1. INTRODUCTION

Improving road safety was given top priority in the European Union’s Transport Policy (EC 2001). To reach the overall objective of halving the number of fatalities by 2010, it is necessary to implement effective road safety measures. A prerequisite for this task is reliable knowledge about the effectiveness and efficiency of road safety measures. As believed, better knowledge of safety effects will stimulate more efficient priorities for road safety measures and will enable to employ available resources in such a way as to achieve the greatest possible benefits for society (Baum and Hohnscheid 2001). A more efficient use of road safety measures will result in a significant reduction in road accident injuries and fatalities that will improve public health and save expenditures.

Efficiency Assessment (EA) tools can assist policy-makers to identify the most cost-effective and profitable road safety measures. The major advantages of the EA tools are that they: (a) provide input to complex decision-making based on clear rational-choice models, which is compatible with basic democratic principles; (b) follow the principle of getting the most out of typically limited resources; (c) provide a systematic and transparent structuring of the objectives considered (Elvik and Veisten 2005). Recent evaluations of road safety priorities for Norway and Sweden demonstrated (Elvik 2003; Elvik and Amundsen 2000) that alternative strategies for road safety policies, which are strictly based on cost-benefit analysis of road safety measures, would be 4-5 times more effective in terms of saved accident casualties than the business-as-usual strategies.

EA tools typically comprise cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA). CEA sets out from given road safety targets or road safety budgets and ranks measures according to lowest monetary costs for, e.g. one casualty saved (Tengs et al 1995). CBA involves monetary assessment of both costs and effects/benefits of a measure and enables to consider both safety and other effects of a measure (mobility, environment).

A recent literature survey (BASt 2003) demonstrated that there exist many cases of both CBA and CEA of road safety measures which were performed in European and other countries. However, a close consideration of decision-making practices revealed that in most countries the EA is not regularly used in the assessment of road safety priorities (Elvik and Veisten 2005). The screening of safety evaluation studies (BASt 2003) demonstrated that:
- the EA methods are applicable for different groups of road safety measures, i.e. infrastructure-, vehicle- and user-related measures, whereas more routine techniques are available for assessing infrastructure improvements;
- the tools can be applied on different scales, e.g. national, regional or local, and at different stages of transport projects, e.g. design, maintenance or rehabilitation;
- the assessment results can provide the decision-makers with: (a) a comparison between several alternatives for safety investment within a defined safety budget; (b) support for regular work, e.g. comparisons of options for black-spot treatments, a priority ranking of sites for safety improvements; (c) qualified answers to specific questions concerning interventions in the system, e.g. introducing a new traffic regulation, initiating enforcement campaign.

However, for the EA to be applied, several prerequisites are required such as knowledge on values of safety effects associated with various measures, monetary values of accidents, as well as qualified basic assumptions with regard to implementation of the evaluation techniques, e.g. on typical project life, annual traffic growth, a relation between the accident numbers and traffic volumes, etc. The lack of these prerequisites seemed to create technical barriers which deterred the EA application in some countries (BASt 2003).

Thus, the study described below was initiated in order to deal with typical technical barriers to the EA tools' application to road safety measures. The study aimed to define a common framework for the EA in road safety, to test the suggested framework on a range of practical examples and to examine the experience gained from the viewpoint of further development and needs of the evaluation framework.

2. THE EVALUATION FRAMEWORK

The standardized EA techniques include CBA and CEA of road safety measures. The main steps and data components, which are required to perform a CBA/ CEA of a road safety measure, are presented below. The description refers to: basic formulae, safety effects, accident costs, implementation units and costs, and side-effects.

