Cost-benefits analysis as a tool to improve road safety

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SYNOPSIS

Road safety is at the moment one of the main priority of the European Commission: the White Paper "European Transport Policy for 2010: time to decide" sets the objective of halving the number of fatalities by 2010 throughout Europe. At national level, member states define national road safety plans to reach this objective (e.g. Italy, The Netherlands)

This paper provides a description of the political framework that regulates road safety in Italy and in The Netherlands in order to stress the main differences between the two legislative approaches. It was decided to set The Netherlands has reference country being one of the most advanced European countries in road safety.

Moreover, to provide a more comprehensive analysis a comparison on road safety design procedures is also performed between Italy and USA, being the USA a leading country in the design and definition of road accident countermeasures since this issue has been deeply analysed from the '80s.

The analysis shows that in Italy there is still a "traditional" approach toward road safety problems while in other countries more "objective" approaches based on scientific tools, as the cost-benefits and cost-effectiveness analysis, are taking over.

The road safety project carried out on "Via Ostiense – Via del Mare" by STA - Rome's Mobility Services Agency - is then analysed and application of the cost-benefits analysis is performed for a specific measure, in order to provide a detailed description of how this methodology should be applied and on the benefits related to its application.

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INTRODUCTION

Road safety is at the moment one of the main priority of the European Commission: the White Paper "European Transport Policy for 2010: time to decide" sets the objective of halving the number of fatalities by 2010 throughout Europe. At national level, member states define national road safety plans to reach this objective (e.g. Italy, The Netherlands)
The aim of this paper is to stress the importance of using an economic tool as the cost-benefit analysis in the road safety analysis.
To achieve this objective this paper has been structured into five sections. In the first one a description of the Italian political framework that actually regulates road safety issues (in terms of resources allocation and measures evaluation) is provided. Then a description of the approach used by the Dutch transport Ministry to evaluate the impact of the measures foreseen by the Dutch National Traffic and Transport Plan is given in order to point out the differences existing between the approaches followed by both countries.
In section two a description of the methodology actually used in Italy to perform road safety analysis and the approach undertaken in the USA by the Iowa Department of Transportation are provided.
In section three the definition of the cost benefits analysis is provided both in general terms and with particular regard to road safety measures.
In section four a real case application of cost-benefits analysis is reported on a measure that has been identified by STA - Rome's Mobility Services Agency to reduce road accident on "Via del Mare – Via Ostiense" corridor. This section is divided into two sub-sections; the first one provides a brief description of the study that led STA into the definition of a set of road accident countermeasure on the analyzed corridor. The second sub-section provides a detailed step-by-step description of an application of the cost benefit analysis; it has been performed on one of the countermeasure identified by STA.
Finally, in section five, conclusion on the performed analysis are drawn up.

POLITICAL FRAMEWORK

Within this section the Italian political framework will be depicted focusing either on the objectives and resources allocation criterion defined by the National Road Safety Plan and on the criterion adopted by the Regions to rank different road safety related projects and then co-finance them.
Then, a brief description of the approach undertaken by The Netherlands Transport Ministry to evaluate, within the Dutch National Transport Plan, the impacts of road safety measures will be provided.

The Italian Road Safety National Plan

The Road Safety National Plan [5] was drawn up by drawn up by the Ministry of infrastructures and Transport in year 2000. It is designed to reduce the number of road accident deaths and serious injuries by 40% by 2010, as foreseen by the European Commission White Paper "European Transport Policy for 2010: time to decide" [8]. It can be considered the national *strategic planning tool* for road safety, pointing out the objectives and actions that each Region should undertake to improve road safety at local level; it also provides the resources allocation criterion used by the Ministry to split economic resources among the different Territorial area (e.g. Regions).
The economic resource allocation criterion defined by the Road Safety National Plan is based on the comparison of a specific parameter (P) that allow to evaluate the total social cost related to road accidents and its trend over the last 5 years. The P parameter is calculated by means of the following equation:

$$P = \left[0.7(M \cdot Csm + F \cdot Csf) + 0.3Es\right] D$$

where

P = total "weight" for the financial allocation
M = annual average number of deaths in the last 5 years
Csm = average social cost of a death (million €)
F = annual average number of injured in the last 5 years
Csf = average social cost of an injury (million €)
Es = length of the road network at a regional, provincial and municipal level (km)

D = weight factor, depending on road accident trends in the last 5 years; it is equal to 1.1 (+10%) in the areas characterized by a variation of the product (M x Csm + F x Csf) higher than the national average (+2.1%).

This criterion aims to ensure a resources allocation, among different territorial areas (e.g. Regions), proportional to their estimated social costs related to road accidents. The criterion used to allocate the economic resources is based on the “premium principle”: the higher is the social costs reduction related to the implementation of specific project, the higher is the economic contribution to that territorial area with the constraint of allocating at least the 35% of the total resources to the Southern part of Italy.

In detail, once the P_i parameter has been calculated for each territorial area, the percentage of resources related to that particular territorial area (Q_i) is determined dividing the P_i parameter by the sum of all P_i; this can be expressed by the following formula:

$$Q_i = 100\left(\frac{P_i}{\sum_i P_i}\right)$$

Once the total resources (Q_i) have been determined and split at strategic (national) level among the territorial areas (e.g. Region), the next step is represented by the distribution of this resources at local level (e.g. provincial level, city level). It is important to point out that at this level, each Region defines its own resource allocation criterion; however this is always defined according to the objectives and priorities indicated by the Road Safety National Plan and in the "Implementation National Plans" (4). Moreover, Regions do not entirely finance the interventions but only co-finance them; an example of co-financing rate is reported in Table 1.

Table 1 – Example of co-financing rate (source: Abruzzo Region)

	Cost (thousand €)	**Co-financing rate**
INTERVENTION ON THE ROAD NETWORK		
Province and Provincial Capital	2,000	50 %
Municipality > 10.000 inhabitants	1,000	55 %
Municipality < 10.000 inhabitants	500	60 %
ALL OTHER INTERVENTION		
Province and Provincial Capital	800	50 %
Municipality > 10.000 inhabitants	400	55 %
Municipality < 10.000 inhabitants	200	60 %

The methodology adopted by each region to define which project should be co-financed is based on pre-established criteria that allow to define a ranking list of the projects; it will be firstly co-financed the proposal with the highest score and then all the remaining, in a score decreasing order, up to exhaustion of funds. However plans that have not reached a minimum score, e.g. 40 points on a 0 to 100 scale, will not access to funding.

