliki) were constructed during the period 1990-1995 and are operational since then. The project was financed by the European Union Cohesion Funds (75%), and National public investment and loans (25%).

The upgrade of the particular road axis aimed both at increasing road traffic capacity and decreasing the number of road accidents and related casualties. The old road was a two-way, one lane per direction road (plus emergency lane) without median and the new road is a two-way, three lanes per direction road (plus emergency lane) with median, resulting to an important decrease of accidents and related casualties. In a research carried out at the Department of Transportation Planning and Engineering of the National Technical University of Athens, Police accident data were combined with toll traffic data for the extraction of accident rates and their comparison as shown in Table 2 (*Evangeliou, 2003*).

Table 2: Basic road safety related figures in the examined axis before-and-after the upgrade into motorway.

	Before (1986-1990)		After (1996-1999)		**Change**
	total	per year	total	per year	
Accidents	1279	259	559	140	**-46%**
Persons killed	369	74	145	36	**-51%**
Veh-Km (billion)	8,5	2	9,54	2	**40%**
Accidents per billion veh-Km		153		59	**-62%**
Killed per billion veh-km		43		15	
Killed per 100 accidents		28		26	**-9%**

A before-and-after assessment methodology with large control group (including the sections of the particular axis not improved up to 1999) was used for the estimation of the safety effects of the project, as well as the respective statistical significances, separately on the Athens - Korinthos and the Athens - Yliki sections. The safety effect was quantified by using the odds-ratios technique. The results presented in Table 3 show that the percentage change was statistically significant (95% significance level) in both sections. In particular, the upper and lower thresholds of the safety effect are lower than one, indicating a significant effect.

Table 3: Safety effect of the construction of motorways

	Athens - Lamia sections				Athens - Korinthos sections			
	Treatment group		Control group		Treatment		Control group	
	Before	After	Before	After	Before	After	Before	After
Number of accidents	159	66	437	341	210	79	437	341
Odds	0,415		0,780		0,376		0,780	
Odds ratio	0,532				0,482			
Ln(OR)	-0,631				-0,730			
Safety effect	**47%**				**52%**			
Lower limit	27%				64%			
Upper limit	61%				35%			
Number of accidents prevented	**157**				**245**			

The related average accidents costs were calculated by weighting the reference values presented in the previous section (for accidents with persons killed and injured) to the respective proportion of casualties per severity in the examined sections. Additionally, the total implementation costs of the construction of the selected sections were obtained from the Ministry of Environment, Physical Planning and Public Works. It is noted that, as the lifetime investment of motorways construction is considered to be 25 years, the costs corresponding to the examined "after" period (1996-1999) were calculated as a proportion of the total cost of the project. Additionally, a 15% of the total construction cost was considered as maintenance costs.

On the basis of the above, a cost-benefit evaluation was carried out as far as safety benefit is concerned. No overall evaluation of the efficiency of the project was attempted. This would include traffic, environmental and other social components, making the task significantly more complex and far beyond the scope of the present research. Obviously, the results presented in the following Table 4 are not representative of the overall cost efficiency of motorways.

Table 4: Cost-benefit analysis of the construction of motorways (in terms of safety only)

	Athens - Lamia	Athens - Korinthos
Number of accidents prevented	157	245
Average accident cost	347.920	373.902
Present value of benefits (€)	54.571.805	91.477.809
Total Cost (€)	31.602.789	43.084.780
Benefit - Cost Ratio	**1,7 : 1**	**2,1 : 1**

It is interesting to notice that the safety benefit alone accounts for cost efficiency of the project, yielding a satisfactory benefit-cost ratio in both sections, although the high construction cost of motorways, especially on an often difficult landscape, further increased by the long planning, design and tendering process conforming to a complex institutional framework (competition, technical standards, environmental impact, etc.), resulted to a rather high implementation cost for the examined period.