2.1. Basic formulae

The cost-effectiveness of a road safety measure is defined as the number of accidents prevented per unit cost of implementing the measure:

\[
\text{Cost-effectiveness} = \frac{\text{Number of accidents prevented by a given measure}}{\text{Unit costs of implementation of measure}}
\]

For this calculation, the following information items are needed:
- A definition of suitable units for implementation of the measure,
- An estimate of the effectiveness of the safety measure in terms of the number of accidents it can be expected to prevent per unit implemented of the measure,
- An estimate of the costs of implementing one unit of the measure.
The accidents that are affected by a safety measure are referred to as target accidents. In order to estimate the number of accidents that can be expected to be prevented per unit implemented of a safety measure, it is necessary to:

- Identify target accidents,
- Estimate the number of target accidents expected to occur per year for a typical unit of implementation,
- Estimate the safety effect of the measure on target accidents.

The numerator of the cost-effectiveness ratio is estimated as follows:

\[
\text{Number of accidents prevented (or expected to be prevented) by a measure} = \text{The number of accidents expected to occur per year} \times \text{The safety effect of the measure}
\]

The benefit cost ratio is defined as:

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

When a CBA is applied, then, besides the above CEA’s components, the monetary values of the measure’s benefits are also required. The monetary values imply, first of all, accident costs and, depending on the range of other effects considered, may also include costs of travel time, vehicle operating costs, costs of air pollution, costs of traffic noise, etc.

In order to make the costs and benefits comparable, a conversion of the values to a certain time reference is required. Such an action needs a definition of the economic frame, i.e. the duration of effect (length of service life of the project) and the interest rate, which are those commonly used for the performance of economic evaluations in the country.

In a basic case, where the benefits come from the accidents saved only (and no influences on travel expenses and the environment are expected), the numerator of the benefit-cost ratio will be estimated as:

\[
\text{Present value of benefits} = \text{Number of accidents prevented by the measure} \times \text{Average accident cost} \times \text{The accumulated discount factor},
\]

where the accumulated discount factor depends on the interest rate and the length of life of the measure.

### 2.2. Safety effects

The most common form of a safety effect is the percentage of accident reduction following the treatment (Ogden 1996; Elvik and Vaa 2004). The main source of evidence on safety effects are observational before-after studies. Other methods for quantifying safety effects are also possible. Those, mostly, provide theoretical values of the effects based on known relationships between risk factors and accidents. For example, speed limiters in cars have not yet been introduced on a wide scale. Their actual safety effects are
therefore unknown. Predictions of reductions of accident occurrences can be made on the basis of the effects estimated in speed simulation, utilizing the mathematical relationships between speed change and change in accident frequency (Carsten and Tate, 2000).

One should remember that the safety effect of a measure is stated as available if the estimates of both the average value and the confidence interval of the effect are known. One should also ascertain that both the type of measure and the type of sites (units) for which the estimates are available, correspond to those for which the CBA/CEA is performed.

Typically, it is desirable to apply the local values of safety effects, i.e. those attained by the evaluation studies performed in the country. When the local values do not exist, summaries of international experience (e.g. Elvik and Vaa 2004) can alternatively be used.

If the value of a safety effect is provided by a study, for which the CBA is performed, the estimation of safety effect should satisfy the criteria of correct safety evaluation. This implies that the evaluation should account for the uncontrolled environment, e.g. general accident trends, changes in traffic volumes, and for the selection bias if relevant (further details can be found in Gitelman & Hakkert, 2005).

2.3. Accident costs

A detailed survey of practices in estimating road accident costs in the EU and other countries was made by the international group of experts Alfaro et al (1994). Five major items of accident costs were identified as follows:

(1) Medical costs
(2) Costs of lost productive capacity (lost output)
(3) Valuation of lost quality of life (loss of welfare due to accidents)
(4) Costs of property damage
(5) Administrative costs

The relative shares of these five elements differ between fatalities and the various degrees of injuries, and also differ among countries. In the current study, it was assumed that each country has its official valuations of accident injuries and damage. Otherwise, the comparative figures from recent studies (Hakkert and Wesemann 2005) can be of help. It was agreed that for the test cases described below, any national value could be applicable but, in every case, there should be a clear indication which items of the above accident costs are included.