Here after a brief description of the methodology used to calculate the score of a project is provided.

The final score of an intervention is calculated applying the following relation:

$$A + B + C + D$$

where the elements that concur to the final score are:

A : this parameter indicates the <u>importance of the proposal</u>; higher score is given to those interventions that will introduce interventions characterized by high benefits in terms of accident reduction and social damage reduction. It is calculated as:

$$A = (A_1 + A_2) \times A_3 = (A_1 + A_2) \times (A_3' + A_3'' + A_3''') \qquad \text{[up to 30 points]}$$

where:

A_1: Social damage

A_2: Level of risk

A_3: Ability to reduce danger, it is obtained as the sum of 3 parameters: a "self-consistency of the plan and coherence with National Road Safety Plan objectives" parameter (A_3'); a "guarantee of intervention duration” parameter (A_3'') and a parameter who expresses "the victims reduction ratio” (A_3''')

B : this parameter indicates the <u>strengthening of the ability to government</u>. It is calculated as:

$B = B_1 + B_2 + B_3$ [up to 30 points]

where:

B_1: Strengthening, constitution of a technical structure dedicated to the road safety

B_2: Strengthening, constitution of a road safety monitoring centre

B_3: Presence, strengthening, constitution of a road safety consult or of a similar office

C : this parameter indicates the completeness and integration of the proposal. It is calculated as:

$C = C_1 + C_2$ [up to 20 points]

where:

C_1: Multisector and land use

C_2: Integration of the proposal in a road safety plan or program

D : this parameter indicates the timeliness, understanding like the definition of those elements that ensure that implementation times are the one reported in the proposal. It is calculated as:

$D = D_1 + D_2 + D_3$ [up to 20 points]

where:

D_1: Level of detail of the planning (executive, final or preliminary design)

D_2: Completeness of the administrative part of the proposal

D_3: Availability of all the necessary factors

The Dutch National Traffic and Transport Plan

The Dutch National Traffic and Transport Plan (NVVP), presented in year 2001, is the successor of the Second Transport Structure Plan of 1989 and aims at achieving the target set in 1986 for the year 2010: a maximum of 750 deaths and 14,000 in-patients [7].

Among the activities carried out to finalize the NVVP, the Dutch Ministry of Transport asked to the Dutch Institute for Road Safety (SWOV) to calculate the effect of the Plan measures, in order to evaluate the feasibility of the foreseen objectives.

The SWOV Sustainable Safe approach served as a starting point for identifying the various measures. It consists in considering the traffic system characterized by: road infrastructures that have been adapted to the limitations of human capacity through proper road design; vehicles that are technically equipped to simplify driving and to give all possible protection to vulnerable human beings and by road users that have been properly educated, informed, and, where necessary, deterred from undesirable or dangerous behaviour.

Consequentially, four categories of measures were distinguished, that is infrastructure, behaviour, vehicles, and intelligent transport systems (ITS). When performing the calculations, as much use as possible was made of known (research) data, such as knowledge on the effects of measures in general and the extent to which, and the speed in which, they are carried out. Where necessary, the data was supplemented by a "best guess".

The study carried out by SWOV consists of two parts: in the first part, the effect of each measure separately was totalled to calculate their combined effect on the national casualty reduction; the second part examined the cost and cost effectiveness of each measure. These were calculated to examine the costs of the total package of measures. To calculate the costs of the measures, a close cooperation went on between SWOV and the Transport Research Centre of the Ministry of Transport, the Ministry's Road Construction Division, the Inter-Provincial Consultation and a consultation firm.

In order to prevent overestimation of the total effect of the measures on the national casualty reduction, the overlapping effects of a number of measures were taken into account. To rank the efficiency of the measures foreseen by the Plan, SWOV used the cost-effectiveness ratio (C-E ratio); it expresses the costs per victim (death or injured) saved implementing the road safety measures.

The methodology adopted by the Dutch Ministry of Transport to evaluate the impacts of road safety and reported in this section wants to stress the importance of using tools as the cost-benefits and cost-effectiveness analyses to define the most efficient road safety measures [6].

These tools should be considered powerful instrument to objectively rank the benefits related to the implementation of a road safety measure. Then, even if the final decision will always depend on political reasons, these tools will help the decision makers during the decision process providing a description of which measure will produce, with a fixed budget, the highest benefits.

ROAD SAFETY DESIGN

Within this section the methodology defined by the Italian Ministry of infrastructures and Transport to perform road safety preventive analysis, namely the Road Safety Review, is compared with the methodology defined by the Iowa Department of Transportation (USA) based on the Crash Reduction Factors.
The description of the two methodologies wants to stress the main differences between the two approaches.

The National Road Safety Plan: guidelines for road safety preventive analyses

description of the methodologies that should be used in order to implement the most efficient countermeasure to face road accident.
Among these, the report "Guidelines for road safety analysis" [9] provides a detailed description of the methodology that should be used to perform a preventive road safety analysis. It distinguishes two different types of analyses:

- the *Road Safety Audit* (referred to roads to be build);
- the *Road Safety Review* (referred to existing roads),

Both instruments represent preventive processes that aim at identifying potentially dangerous situations, before accidents occur [4].
An independent and qualified examination group performs these analyses; the examination group carries out the analyses of the potential dangers of accidents and of safety performance. In order to ensure a multidisciplinary approach to these analyses, the examination group is made of experts of different areas, such as transport, economic, environment, etc.
The examiners' work is then illustrated in an analysis report that identifies which countermeasures should be implemented to improve road safety on the examined route, for example:

- amendments to planning features (e.g. inappropriate layout of intersections) or functional irregularity (e.g. objects obstructing vision);
- action to lessen consequences and seriousness of accidents (e.g. surfacing roads with high friction or amendments to absorption devices).