The magnitude and significance of the results indicate that the safety benefit, although not sufficient to support decision making itself, is an important additional benefit from motorways development. The use of before-and-after assessment showed that there is a statistically significant decrease in the number of accidents and related casualties in the upgraded national road network, which can be attributed mainly to the motorway construction. The quantification of traffic, environmental and other effects would certainly allow further validation of the relative importance of the safety effect of motorways.

3.2 Traffic calming

In Greece, less than 1.600 persons killed and 19.000 persons injured are recorded in more than 16.000 road accidents annually *(NTUA/DTPE, 2004),* and more specifically, 76% of the total number of road accidents occur in urban areas. Speed is the most significant factor leading to a continuously increasing trend of road accidents, as it affects both their occurrence and their severity *(Kanellaidis et al, 1995).*

There is a wide variety of methods and techniques used for reducing road accidents in urban areas, such as enforcement, intensive campaigns, specific traffic management techniques, however, Low Cost Traffic Engineering Measures (LCTEM) (or traffic calming measures) are deemed to be the most efficient measures towards tackling the problem. At local level in Greece, the Municipality of Neo Psychiko is the only area in the Greater Athens Area, which inaugurated an extensive road traffic calming programme at the beginning of 1990's in an attempt to improve road safety in this area. Several speed humps and woonerfs were mainly implemented in one direction and one lane streets between the years 1991 and 1999, according to technical specifications, aiming at creation of calm driving areas and decrease in the number of road accidents and related casualties *(Municipality of Neo Psychiko, 2001).* The target group of the measures included the inhabitants of the Municipality, especially the vulnerable road users groups (pedestrians, children, two-wheelers, pedalcyclists) who mainly benefit from the implementation of the traffic calming measures in the area, but the reduction of road accidents also concerns the drivers and passengers circulating in the area. The present research concerns a cost-benefit evaluation of the installation of speed humps and woonerfs in the Municipality of Neo Psychiko and for this purpose their implementation cost was calculated, as well as the cost of the safety effects deriving from these measures.

The total cost for the implementation of traffic calming measures in the Municipality of Neo Psychiko can be distinguished into implementation cost for speed humps and implementation cost for woonerfs. The cost of speed humps includes the designing and construction/installation costs, depending the type of material used (asphalt or plastic) as well as the respective road markings. In the case of Neo Psychiko, 49 speed humps were installed in 21 one-lane, one-direction roads and the total cost was 111.518€ (1998 prices). The implementation cost of woonerfs is considerably higher, as it concerns larger areas and includes the design cost, cost for the configuration and pavement of the respective areas, cost for hydraulic works, electrical works and sewage pipelines installation. In the case of Neo Psychiko, a total area of 100.000m^2 in 40 local roads was transformed into woonerfs between 1991 - 1999. According to the data provided by the technical department of the Municipality of Neo Psychiko, 3.081.438€ (at 1998 prices) was the total cost for the implementation of woonerfs, which is considered quite high. Generally, increased construction cost is a particularity of the Greek project tendering system. It is noted though, that the above costs are considered to refer to the entire lifetime investment of the construction, which in this case is 10 years. Thus, the implementation costs corresponding to the examined "after" period (1994-1999) were calculated as a proportion of the total implementation cost of the project. The above mentioned implementation costs are presented in Table 5.

Table 5: Traffic calming measures implementation cost (1998)

Traffic calming measures	**Amount**	**Cost**
Speed humps	49 units	111.518€
Woonerfs	100.000m^2	3.081.438€
Total Implementation Cost	3.192.956€	
Implementation Cost (Period examined)	1.596.478€	