The literature discusses mostly the valuations of fatalities and injuries, whereas a CBA usually needs average accident costs. In a simple case, the average accident cost can be estimated as a sum of injury costs multiplied by the average number of injuries with different severity levels, which were observed in the target accidents’ group; the damage value per accident should be stated and added to the injury costs.
2.4. Implementation units and costs

In the case of infrastructure measures, the implementation unit is typically one junction or one kilometre of road. In the case of area-wide or more general measures, a suitable unit may be a typical area or a certain category of roads. In the case of vehicle safety measures, one vehicle will often be a suitable unit of implementation, or, in the case of legislation introducing a certain safety measure on vehicles, the percentage of vehicles equipped with this safety feature or complying with the requirement. For police enforcement, it may be a kilometre of road with a certain level of enforcement activity (e.g. the number of man-hours per kilometre of road per year); in the case of public information campaigns - the group of road users, which is supposed to be influenced by the campaign.

The implementation costs are the social costs of all means of production (labour and capital) that are employed to implement the measure. They are generally estimated on an individual basis for each investment project (ETSC 2003). As no strict rules are available on the issue, all the components of the implementation costs should be examined and explained for each case. Typical costs of engineering measures, which are common for the CBA evaluations in the country, are recommended for the application.

The implementation costs should be converted to their present values, which include both investment costs and the annual costs of operation and maintenance.

2.5. Side-effects

Road safety measures can produce three kinds of effects: safety, mobility and environmental (ETSC 2003). The mobility effects comprise changes in travel time and vehicle maintenance expenses; quantitative techniques for estimating the mobility effects of transportation projects are well developed and can be found in guidelines and computer programs for economic evaluations in transport, e.g. BVWP, EWS-97, RAS-W in Germany; TUBA, COBA, NESA in the UK; STEAM in the USA, etc (BASt 2003).

As many road safety measures affect the amount and/or speed of travel, they may also have impacts on emission and noise. For example, an increase in the use of fuel, which arises with day-time running lights (DRL), will increase emissions of exhaust gases; an additional fuel consumption due to DRL use for all vehicles is estimated to be about 1%, or the environmental effect of the measure will result in expenses of Euro 0.20 million, per year (ETSC 2003). Examples of values for estimating side-effects of safety measures are given in Hakkert and Wesemann (2005).

3. TEST CASES SELECTED FOR THE ASSESSMENT

To test the EA framework, a representative list of road safety measures was selected. The cases had to be real, i.e. consider actual road safety measures which were applied or are planned to be applied in participating countries:
Austria, Finland, France, Greece, Israel, Czech Republic (and also Germany, the Netherlands for which the data were available).

Selecting the cases, the following considerations were accounted for:
- different categories of safety-related measures, i.e. user-related, vehicle-related or infrastructure-related measures;
- different levels of implementation, i.e. national, regional and local;
- the measure's appearance in national road safety programmes;
- providing a mixture of ex post and ex ante evaluations.

According to the above, eleven test cases were selected covering as many types of road safety measures as possible - Table 1. The applicability of the EA techniques was tested in light of both the limitations of available data and restrictions of decision-making procedures in different countries. In all cases, a later feedback of the decision makers was recorded and discussed (Winkelbauer and Stefan 2005).

3.1. Assessment example: installation of speed humps on a section of urban street (Israel)

*Introducing the measure:* Speed humps are one of the design elements of traffic calming. They are frequently applied by the authorities when the street design does not satisfy safety demands, i.e. when actual vehicle speeds are higher than they should be for the given road type and surroundings, or when speed-related road accidents occur on the street or in the area considered.

Speed humps are defined as raised areas over the road surface, which are installed over the whole or partial road width, and present a physical measure for reducing travel speeds. Safety effects of speed humps are associated with two basic reasons: typically, a reduction in travel speeds and, sometimes, a reduction in traffic volume, following the humps' installation. In Israel, two basic types of speed humps are recommended for use in urban areas: circular humps and trapezoidal humps (Guidelines 2002).