In the following section a more detailed description of the Road Safety Review is given.

Road Safety Preventive Analyses on operating road: the Road Safety Review

As defined by the Road Safety National Plan (Guidelines for road safety analysis): "The Road Safety Review aims at identifying all the aspects of road environment that can be rapidly modified in order to reduce the actual rate of accidents".
The Road Safety Review methodology has been defined starting from the comparison, study and analysis of real cases applications on operating road, from the procedures defined by the Italian National Research Centre (C.N.R.) and from other international experiences. As results, the methodology that has been defined allow to:

- evaluate the level of safety of a road based on the number of accident with death or serious injuries that occur within a defined time interval;
- determinate actual level of safety;
- define the most suitable countermeasure to improve road safety on operating road.

In terms of real case applications, the methodology can be briefly schematized as follow: the road (or part of the road network) is divided into a series of *homogenous link* (in terms of geometrical characteristics, traffic flows, traffic regulations, etc.) then a quantitative analysis of collected accidents data is performed. For each homogenous link is estimated the accident average rate that is then compared with the national accident average rate for the same type of road; this allow the classification of the homogenous link into "low", "average" or "high" accident rate link.
Then a detailed analysis on each link is performed trying to find out a relationship between the accident rate and the characteristics of the link. This analysis is subdivided into three steps:

- the <u>preliminary analysis</u>, all information that have been collected during the verification of road's geometric and functional characteristics are elaborated in order to identify the most dangerous links or intersections, in terms of accidents' number and risk factors;
- the <u>site inspection</u> in order to estimate the real road safety conditions; it must be separated from other inspections carried out for different purposes (geometric surveys, traffic counts, etc.). It must be carried out both during the day and the night and the road must be drive along in both directions several times. To help the examiners, the Ministry settled up a "checking list" of the most common problems;
- the <u>problems analysis and definition of the analysis report</u>, the examination group analyse all the issues that arose during the site inspection and defines all the possible solutions that will then be included in the final report. It should be highlighted that the examination group will only examine the road safety related issues.

The Road Safety Review allows to identify the must dangerous elements of the road network; usually all the countermeasure identified using this analysis are low-cost and need very short period of time to be realized.

It is a very flexible methodology and can be applied to any element of the road environment (intersections, roads, bridges. etc); it can be applied either to the whole road then to a single intersection. Obviously, the level of detail that can be reached by this methodology is strictly related to the available information (type of data, historical data, etc).

The SEMCOG traffic safety manual of Iowa Department of Transportation (USA)

In order to highlight the differences between Italian and foreign countries approach to road safety measures planning, in this section the road safety measures analysis methodology defined by the Iowa Department of Transportation (U.S.A.) is reported.
The methodology described hereafter is the one described by the SEMCOG (Southeast Michigan Council of Government) Traffic Safety Manual [2]; this was financed in part through grants from the Federal Highway Administration, the Federal Transit Administration, the Michigan Department of Transportation (Office of Highway Safety Planning), and local membership contributions. It provides a set of user-friendly tools for checking a location's crash history, identifying possible crash causes and countermeasures, and conducting a preliminary benefit/cost analysis of those countermeasures selected for further consideration.
The SEMCOG manual provides a set of tables and appendixes that drive the user all the way up to the definition of the best countermeasure to implement to solve a significant crash pattern.; a crash pattern is said to exist when crashes of a particular type constitute an unexpectedly large proportion of a location's reported crashes, a significant crash pattern is said to exist.
The manual also provides countermeasures' total Crash Reduction Factor (CRF) for signs, signals, and markings, canalizations, pavement, roadway, pedestrian, driveways, barriers, railroad crossing, and miscellaneous countermeasure categories. The CRF allow the evaluator to determine the benefits (in terms of saved human lives and reduction of the number of injuries) related to the implementation of a specific countermeasure; an example of a CRF table, also reporting an estimation of both implementation related costs and operating and maintenance (O&M) costs per year, is given in Table 2.

Table 2 - Example of countermeasure default values for SIGNALS (source: SEMCOG*)*

Countermeasure	**Service Life** (yrs)	**Costing Unit**	**Unit Costs ($)**		**Units/ Project**	**Project Costs ($)**		**Total CRF** (%)
			Implementation	**O&M/yr**		**Implementation**	**O&M/yr**	
Signalize intersection	15	Intersection	45,000	2,600	1	45,000	2,600	**20**
Retime traffic signal	1	Intersection I/S	900	0	1	900	0	**10**
Increase yellow change interval	1	Intersection I/S	900	0	1	900	0	**15**
Add all-red clearance interval	1	Intersection I/S	900	0	1	900	0	**15**
Revise signal phasing/sequence	3	Intersection I/S	1,600	0	1	1,600	0	**25**
Provide right-turn overlap (green arrow)	3	Intersection I/S	1,600	0	1	1,600	0	**25**

In detail, the methodology used to determine countermeasures, crash-reduction factors, and costs can be summarized in the following steps:

- Compute the location's crash percentage for each possible crash pattern.
- Define the location type. Categorize the location by as many of the following features as possible:
  - area type (urban/rural);
  - roadway functional class (arterial/collector/local) — for an intersection, the higher or highest functional class of the intersecting roadways, where an arterial is the highest class (meant primarily to carry through traffic) and a local is the lowest class (meant primarily to provide access to abutting properties);
  - number of lanes — for an intersection, the number of through lanes on the widest approach;
  - predominant traffic control — for an intersection, the presence or absence of signalization and for a segment, the speed limit;
  - average daily traffic (ADT) volume for an intersection, the sum of the volumes on all approaches.
- Determine regional average crash percentages for each possible crash pattern.