The main safety effect considered in this case-study, is the number of all injury accidents prevented in the area, after the implementation of traffic calming measures. Social and environmental effects for the residents of the area are not taken into account, as it is difficult to be quantified and moreover, their benefits are not essential comparing to the accident reduction. However, the time lost (for the road users) due to the reduction of travel speed should be incorporated into the benefits calculation. For the estimation of the accidents prevented the "before and after methodology with large control group" was considered. This is the methodology with the highest degree of accuracy, as the size of control group is quite large and moreover, when there is a sufficient number of years "before" and "after" the implementation of traffic calming measures the phenomenon of the regression to the mean is eliminated, making the "before and after methodology with large control group" the most appropriate and reliable methodology for the estimation of the potential safety effect. The control group should include large areas with similar characteristics to the area considered, where traffic calming measures were not implemented. The neighbouring Municipalities of Holargos and Agia Paraskevi in the Athens Greater Area present similar road network, population density, land use and traffic volumes characteristics with the Municipality of Neo Psychiko and were therefore chosen as the large comparison group. The results of a recent research were exploited (*Georgopoulou, 2002*) allowing for the direct calculation of the number of accidents prevented by the measures. The examination of the statistical significance of the safety effect is based on the Test X^2 and the number of accidents occurring in the area examined are compared with the accidents occurring in the control group, as indicated in the following Table 6.

Table 6: Total number of accidents "before" and "after" in one direction - one lane streets

Time period	Area	
	Area examined	Control group
Before (1985-1990)	$X = 36$	$X_E = 101$
After (1994-1999)	$\Psi = 33$	$\Psi_E = 149$
Change	-8.3%	47.5%

The estimated $X^2 = 3.972 > 3.84$ (X^2 value for 95% probability standard), so a statistical significant reduction in the total number of accidents is noticed. The effects observed are weighted by means of Odds-ratio in "before" and "after" treatment period, resulting in Table 7, where the mean value of the estimated number of accidents and the confidence interval for this value are presented.

Table 7: Safety effect of speed humps and woonerfs estimated for Neo Psychiko

Treatment type	**Estimated effect (WME)***	**WME confidence interval**
Speed humps and woonerfs in the Municipality of Neo Psychiko	0.621	(0.363, 1.061)

* WME: Weighted Mean Effect

The average safety effect of speed humps and woonerfs implementation in Neo Psychiko is a 38% reduction in of the total number of road accidents, thus, 14 accidents were prevented by the presence of these traffic calming measures, as no other road safety measure occurred in the area at the same period. In order to calculate the average accident cost for accidents that occur in urban areas in Greece, the costs of fatal and injury accidents were weighted in relation to the average distribution of accident casualties per casualty severity in urban areas. The value of the average accident cost occurring in urban area was 284.667€. at 1999 prices.

Furthermore, the time lost (for the road users) due to reduced travel speeds (a reduction of 8km/h – 15km/h is usually observed) by the implementation of traffic calming measures could also be incorporated into the benefits calculation as negative effect and its value is estimated according to the following equation:

$$T = D * Q * V * P$$

Where T: the value of time lost due to delays resulting traffic calming measures implementation

D: average delay per vehicle

Q: average daily traffic volume in the area considered

V: average value of time (hourly) per vehicle

P: period

The average delay per vehicle (time lost due to implementation of speed humps and woonerfs) when circulating in the area of Neo Psychiko is approximately 60 sec. This estimation is based on field measurements, which took place in the area considered. The average daily traffic volume in the Municipality of Neo Psychiko was 8.680 vehicles. The hourly cost of the delay of an average vehicle is 4,5€/hour (1999). This calculation takes into account the average value of time per person (hourly) for 1999, which is 3€, as well as the average vehicle occupancy, which is 1,6 (*Attiko Metro, 1997*). Finally, the examined period is the number of working days over a year (260 days). Consequently, the yearly value of time lost in the area considered due to traffic calming measures implementation is:

T = 60sec/vehicle * 8.680vehicles/day * 4,5€/hour * 260days * 1/3.600hours = 180.544€ (1999 prices)

The cost-benefit ratio calculation followed the identification and quantification of the costs related to the implementation of traffic calming measures and their benefits, previously described. An accumulated discount factor was applied to the implementation cost calculation, on the basis of an interest rate of 4% (*National Statistical Service of Greece, 2003*). Two scenarios are developed, according to the calculation of the value of benefits. In the first scenario, the value of benefits derives only from the number of accidents prevented in the area (scenario 1) and in the second one the yearly value of time lost in the area due to traffic calming measures implementation is also considered (scenario 2). On that purpose two ratios are calculated:

Table 8: Calculation of the cost-benefit ratio

	Scenario 1 Safety benefits only	**Scenario 2 Including time lost**
Present value of benefits		
Number of accidents prevented	14	14
Average accident cost - 1999 (€)	284.667	284.667
Value of time lost (Period examined) - 1999 (€)	-	902.720
Total (€)	3.985.338	3.082.613
Present value of costs		
Implementation cost - 1998 (€)	1.596.478	1.596.478
Implementation cost - 1999 (€)	1.660.337	1.660.337
Cost-benefit Ratio	**2,4 : 1**	**1,9 : 1**

The yielded cost-benefit ratio in both scenarios indicated in the above Table proves that the implementation of speed humps and woonerfs in a broad local area can be cost-effective.

3.3 Intensification of speed and alcohol enforcement

Road accidents and related casualties presented an increasing trend during the past decade in Greece, mainly due to insufficient maintenance of the road network, inappropriate behaviour of the road users and lack of efficient and systematic enforcement (*NTUA/DTPE, 2003*). In 1998, the Greek Traffic Police started the intensification of road safety enforcement, having set as target the gradual increase of road controls for the two most important infringements: speeding and drinking and driving. Since then, all controls and related infringements recorded are systematically monitored and the related enforcement and casualty results at local and national level are regularly published, as shown at the following Table 9 with basic road safety related trends in Greece.

Table 9: Basic trends of road safety related figures in Greece (1998-2002)

	1998	1999	2000	2001	2002	5-year change
injury road accidents	24.819	24.231	23.127	19.710	16.852	**-32%**
persons killed	2.182	2.116	2.088	1.895	1.654	**-24%**
vehicles (x1000)	4.323	4.690	5.061	5.390	5.741	**33%**
speed infringements	92.122	97.947	175.075	316.451	418.421	**354%**
drink & drive infringements	13.996	17.665	30.507	49.464	48.947	**250%**
drink & drive controls	202.161	246.611	365.388	710.998	1.034.502	**412%**

The target group of the measure included the entire population of Greek drivers. Although the intensification of enforcement was more significant on the interurban road network, it is considered that the entire number of accidents was affected, as the enforcement was nationwide and concerned all types of traffic violations. The present research concerns a cost-benefit evaluation of police enforcement for speeding and drinking-and-driving in Greece for the period 1998-2002.

Enforcement costs include police labour costs, police vehicle costs and police speed and alcohol enforcement equipment costs (speed cameras, alcoholmeters etc.). As the intensification of enforcement in the examined period was not part of a specific project with a specific budget and resource allocation foreseen, there was very little information available on the police related costs. The additional necessary information for CBA calculations was obtained by means of exhaustive interviews with Head Officers of the Police. In particular, on the basis of the available detailed information on the yearly numbers of infringements, the interviews aimed at yielding the related labour and capital parameters through the adoption of typical conversion measures. The total labour, vehicle and equipment cost of speed and alcohol enforcement is summarized in the following Table 10.

The calculations are based on the following assumptions, as reported from the experience of the Head Police Officers interviewed:

- 75% of infringements are recorded on typical days
- 25% of infringements are recorded on special days (weekends, holidays, special events)
- An average of 15 infringements for speeding and 1 infringement for drinking-and-driving per shift are recorded on typical days
- An average of 20 infringements for speeding and 2 infringements for drinking-and-driving per shift are recorded on special days
- 3% of speed infringements and 10% of alcohol infringements recorded result to driver's prosecution, both on typical and special days

Table 10: Enforcement Implementation Costs 1998-2002 (prices of 2002)