In the current evaluation, the installation of speed humps on a typical urban street with a 50 kph speed limit was considered. The road section for the treatment is about 500 m in length. The purpose of the installation is to assure the level of actual speeds (85-percentage) below the speed limits (50 kph). Based on the known relationships between the density of speed humps and actual travel speeds along the road (Guidelines, 2002), the recommended distances between the humps considered should be: 100-130 m for circular humps and 90-110 m for trapezoidal humps. Therefore, on the road section, 5 speed humps should be installed.

*Target accident group:* Considering the speed humps' installation, the safety effect usually refers to all injury accidents. This is based on the assumption that reducing actual speeds creates a moderating effect on all accident types, i.e. single-vehicle accidents, multiple-vehicle collisions and pedestrian accidents. However, according to Guidelines (2002), a warrant for the installation of speed humps suggests to account for a weighted number of accidents, where a severe (with a fatality or a serious injury) accident of any type has the weight of 5; a pedestrian accident – the weight of 1; other
accidents – weights of 0.5. Such an approach strengthens the consideration of speed factor in accident occurrences.

On the urban street considered in this study, 3 injury accidents occurred over the three last years, of which one was a pedestrian accident and two – vehicle collisions; all the accidents with slight injuries. Using the warrant's approach, the weighted number of accidents on the street of treatment will be $1 \times 1 + 2 \times 0.5 = 2$ injury accidents in 3 years, or 0.67 accidents per year.

**Safety effect of the measure**: The safety effect from the installation of speed humps on urban roads in Israel was estimated by a study Gitelman, Hakkert et al (2001). The data were collected from three municipalities: Tel-Aviv, Netanya and Haifa, where, in the years 1994-1998, speed humps were installed on 94 streets. The mean value of the safety effect estimated was 0.603 with a confidence interval of (0.440; 0.828), meaning a significant accident reduction observed following the treatment. Thus, the average safety effect of speed humps installed on urban roads in Israel was a 40% reduction in injury accidents, which is comparable with the international value reported by Elvik and Vaa (2004).

**Accident costs**: in the current Israeli practice, the average accident cost is estimated as a sum of injury costs and damage costs of an average accident in the target accident group. The injury costs are a sum of injury-values multiplied by the average number of injuries, with different severity levels, which were observed in the target accident group. The road accident injury values are usually taken as $500,000 per fatality, $50,000 per serious injury, $5,000 per slight injury; the damage value is stated as 15% of the injury costs (Guidelines, 2002). Over the period 1996-2000, the average numbers of injuries per accident on an urban Israeli road were 0.01, 0.11 and 1.59 for fatalities, serious injuries and slight injuries, accordingly. Thus, the value of average injury accident was 89,114 New Israeli Shekel (NIS), at 2000 prices, where $1 = 4.2$ NIS.

**Treatment costs**: the costs of the measure are a direct result of the initial investment, which is required for the design and installation of speed humps along the street considered. No special maintenance expenses are required as this is supposed to be a part of regular road maintenance. When more than one unit of speed humps is installed, the unit cost times the number of the installed units should be taken into account. Based on typical cost values of the regular speed humps, the cost value of one unit may range from 3,000 to 6,000 NIS. Therefore, the costs of installation of speed humps over the street considered will be NIS 15,000-30,000 (at 2000 prices).

**Treatment benefits**: The main benefit from the installation of speed humps stems from the accident reduction expected after the treatment. The one-year value of benefits is estimated as:

$$0.67 \text{ accidents} \times 0.4 \times 89114 \text{ NIS/ accident} = 23,883 \text{ NIS (at 2000 prices).}$$

However, due to a reduction in vehicle speeds which will be attained on the treated road, a loss in travel time by the vehicles passing the road should be accounted for, too. The economic value of the time lost should be subtracted from the value of benefits.
The one-year value of time losses due to the humps' installation is estimated as a product of the time lost by one vehicle, the average daily traffic volume, the time costs and the number of working days over the year. The average delay for a vehicle will be of 4 sec/vehicle. With the daily traffic volume of 8000 vehicles, the cost of delay on a local street of 3.96 NIS/hour per vehicle and 260 working days (as the time costs at weekends may be neglected), the one-year value of time lost due to the humps' installation on the street will be:

\[
4 \text{ sec/vehicle} \times \frac{1}{3600} \text{ hours} \times 8000 \text{ vehicles} \times 3.96 \text{ NIS/hour} \times 260 \text{ days} = 9,152 \text{ NIS (at 2000 prices)}.\]

Cost-benefit ratio (CBR): both the costs and benefits are considered for 5 years, with a 4% discount rate. Table 2 illustrates the CBR calculation for the speed humps' installation. The value of costs is 15,000-30,000 NIS (at 2000 prices) or 3,600-7,200 Euro (at 2002 prices).