- Compare each crash percentage computed for the location to the corresponding regional crash percentages. If the location's crash percentage exceeds one or more of the regional crash percentages, the location has an above-average proportion of crashes of the indicated type and can be said to have a significant crash pattern of that type.
- Compute the average of all regional crash percentages which are less than the location's crash percentage.
- Compute an over-representation ratio (ORR)

  $$ORR = \frac{10}{PPI \cdot SW}$$

  Divide the location's crash percentage by the corresponding average regional crash percentage and enter the ratio in the appropriate box of the worksheet. The ORR should be greater than 1.
- Determine a severity weighting (SW). Some crash types are typically more severe than others; for example, angle crashes result in more serious personal injuries, on average, than do rear-end crashes.
- Determine pattern priority. Compute a pattern priority index (PPI) for each significant crash pattern by substituting the values of ORR and SW determined in previous steps. The pattern with the smallest value of PPI should receive the highest priority, and the pattern with the largest value of PPI, the lowest priority. PPI values will function in a manner similar to normal priority rankings, but they will not be whole consecutive numbers.
- Determination of possible causes. They may be determined for just one, a few or all significant crash patterns found at a location. Focusing first on the more highly over-represented and severe crash patterns will speed up the process of isolating those causes responsible for the greatest crash losses occurring at a high-crash location.
- Determination of possible countermeasures. Having identified the possible causes of a location's most troublesome crash types, the next logical step is to determine possible countermeasures. Such countermeasures can be determined for a specific multiple-vehicle crash pattern and cause by consulting one of the following tables:
- Data for b/c analysis. To compute the B/C ratios used to compare the relative economic attractiveness of alternative crash countermeasures, an interest rate and the following countermeasure-specific inputs must be determined:
  - benefits in terms of overall crash-reduction potential, and
  - various cost-related parameters, including: implementation cost, operating and maintenance (O&M) cost, service life, and salvage value.

A DECISION SUPPORT TOOL FOR ROAD SAFETY: THE COST-BENEFITS ANALYSIS

Cost-benefit analysis is based on the principle of social efficiency. Social efficiency is a technical term in welfare economics. A policy or a programme is regarded as efficient if it improves the welfare of at least one person without reducing it for anybody else. Policies that are efficient in this sense satisfy the criterion of Pareto-optimality. It has long been recognised, however, that Pareto-optimality is a much too stringent criterion of social efficiency.

Most economists therefore subscribe to a less demanding criterion (potential Pareto-improvement) stating that a project improves welfare if those who benefit from it can, at least in theory, compensate those who lose from it and still retain a net benefit. This is equivalent to saying that projects for which the monetary values of the benefits, estimated according to the willingness-to-pay principle, exceed the monetary value of the costs, estimated according to the opportunity cost principle, are efficient, whereas projects for which the benefits are smaller than the costs are inefficient.

Various measures of efficiency are used in cost-benefit analysis. These are the net present value of a project, the benefit-cost ratio, and the internal rate of return.

Within this paper we will focus on the benefit-cost ratio that is defined as:

$$\text{Benefit-cost ratio} = \frac{\text{Present value of all benefits}}{\text{Present value of implementation costs}}$$

The benefit-cost ratio allows to describe the economical feasibility of a specific measure; precisely, when the ratio is greater than 1.0 it means that the present value of the benefits is grater than the present value of the implementation costs and it reflects relative economic desirability by the degree to which it exceed 1.0.

The main problems related to the applicability of the cost-benefits analysis (CBA) are strictly related to the difficulties of defining the monetary value of intangible or immeasurable assets such as human life or environmental benefits.

Usually, to overcome these difficulties, the monetary value of human life is calculated estimating the earnings that the person would have received if he had continued his normal working life and reached average life expectancy. The monetary valuation of avoided biological damage is calculated by counting

medical expenses not allocated, and the salary received from the number of working days which would have been lost because of the accident.
To calculate the economic value that drivers give to an increase of road safety conditions, it is used the so-called “contingent analysis”; it is based on the definition of drivers’ willingness-to-pay to reduce accident probabilities.
According to its definition, the CBA represents a tool which aids the decision makers into the definition of the most efficient road safety measure since, through the calculation of the benefits and costs related to its implementation, allows identifying of the best plan to be implemented [3].
Moreover the CBA represents an objective tool to rank a set of possible measures and it allows the definition of the most efficient measure to be implemented according to a fixed budget.
The importance of using this approach to analyse road safety measure is also strengthened by the European Commission that had and is co-financing several number of projects aiming at improving the knowledge on specific tools able to support decision makers at defining the most efficient countermeasures (e.g. cost-benefit analysis, cost-effectiveness analysis).
One of this projects is the thematic network ROSEBUD (Road Safety and Environmental Cost-Benefit and Cost-Effectiveness Analysis for Use in Decision-Making), where DITS - Department of "Idraulica, Trasporti e Strade" of the University of Rome “La Sapienza” - is the Italian partner. This network is co-financed by the European Commission Directorate-General for Energy and Transport (2002-2005), and aims at evaluating the degree of knowledge and usage of tools as the cost-benefits and cost-efficiencies analysis and which issues need to be boosted to spread out their usage among European decision makers.

ROAD SAFETY PROJECT OF “VIA OSTIENSE - VIA DEL MARE”

Within this section, it will be initially described the analysis carried out by STA – Rome’s Mobility Services Agency on “Via Ostiense -Via del Mare” corridors that in year 2000 resulted to be the most dangerous road of the whole national transport network. This analysis aims at identifying the most suitable countermeasures to be implemented along “Via Ostiense – Via del Mare” corridor, in order to reduce the number of accidents.
Then, a specific section provides a detailed application of the cost benefit analysis to a specific countermeasure identified by the STA analysis. This section wants to describe how the cost benefits analysis should be applied to road safety measures.

The study of “STA – Mobility Services for the City of Rome”

"Via Ostiense - Via del Mare" corridor is located in the southern part of the city and represents the main connection between Rome’s City Centre and the City of Ostia and all suburban areas located in-between (Figure 1). It is characterized by high traffic volumes, especially commuters that during the morning and evening peaks hours cause high level of traffic congestion on the corridor itself.