	Speed		**Alcohol**	
	Shifts	Arrests	Shifts	Arrests
Number of infringements	1.007.894		146.583	
Number of activities	62.993	30.237	128.260	14.658
Person-hours per activity	24	14	24	14
Hourly rate (€)	7,50		7,50	
Labour Costs	11.338.808	3.174.866	23.086.823	1.539.122
Total Labour Costs (€)	**14.513.674**		**24.625.944**	
Number of vehicles per activity	1	1	1	1
Average distance travelled per activity (Km)	20	5	5	5
Unit Cost per Km (€)	0,10	0,10	0,10	0,10
Vehicle Costs	125.987	15.118	64.130	15.118
Total Vehicle Costs (€)	**141.105**		**79.248**	
Total Equipment Costs (€)	**159.950**	**-**	**4.670**	**-**
Total Implementation Costs (€)	**39.524.591**			

On the basis of the above, the yearly numbers of police control shifts on speed and alcohol enforcement and prosecutions for speeding and drinking-and-driving were calculated. Additionally, the detailed labour breakdown for control shifts and prosecutions, obtained though the interviews (number of persons and person-hours of a typical control shift / prosecution, typical policeman hourly rate), was used to calculate the total yearly labour costs.

For the estimation of the number of accidents prevented from the intensification of speed and alcohol enforcement, the results of a recent research were exploited (*Agapakis, Mygiaki, 2003*). This research concerned a macroscopic investigation of the effect of enforcement on road safety improvement in Greece, aiming in particular at determining the separate effect of different types of enforcement (speeding, drinking and driving, violating signals, failing to yield etc.), as well as the effect of other safety related parameters (vehicles fleet, vehicle ownership, population) on the significant overall improvement of road safety in Greece during the last few years.

This study included two distinct parts; the first part concerned a cluster analysis aiming at identifying groups with similar characteristics within the 52 departments of Greece. Results indicated four groups ranging from I to IV, according to the population, the accident rates and the infringement frequencies (high, medium, low) of the various departments. The second part of the study concerned the development of Poisson regression models for the quantification of the separate effect of various types of enforcement, as well as other parameters on the total number of accidents in each Group of departments. In each case, the marginal effects of the various significant parameters were also calculated. Additionally, the modelling process was developed for two different assumptions concerning the effect of enforcement, resulting in two categories of models;

- Models with no time-halo in the effect of enforcement
- Models with a time-halo in the effect of enforcement

The above classification rises from the international experience, according to which, there may be a delay of several weeks before a significant effect of enforcement is observed (*Holland, Corner, 1996, Vaa, 1997*). It is interesting to note that, among the various types of enforcement examined in this study, the enforcement of speeding and drinking-and-driving was found to have a significant effect on the total number of accidents only in Groups II and IV, whereas in the other Groups, other types of enforcement were found significant, such as traffic signals violations, failing to yield etc.

In the first group of models (no time-halo effect), it was found that an increase of 1000 speed infringements prevents approximately 1 accident in Group II departments and 2 accidents in Group IV departments. Additionally, it was found that and increase of 1000 alcohol controls prevents approximately 2 accidents in Group II departments and 1 accident in Group IV departments. In the second group of models (with time-halo effect), the number of controls and infringements of one month were combined with the accidents of the next third month. In particular, it was found that an increase of 1000 speed infringements prevents approximately 1 accident in Group II departments and 2 accidents in Group IV departments. Additionally, it was found that and increase of 1000 alcohol controls prevents approximately 2 accidents in Group II departments and 1 accident in Group IV departments.

In the framework of the present research, the above results were combined with the related enforcement trends data for the period 1998-2002, which are available in detail from the National Police, in order to calculate the total number of accidents prevented from the intensification of enforcement in the examined period. The results are presented in detail in the following Table 11.

Table 11: Safety effect of enforcement 1998-2002

	No time-halo-effect				**Two months time-halo-effect**			
Department Group	I	II	III	IV	I	II	III	IV
Marginal effect* of speed infringements		-1,239		-1,542		-2,224		-2,053
Marginal effects* of alcohol controls		-1,929		-1,373		-2,265		-2,684
Number of accidents prevented		475		297		614		528
Total number of accidents prevented	**772**				**1.142**			