The total value of benefits is calculated as the difference between the costs of accidents saved and the costs of time losses, multiplied by the accumulated discount factor. The total value of benefits is 60,397 NIS (at 2000 prices) or 14,408 Euro (at 2002 prices). Depending on the measure's costs, the CBR ranges from 1 : 4 to 1 : 2.

Thus, for the local street considered, the installation of speed humps appears to be cost-effective. The current evaluation accounted for the time losses due to speed humps, which is not common in the economic evaluation of this measure. One should remember, that under certain conditions (e.g. for a road with higher traffic volume), the measure might stop being beneficial.

4. DISCUSSION: OVERVIEW OF THE EVALUATION RESULTS

4.1. Characteristics of the assessments performed

Table 3 summarizes the characteristics of evaluation methods applied and the results obtained. In total, 18 case-studies were carried out, which covered ten groups of safety-related measures. Out of the 18 case-studies:

- 3 cases concerned vehicle-related measures - fitting motorcycles with ABS; compulsory DRL for the whole year;
- 9 cases concerned infrastructure-related measures - traffic calming measures in urban areas; grade separation of at-grade rail-road crossings; installation of roadside guardrails; introducing signal control at a rural junction; constructing 2+1 road sections;
- the remaining 6 cases concerned user-related measures - automatic speed enforcement; large-scale projects of intensive police enforcement; compulsory helmet wearing for cyclists.

It can be seen from Table 3 that enforcement-related measures appear to be more cost-effective than other measures, obviously due to lower implementation costs. The efficiency of other user-related measures and of vehicle-related measures is also relatively high due to the same reason (low implementation costs per unit of implementation). On the other hand, the efficiency of infrastructure-related measures varies widely, depending both on the construction costs and safety effects of the measures.
National-level measures are generally more cost-effective than local-level measures. However, this finding mostly stems from the fact that the majority of local-level measures are road infrastructure improvements. No significant differences can be found in the efficiency of similar measures applied in different countries.

The target accident group/target population usually includes all road accidents/all drivers, with some obvious exceptions such as case A ("fitting motorcycles with ABS") for which "motorcycle riders" are the natural target population; case G ("implementation of roadside guardrails") which is dedicated to the prevention of roadside collisions with trees; case J ("2+1 roads") which struggles with head-on collisions; and case K which concerns bicycle riders only.

For the calculation of safety effects, before-after considerations with control-groups were the most common. In some cases, estimates from the literature or from previous research were applied.

Additional (other than safety) effects were estimated in half of the cases. In some cases, a need to account for the additional effects was mentioned but not realized due to lacking data/models which could isolate the effects (i.e. changes in air pollution, noise level, travel time or fuel consumption) associated with the measure.

4.2. The evaluation techniques applied

All the case-studies followed the standardised procedure of cost-benefit analysis. None of the studies selected the cost-effectiveness analysis due to obvious limitations of the CEA when a single measure is evaluated and, especially, when the evaluation should also account for other (other than safety) effects. Besides, the discussions on the EA results with decision-makers seem easier when the results are presented in usual monetary terms.

None of the studies considered project alternatives; by default, each study compared "implementation of the measure" with a "do-nothing" alternative. All other steps of the CBA evaluation procedure, i.e. a consideration of safety effects and side effects (on mobility and environment), monetising all effects, estimating implementation costs, calculation of present values of costs and benefits, and of the efficiency measure (CBR), were applied by the majority of the studies. The exceptions were generally due to lacking data.