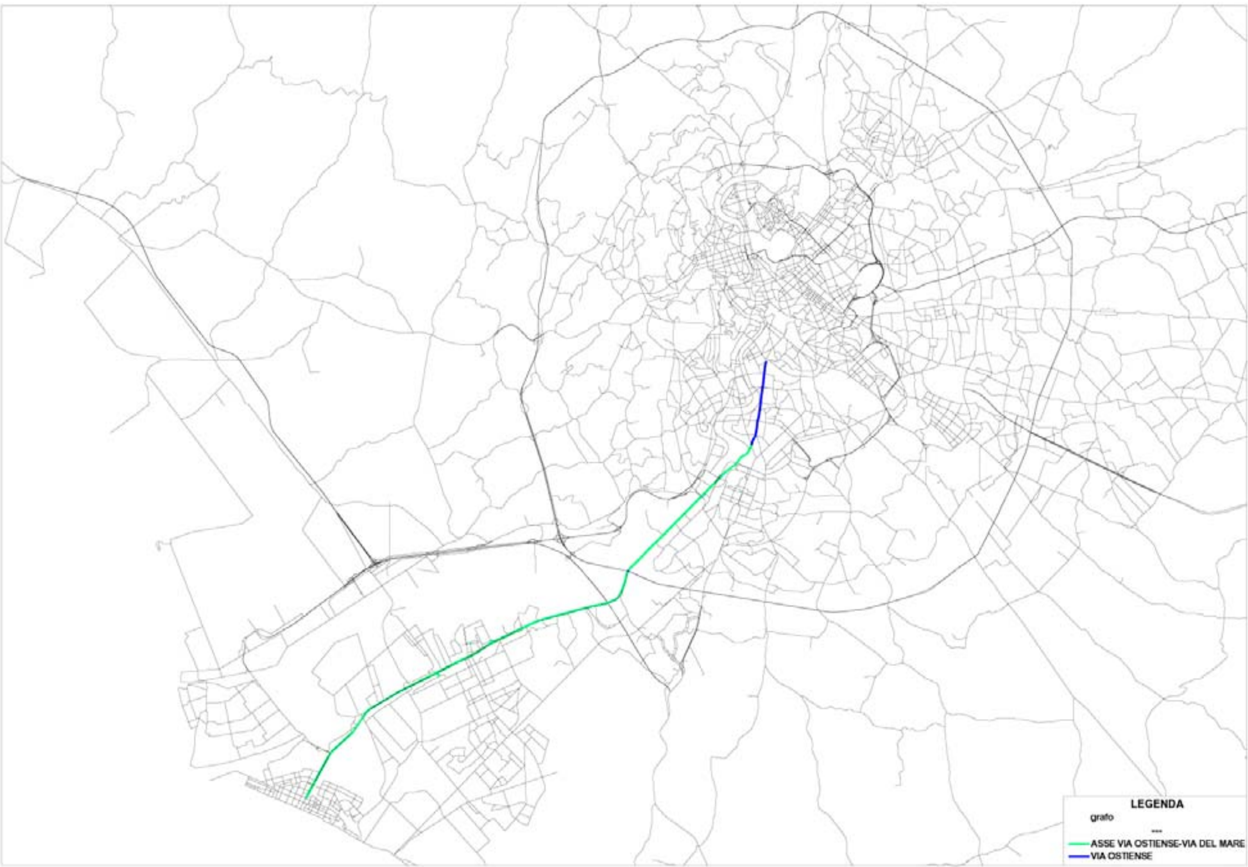

Figure 1 - “Via Ostiense – Via del Mare” corridor (highlighted in green)

The analysis carried out by STA pointed out that in year 2000 an average of 8 accidents per Km were detected along “Via del Mare”; it represented the highest national accident rate. For this reason both the Municipality and the Province of Rome decided to initially define a set of countermeasure that could be implemented in relatively short period; while in the long-medium period more complex actions will be carried out aiming at transforming “Via Ostiense – Via del Mare” in two one-way roads.
Hereafter, the description of the methodology undertaken by STA to identify road safety measures will be depicted; it is part of the main STA report “Improvement and implementation of road safety measures on Via del Mare - Via Ostiense corridor”.

<u>Study Methodology</u>
The methodological approach undertaken by STA is based on the “Guidelines for Road Safety Analysis” and “Guidelines for Urban Road Safety” produced by the Ministry of Infrastructure and Transport and on the report “Methodology to identify road safety action: application to S.S. 148 Pontina”, produced by ACI (Automobile Club Italy) [1].
The methodology is structured in four phases (Figure 2):

Phase 1: aims at acquiring all road data in terms of technical-functional characteristics (*static indicators*), actual usage level (traffic flow) and safety (accident rate and number of deaths and injured) (*dynamic indicators*);

Phase 2: aims at identifying the cause of road accidents, it is performed carrying out::
- the analysis of accident data, related to traffic flow;
- the road safety review.

Within the first procedure, the accident data are supplied by ISTAT (Italian National Statistical Institute) and by the Municipal Police. Within the road safety review, the phenomenon is analysed according to the “Guidelines for road safety analysis” provided by the Ministry of Infrastructures and Transports.

Phase 3: aims at dividing the analysed road into “homogeneous links”; within this study, these are defined according to the environment and road characteristics and to traffic characteristics.

Phase 4: aims at identifying all the countermeasures necessary to improve road safety, according to previous phase’s results. All the countermeasure will be analysed in terms of implementation costs, benefits (in terms of accident reduction) and feasibility.