*expected accidents prevented from a 1000 infringements/controls increase

According to the results of the consideration without delay in the effects of enforcement, a total number of 772 accidents were prevented in the examined period in Greece. This consideration will be adopted as the "conservative scenario" of the present cost-benefit evaluation, corresponding to a minimum effect of enforcement. The results of the consideration with two-month time-halo in the effects of enforcement indicate a total number of 1.142 accidents prevented in the examined period in Greece. This consideration will be adopted as the "best scenario" of the present cost-benefit evaluation, corresponding to a maximum effect of enforcement. On the basis of the approach described above, the Benefit/Cost ratio was calculated for the "conservative" scenario and the "best" scenario. An accumulated discount factor was applied to the benefits calculation, on the basis of an interest rate of 4% (*National Statistical Service of Greece, 2003*). Additionally, the average accident cost was calculated by weighting the costs of fatal and injury accidents in relation to the average distribution of accident casualties per casualty severity in Greece.

Table 12: Results of Cost-Benefit Analysis for speed and alcohol enforcement

	Conservative scenario No time-halo-effect	**Best Scenario** Two months time-halo-effect
Number of accidents prevented	772	1.142
Average accident cost	309.723	309.723
Present value of benefits (€)	259.313.657	383.471.514
Cost of speed enforcement	14.814.729	
Cost of alcohol enforcement	24.709.862	
Total Implementation Cost (€)	39.524.591	
Benefit - Cost Ratio	**6,6 : 1**	**9,7 : 1**

As shown in the above Table 12, the "conservative" scenario yielded a very high Benefit/Cost ratio equal to (6,6 : 1). Accordingly, the "best" scenario yielded an even higher

Benefit/Cost ratio equal to (9,7 : 1). In both scenarios, the nationwide intensification of speed and alcohol enforcement in Greece was found to be highly cost-effective.

4 CONCLUSIONS

Cost benefit analysis is considered to be one of the most important tools in the hands of decision makers, for the economic appraisal of road safety measures, implemented in several cases. However, the present research revealed very limited exploitation of assessment methods in the overall decision-making process in Greece. Only a small number of cost-effectiveness studies on road safety measures in general were conducted by independent institutions and organisations. These occasional research initiatives provide some insight on the existing activities, but are scarcely leading to interesting conclusions and thus are not usually transferred to policy-makers.

Therefore, the cost-benefit assessment of different yet representative road safety measures in Greece gives some insight in the efficiency of the related policies. Although the small number of case-studies makes it impossible to draw generalized conclusions, it suggests, as in other studies, that important benefits can be obtained with relatively limited resources. The three case-studies presented in this paper, although significantly different, cover a broad range of typical road safety measures, ranging from user- to infrastructure-oriented measures, and from local to regional and national level.

In particular, as far as the development of motorways in Greece is concerned, the safety benefit alone does account for cost efficiency of the treatments, yielding a satisfactory benefit-cost ratio in both sections. The magnitude and significance of the results indicate that the safety benefit, although not sufficient to support decision making itself, is an important additional benefit from motorways development. The use of before-and-after assessment showed that there is a statistically significant decrease in the number of accidents and related casualties in the upgraded national road network, which can be attributed mainly to the motorway construction.

The cost-benefit analysis applied to the second case-study, in order to evaluate the economic effectiveness of certain traffic calming measures (speed humps and woonerfs) in urban areas, showed that these measures' implementation was satisfactorily cost-effective, despite the high implementation cost of the traffic calming measures, a particularity of the project tendering system in the Greek construction sector.

As far as road safety enforcement is concerned, the lack of systematic and appropriate cost data complicated the assessment process. The cooperation of the decision makers, who provided useful data based on their experience, was very important in dealing with this problem. However, it is obvious that a lot of additional effort is required, in order to achieve a systematic recording of police labour and capital costs, in a similar way that the related controls and infringements were monitored since the intensification of police enforcement in Greece. Finally, the important benefit obtained from the intensification of speed and alcohol enforcement, in terms of number of accidents and casualties prevented, could motivate decision makers towards further improvement of the implementation and monitoring of the measures.