Estimating safety effects of the measures, the emphasis was put on the application of a correct safety evaluation. In the ex ante evaluations, the best available values of safety effects (which are based on a summary of previous experience/research) were typically applied. In the ex post evaluations, the safety effect value was typically estimated by means of the odds-ratio with a comparison group. A weighted value of the effect, based on the safety experience of a group of treated sites, was applied, when possible. In these cases, confidence intervals for the estimated safety effects were provided.
For the economic evaluation, typical scenarios adopted were "conservative" or "best estimate", although these were based on different approaches in each case. In some cases, different scenarios were dictated by several values of safety effects; in others, by a consideration of safety effects only versus a combination of safety effects with other side-effects. In any case, consideration of a number of scenarios appears to be useful for testing sensitivity of the results and, therefore, should be recommended for the usual evaluation practice.

Summarizing the performance of the evaluation studies, several points can be mentioned indicating common technical problems which might occur during the CBA evaluations. They are:

- a correct application of the odds-ratio technique, e.g. in the case of zero-values of some of the numbers;
- ways for checking the statistical significance of the evaluation results;
- selecting the side-effects to be considered along with safety effects;
- a correct distinction between the implementation costs and negative side-effects of the measure (e.g. an increased fuel consumption or travel time).

4.3. State of the efficiency assessment components: data and values

Typically, the accident costs come from official national data. In a few cases such as Israeli and Greek case-studies on infrastructure-related measures and intensive police enforcement, adaptations of the official injury costs were made to provide a valuation of an average accident.

The availability of implementation costs was problematic in many cases. Nevertheless, in the majority of cases the estimates of implementation costs were based on the data provided by relevant authorities. In the cases where the evaluation was performed prior to the measure's implementation (e.g. ABS for motorcycles, DRL, compulsory helmets for cyclists) some practical assumptions or the valuations of similar measures applied in other countries (i.e. the "literature" source) were accounted for in the costs. Establishing databases with typical implementation costs of safety improvements seems to be a practical solution for the systematic use of these values for the EA studies.

While the ex post studies typically estimate the actual safety effects which can be associated with the application of safety measures, the ex ante studies apply the available values, which should be based on previous research. To stimulate the application of more uniform and well-based values of safety effects, it would be useful to establish a database with typical values of the effects, based on international experience.

Lack of models for evaluating side-effects associated with safety measures and lack of local valuations of these effects deter the consideration of these effects by the EA studies. The problem may be tackled by a systematic accumulation of recommended values and solutions (depending on safety measures considered) within the guidelines for the EA performance.
5. CONCLUSIONS

Based on the testing results, the recommendations addressing the “best practice” guidelines for the EA framework of road safety measures were as follows.

1) Further development of the EA methods is required. Particularly, for a more correct and uniform CBA performance it would be useful to elaborate a categorization of cases, indicating the types of impacts (e.g. safety, mobility, noise, air pollution) to be considered in the evaluation of each category of measures. For example, in the cases of infrastructure or enforcement measures, which have an implication on travel speeds, a consideration of changes in travel time is essential. Another question concerns the inclusion of fines in the economic evaluation of enforcement measures. A possible compromise may be as follows: to fully include the investments made for enforcement measures in the costs is a necessary condition for consideration of fines as a benefit.

2) When a number of impacts are combined in the evaluation of a measure, a distinction should be made between the implementation costs and negative benefits of the measure. The implementation costs should include the social costs of all means of production (labour and capital) that are employed to implement the measure, whereas the benefits should include all effects which stem from the measure’s application. Some benefits may be negative, e.g. increased travel time. In this case, their values are subtracted from the total benefits.

3) Safety effects estimated should satisfy the criteria of correct safety evaluation. A distribution of a brief guide on standardized techniques for the evaluation of safety effects would be helpful for safety practitioners, in general, and particularly, for the improvement of quality of the EA studies. Consideration of a number of scenarios is useful for testing sensitivity of the results and should become common for the usual evaluation practice.