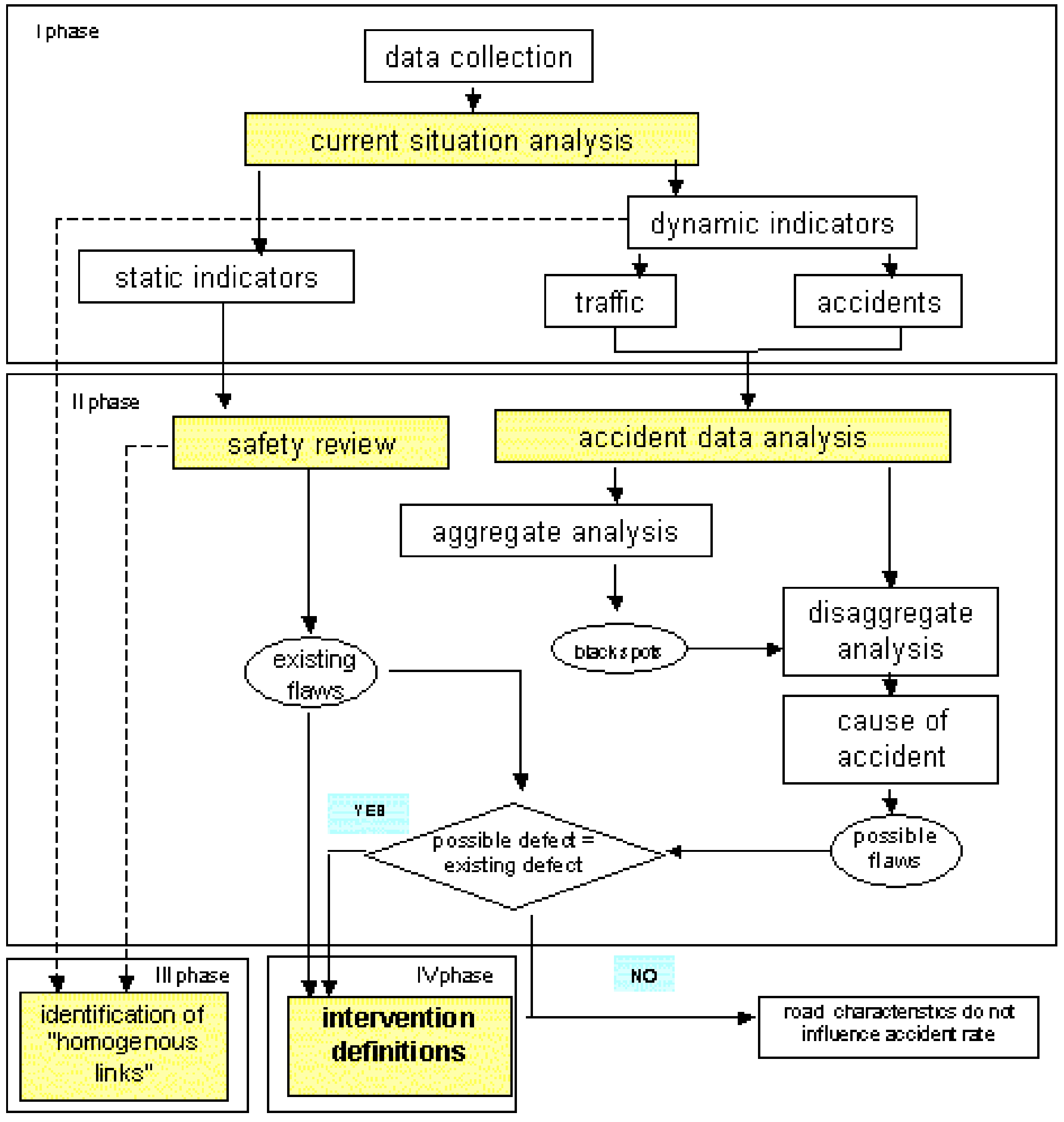

Figure 2 – Flow-chart describing the methodological approach undertaken by STA

Phase 1: Current situation analysis

The analysis of the current situation is based on the analysis of traffic flows and detected accidents (in terms of number and type). The former were collected by STA carrying out traffic counts both along the corridor and at the main intersections, the latter were collected by ISTAT and Municipal Police and refers to the period 1995-2000.

The analysis carried out on the accidents locations allowed to define the characteristics of the road where the accidents occurred. It focused on the type of road (e.g. number of carriageways), surfacing (in good and bad conditions), presence or absence of intersections, the type of signals (if existing), the weather conditions, the road surface condition (dry, wet), etc.. The results of this analysis showed that on "Via del Mare" (Table 3) about 73% of accidents occur on straight road with two carriageways, while for "Via Ostiense" (Table 4) accidents are mainly located at intersections of one carriageways road (34%) or on straight stretches of one carriageways road (29%).

Table 3 - "Via del Mare" - Accidents type according to road characteristics

ROAD TYPE	Intersection	Roundabout	Straight road	TOTAL
single carriageways	18%	2%	73%	**94%**
double carriageways	4%	0%	2%	**6%**
TOTAL	**22%**	**2%**	**76%**	**100%**

Table 4 – "Via Ostiense" - Accidents type according to road characteristics

ROAD TYPE	Intersection	Roundabout	Signalized intersection	Straight road	Curve	Illuminated tunnel	TOTAL
Single carriageways (one way)	3%	0%	0%	4%	0%	0%	**7%**
Single carriageways	34%	1%	1%	29%	0,5%	0%	**66%**
Double carriageways	6%	0%	0%	9%	0%	0,5%	**16%**
more than two carriageways	4%	0%	1%	5%	0%	0,0%	**10%**
TOTAL	**47%**	**1%**	**2%**	**48%**	**0,5%**	**0,5%**	**100%**

Moreover, the analyses carried out by STA pointed out that accidents mainly occur with good weather conditions and dry roadbed; in detail, these conditions represent 86% and 83% of the total number of accidents that occur on "Via del Mare" (Table 5) and "Via Ostiense" (Table 6), respectively.

Table 5 – "Via del Mare" - Accidents type according to roadbed and weather conditions

Roadbed	**Weather conditions**			
	clear sky	rain	other	**TOTAL**
Dry	86%	0%	2%	**88%**
Wet	10%	2%	0%	**12%**
TOTAL	**96%**	**2%**	**2%**	**100%**

Table 6 – "Via Ostiense" - Accidents type according to roadbed and weather conditions

Roadbed	**Weather conditions**			
	clear sky	rain	other	**TOTAL**
dry	83%	0%	1%	**84%**
wet	11%	4%	0%	**15%**
slippery	1 %	0%	0%	**1%**
TOTAL	**96%**	**2%**	**2%**	**100%**

Phase 2: road safety review and accident data analysis

related to both the excessive width of the carriageways and to the lack of lay-bys along “Via del Mare”. More precisely, the former seems to reduce drivers’ capability to safely overtake other vehicles; they perceive that there is more available space than it really is and so they often cross the centre line to finalise their manoeuvre, creating very dangerous situation.