Summarizing the performance of the case-studies, several common technical problems, which might occur during the CBA evaluations were identified, including the correct application of the odds-ratio technique (before-and-after), the ways for checking the statistical significance of the evaluation results, the selection of side-effects to be considered along with safety effects, the correct distinction between the implementation costs and negative side-effects of the measure.

Finally, this study revealed that two of the major technical barriers for performing efficiency assessment of road safety measures are lack of information on safety effects and costs, as well as doubts on the validity of the available values. Additionally, lack of obligatory procedure for the performance of cost-benefit evaluations of safety effects is known as a major institutional barrier for the application of the efficiency assessment of safety measures (European Commission, 2005).

REFERENCES

Agapakis, J., Mygiaki, E., (2003). "Macroscopic investigation of the effect of enforcement on the improvement of road safety on Greece", Diploma Thesis, NTUA, School of Civil Engineering, Department of Transportation Planning and Engineering, Athens.

Attiko Metro SA. (2000). "Land use characteristics and socio-economical parameters of the Greater Area of Athens", Attiko Metro S.A., Athens.

Elvik, R., (1997). "Effects on Accidents of Automatic Speed Enforcement in Norway", Transportation Research Record 1595, TRB, Washington, D. C., pp.14-19.

Elvik, R., et al., (1997). Trafikksikkerhekshandbok (Traffic Safety Handbook), Institute of Transport Economics, Oslo, Norway.

Evangeliou, P., (2003). "Evaluation of the safety effect of motorways development using before-and-after techniques", Diploma Thesis, NTUA, School of Civil Engineering, Department of Transportation Planning and Engineering, Athens.

European Commission (2005), "Testing the efficiency assessment tools on selected road safety measures", ROSEBUD - Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making - Thematic network, WP4 Final Report.

Georgopoulou X., (2002). "Investigation of Low Cost Engineering Measures' Impact on road safety in urban areas", Diploma Thesis, NTUA, School of Civil Engineering, Department of Transportation Planning and Engineering, Athens.

Gitelman, V., et al, (2001). "A Study of Safety Effects of Road Infrastructure Improvements under Israeli Conditions", Int. Conference Traffic Safety on Three Continents, Moscow, Russia (CD-ROM); VTI konferens.

Hauer, E., (1997). Observational Before-After Studies in Road Safety, Pergamon.

Holland, C.A., Conner, M.T., (1996). "Exceeding the speed limit: An evaluation of the effectiveness of a police intervention", Accident Analysis & Prevention, Volume 28, Issue 5, Pages 587-597.

Kanellaidis G, et al., (1995). "A survey of drivers' attitude towards speed limit violations", Journal of safety Research.

Liakopoulos, D. (2002). "Development of a model for the estimation of the economic benefits from accident reduction in Greece", Diploma Thesis, NTUA, School of Civil Engineering, Department of Transportation Planning and Engineering, Athens.

Municipality of Neo Psychiko, (2001). "Regional Development Programme", Technical Division of the Municipality of Neo Psychiko.

National Statistical Service of Greece, (2003). "Greece in figures", Official Publication of the National Statistical Service of Greece, Athens (www.statistics.gr).

National Technical University of Athens, Dept. of Transportation Planning and Engineering, (2003). "A strategic plan for the improvement of road safety in Greece 1998-2002", Ministry of Economy and Finance.

NTUA/DTPE - National Technical University of Athens / Department of Transportation Planning and Engineering, (2004). "Accident risk investigation of categories of drivers with high accident involvement - second report", Ministry of Transportation and Communication.

Ogden, K.W., (1996). "Safer Roads: A Guide to Road Safety Engineering", Avebury Technical, England.

Smith, N., (1998). "Engineering Project Management", Blackwell Publication.

Vaa, T., (1997). "Increased police enforcement: Effects on speed", Accident Analysis & Prevention, Volume 29, Issue 3, Pages 373-385.

Yannis, G., Kanellopoulou, A., Aggeloussi, K., Tsamboulas, D. (2005), "Modelling driver choices towards accident risk reduction", Safety Science, Vol.43/3, pp. 173-186.