4) A database with typical values of safety effects, based on international experience would be useful for correct and systematic performance of the "ex-ante" studies. The Handbook on road safety measures (Elvik and Vaa, 2004), in combination with other available sources, can serve as a basis for such a database. The database might be open to a European network of experts and provide for general values of safety effects on initial steps of CBA/CEA as well as assist in comparisons of local effects observed. The values of safety effects kept in the database should be regularly updated, in accordance with the last evaluation results in the EU.

5) The implementation costs of safety measures are usually lacking. Establishing databases with typical implementation costs of safety improvements would be of help for the systematic use of these values in the EA studies.

6) It is important to clarify the definitions of projects for which the EA of safety impact should be performed. It is suggested that the EA of safety impacts should be applied mostly for two types of projects: (a) the improvements
which were financed by safety-dedicated budgets and (b) the projects aimed at improving safety.

References


**Notes**

The accidents affected by a safety measure present a target accident group. Depending on the type of safety measure it can also be a target injury group, target driver population, etc.
### Table 1. Cases selected for evaluation

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Case study: safety measure assessed</th>
<th>Category of safety-related measures</th>
<th>Level of decision-making</th>
<th>Evaluation for countries**</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ABS for motorcycle</td>
<td>Vehicle</td>
<td>National</td>
<td>AT</td>
</tr>
<tr>
<td>B</td>
<td>Section control: automatic speed enforcement</td>
<td>User + Enforcement</td>
<td>Local</td>
<td>AT, NL</td>
</tr>
<tr>
<td>C</td>
<td>Daytime running lights: compulsory use for the whole year</td>
<td>Vehicle + User</td>
<td>National</td>
<td>AT, CZ</td>
</tr>
<tr>
<td>D*</td>
<td>Speed cameras</td>
<td>User + Enforcement</td>
<td>Local</td>
<td>FI, IL</td>
</tr>
<tr>
<td>E</td>
<td>Traffic calming (urban areas)</td>
<td>Infrastructure</td>
<td>Local</td>
<td>CZ, GR, IL</td>
</tr>
<tr>
<td>F</td>
<td>Railroad crossings: grade-separation</td>
<td>Infrastructure</td>
<td>Local</td>
<td>FI</td>
</tr>
<tr>
<td>G</td>
<td>Measures against collisions with trees (guardrails)</td>
<td>Infrastructure</td>
<td>Local + National</td>
<td>FR</td>
</tr>
<tr>
<td>H</td>
<td>Road improvement mix (rural areas, national network)</td>
<td>Infrastructure</td>
<td>Local + National</td>
<td>IL</td>
</tr>
<tr>
<td>I</td>
<td>Intensive large-scale police enforcement (speed and alcohol)</td>
<td>User + Enforcement</td>
<td>National</td>
<td>GR, IL</td>
</tr>
<tr>
<td>J</td>
<td>2+1 roads</td>
<td>Infrastructure</td>
<td>Regional</td>
<td>FI, SW</td>
</tr>
<tr>
<td>K</td>
<td>Compulsory helmet regulation for cyclists</td>
<td>User</td>
<td>National</td>
<td>AT, DE</td>
</tr>
</tbody>
</table>

*Further was omitted from the evaluation due to lack of data
** Countries: AT – Austria; NL – The Netherlands; CZ – Czech Republic; IL – Israel; GR – Greece; FI – Finland; FR – France; SW – Sweden; DE - Germany

### Table 2. Estimating CBR for speed humps' installation on a road section (Israel)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Benefits</th>
<th>Costs of accidents saved in one year, NIS</th>
<th>Losses: Costs of vehicle delays in one year, NIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Costs of one speed hump, NIS</td>
<td>3,000-6,000</td>
<td>23,883</td>
<td>-9,152</td>
</tr>
<tr>
<td>Total costs, Euro (2002)*</td>
<td>3,578-7,156</td>
<td>Total benefits, Euro (2002)*</td>
<td>14,408</td>
</tr>
</tbody>
</table>