About the latter, due to the typology of the existing access ways (T intersections), vehicles accessing “Via del Mare” generate sudden speed reduction creating potentially dangerous situation, this is even worst on “Via Ostiense” due to the high number of access points.

Moreover, the analyses performed also highlighted that most of the accidents occur during the night and are due to excessive speed and poor lighting systems, especially in some critical part of the corridors.

Phase 3: identification of “homogeneous link”

Within this phase the whole corridor is divided into “homogenous links” according to the environment and road characteristics and to traffic characteristics. These procedures allow to deeply analysing road characteristics by means of “aggregate indicators”.

In Table 7 an example of aggregate indicators used to identify homogenous ink is provided.

Table 7 – Example of “aggregate indicators”

Aggregate indicator	**Elementary indicator**
Road section	Number of lanes
	Lanes width
	Hard shoulder width
Road planimetry	Curvature
	Road longitudinal grade
	Road transversal grade

Phase 4: measures definition

Within this phase all interventions are defined; to reduce the number of accidents that occur on “Via del Mare - Via Ostiense” corridor several countermeasures involving infrastructure changes were proposed; at this stage, all of them are characterized to be rapidly implemented.

The foreseen interventions are divided into “widespread actions”, related to the whole corridor, and “local actions”. The former, will be implemented on the whole corridor or on most of it while the latter just to specific road sections.

In Figure 3 for example, the list of intervention planned for “Via del Mare” from km 17 to km 20 is shown.

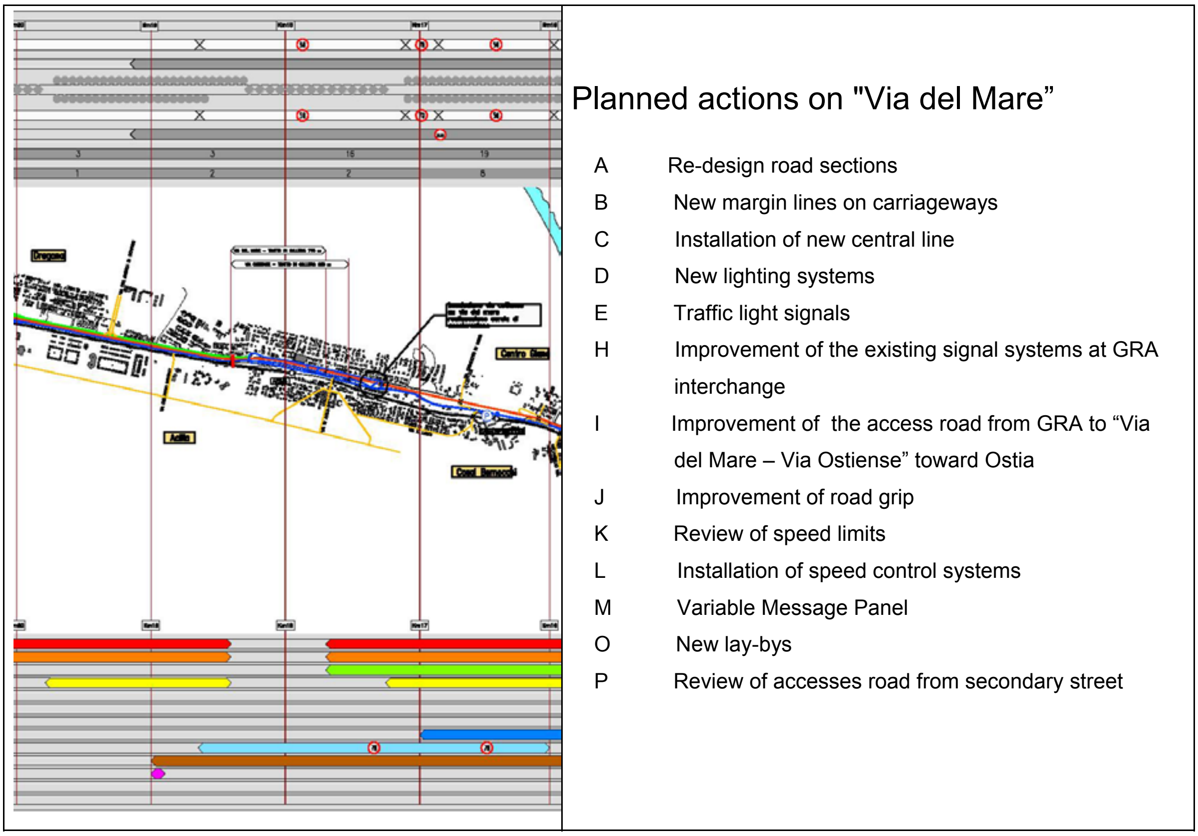

Figure 3 - Planned action on "Via del Mare" (km 17 - Km 20)

A draft analysis on all interventions implementation costs pointed out that a budget of approximately 5.200.000 € will be needed; it will be split as follow: 2.500.000€ for "Via del Mare" and 2.700.00€ for "Via Ostiense".
In Table 8 is reported the extension of each intervention and the number of accidents and deaths that have been detected in the period 1995-2000 on each considered section.

Table 8 – type of interventions that will be implemented on Via del Mare (source: STA)

	Intervention	**Extension (km)**	**N° of accidents (1995-2000)**	**n° of deaths (1995-2000)**
A	Re-design road sections	14	177	26
B	New margin lines on carriageways	14	177	26
C	Installation of new central line	9	137	20
D	New lighting systems	5	52	16
E	Traffic light signals	1,9	27	4
H	Improvement of the existing signal systems at GRA interchange	1,5	18	1
I	Improvement of the access road from GRA to "Via del Mare – Via Ostiense" toward Ostia	0,3	136	18
J	Improvement of road grip	9	19	8
K	Review of speed limits	6	171	23
L	Installation of speed control systems	10	155	22
M	Variable Message Panel	4 junctions	0	0
O	New lay-bys	4 lay-bys	0	0
P	Review of accesses road from secondary street	1	0	0

Cost-benefit analysis applied to "Via Ostiense - Via del Mare"

In this section a Cost Benefits Analysis application on a specific road safety measure, identified by STA analysis, is reported in order in order to provide a detailed description of how this methodology should be used within road safety. Among all the foreseen interventions (Table 8), this application will focus on defining the benefits and costs related to the implementation of "new horizontal signals"; this countermeasure is related to intervention B (new margin lines on carriageways) and intervention C (placement installation of new central line).

This measure (B+C) will be implemented on 14 km of the total 21 km, as pointed out in the study carried out by STA-Mobility Services for the City of Rome. It has been decided to perform the CBA to this specific part of "Via Ostiense – Via del Mare" corridor because in the period 1995-2000, these resulted to be the must dangerous of the whole corridor; precisely, the 14 km that will be analyzed were characterized by a total number of 177 accidents and 26 deaths.

Within the CBA, the "benefits" related to the implementation of this measure are represented by the economic value of accident reduction (number and severity) while "costs" includes designing, implemention, and maintaining of the considered countermeasure. Both benefits and costs will be expressed in euro to facilitate the use of their ratio as a key economic performance indicator.

The total cost related intervention B (new margin lines on carriageways) and intervention C (placement installation of new central line is equal to 264.450€. The details, related at implementation of new horizontal signals for 14 km of the road, are depicted in Table 9.

Table 9 - *Cost related to the implementation on "Via del Mare" of new horizontal signals (interventions B+C)*

Measure	quantity (m)	cost (€ / m)	total cost (€)
strip in thermoplastic of sonorous type (lateral)	29,400	6.45	**189,630**
strip in thermoplastic of sonorous type (central)	17,400	4.30	**78,820**
			264,450

To evaluate the expected benefits related to the implementation of this measure the Crash Reduction Factor (CRF) technique has been used as described in the "SEMCOG Crash Analysis Manual". This technique allows the evaluator to determine the benefits (in terms of saved human lives and reduction of the number of injuries) related to the implementation of a specific countermeasure.

Comparing the countermeasure that will be implemented along "Via del Mare" with the ones considered and analysed within the SEMCOG manual, it has been determined that intervention B plus intervention C can be considered as similar to the countermeasure called "*add centreline + lanelines to unstriped pavement*" and reported in the "Table 4-21 Countermeasures default values: markings" of SEMCOG Crash Analysis Manual. The CRF for this countermeasure has been estimated, for 1 year, equal to a 35% accident reduction.

In table 10, monetary values defined by the "SEMCOG Crash Analysis Manual" for different type of severity related crashes differentiates are reported; these are split into "*cost per crash*" and "*cost per person*". Cost are reported in dollars (original value reported in the SEMCOG manual) and in Euro (conversion rate assumed is 1$ = 0.833 €).

Table 10 – Crash costs, 1993 (source: SEMCOG)

Severity	***cost per crash***		**cost per person**	
	$	***€***	***$***	***€***
Fatal	3,961,000	4,755,102	3,057,000	3,669,868
Incapacitating Injury	278,000	333,733	202,000	242,497
Non-Incapacitating Injury	66,000	79,232	46,000	55,222
Possible Injury	38,000	45,618	22,000	26,411
Property-Damage-Only	2,700	3,241	2,800	3,361

The measure "*add centreline + lanelines to unstriped pavement*" has a pre-defined life period of 1 year, so average annual numbers should be used for both accidents and deaths; these are equal to 35 accidents and 5 deaths.

According to the CRF, this measure will generate a 35% reduction in the number of accident and deaths, it means a yearly "saving" of beyond 12 accidents and approximately 2 deaths.
Applying the economic values reported in Table 10, the total benefits related to the implementation of the analysed countermeasure can be estimated into 10,249,700 € (Table 11).

Table 11 - Expected yearly total benefits (€) related to the implementation of measure “add centreline + lanelines to unstriped pavement” on “Via del Mare”

	n°	**economic value (€)**	**total economic benefit (€)**
Fatal	2	3,669,868	7,339,736
Incapacitating Injury	12	242,497	2,909,964
			10,249,700

Neglecting the “net annual operating and maintenance costs” and “interest rate” and being the total costs related to intervention B (new margin lines on carriageways) and intervention C (placement installation of new central line) equal to € 264.450 (Table 9) and the estimated benefits equal to € 10,249,700 (Table 11) the B/C is:

$$\frac{B}{C} = \frac{10,249,700}{264,450} = 39$$

Therefore the B/C ratio is equal to 39, which fully demonstrate the social benefits related to the implementation of this countermeasure.

CONCLUSIONS

It has been first analysed, at national level, the existing differences between the approaches followed by the Italian and The Netherlands national road safety plans: it was highlighted that in the Netherlands the cost-effectiveness and cost-benefits analyses were used to assess the feasibility of the plans objectives.
It has been then analysed the methodological differences between Italy and USA on road safety design; it was highlighted that in the USA a more scientific approach, based on the Crash Reduction Factors (CRF), is used to rank different measures.
Therefore, the international outline (e.g. EU projects, Dutch Ministry, USA-Iowa Department of Transport) shows that other countries are quite active in the development and use of cost-benefits and cost-effectiveness tools while in Italy it seems to be still preferred a more “traditional” approach. More precisely, it is based on the evaluation performed by an expert group that, even if it is supported by a set of standardized relationship to evaluate the measures, it is always affected by a certain degree of subjectivity.
For this reason it has been introduced. In order to show the usefulness of the cost benefits analysis as a tool to improve road safety analysis a real case application has been performed on the countermeasure identified by STA in the safety analysis performed on the corridor “Via del Mare – Via Ostiense”. The real case application has been reported highlighting all the steps that led to the definition of the final measure’s evaluation. This shows another great potentiality of this tool: if performed on different measures, it allows to compare them in terms of the same parameter: the B/C ratio. This allows to objectively rank a set of possible measures and to define which one is the most efficient measure to be implemented according to a fixed budget.

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