| Cost-benefit ratio | From 1 : 4.0 to 1 : 2.0 |

*Change of price index over 2000-2002 is 1.0687. In 2002: 1 Euro = 4.48 NIS.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Case Study</th>
<th>Category of measures</th>
<th>Level of implementation</th>
<th>Description of measure</th>
<th>Target group</th>
<th>Implementation costs</th>
<th>Accident costs</th>
<th>Source of safety effect value</th>
<th>Other effects</th>
<th>CBA results</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>ABS-Motorcycle</td>
<td></td>
<td></td>
<td>Fitting motorcycles with ABS and reducing ABS taxes</td>
<td>All accidents</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>1.1-1.4</td>
</tr>
<tr>
<td>B</td>
<td>Section Control</td>
<td></td>
<td></td>
<td>Automatic speed enforcement in a tunnel (motorway)</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>n/a</td>
<td>n/a</td>
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</tr>
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<td>C</td>
<td>1 Daytime running lights</td>
<td></td>
<td></td>
<td>DRL for the whole year</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>n/a</td>
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<tr>
<td></td>
<td>2 Daytime running lights</td>
<td></td>
<td></td>
<td>DRL for the whole year</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>3.6</td>
</tr>
<tr>
<td>E</td>
<td>1 Traffic calming (urban areas)</td>
<td>IL</td>
<td>IL</td>
<td>Speed humps (1 road)</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>-</td>
<td>2.0-4.0</td>
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<tr>
<td></td>
<td>2 Traffic calming (urban areas)</td>
<td>IL</td>
<td>IL</td>
<td>Speed humps, woonerfs (area)</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
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<td>1.14-1.2</td>
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<td>3 Traffic calming (urban areas)</td>
<td>CZ</td>
<td>CZ</td>
<td>Roundabouts instead of four-arm intersections</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>1.5</td>
</tr>
<tr>
<td>F</td>
<td>1 Rail-road crossings</td>
<td>IL</td>
<td>IL</td>
<td>Grade separation of at-grade rail-road crossing</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>2.8 (urban)</td>
</tr>
<tr>
<td></td>
<td>2 Rail-road crossings</td>
<td>FI</td>
<td>FI</td>
<td>Grade separation of at-grade rail-road crossing</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>-</td>
<td>√</td>
<td>1.4 (urban)</td>
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<td>+</td>
<td>√</td>
<td>0.94 (urban)</td>
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<td>+</td>
<td>√</td>
<td>2.5 (urban)</td>
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<td>G</td>
<td>1 Measures against collisions with trees (guardrails)</td>
<td>FR</td>
<td>FR</td>
<td>Implementation of roadside guardrails</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
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<td>H</td>
<td>1 Road improvement mix (rural areas)</td>
<td>IL</td>
<td>IL</td>
<td>Introducing traffic signal control at a rural junction</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>1.25</td>
</tr>
<tr>
<td>I</td>
<td>1 Intensive police enforcement</td>
<td>GR</td>
<td>GR</td>
<td>3-year project (interurban roads), with emphasis on speed and alcohol</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>6.6-6.7</td>
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<td></td>
<td>2 Intensive police enforcement</td>
<td>IL</td>
<td>IL</td>
<td>1 year project (interurban roads)</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
<td>√ *</td>
<td>√</td>
<td>3.5-5.0</td>
</tr>
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<td>1 2+1 roads</td>
<td>FI</td>
<td>FI</td>
<td>Constructing a 2+1 road section (without median cable)</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
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<td>√</td>
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<td>2 2+1 roads</td>
<td>SW</td>
<td>FI</td>
<td>Constructing a 2+1 road section (with median cable)</td>
<td>All drivers</td>
<td>√</td>
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<td>1 Compulsory helmet regulation for cyclists</td>
<td>AT</td>
<td>AT</td>
<td>Compulsory bicycle helmet wearing</td>
<td>All drivers</td>
<td>√</td>
<td>√</td>
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<td>1.14-2.28</td>
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<td>DE</td>
<td>AT</td>
<td>Compulsory bicycle helmet wearing</td>
<td>All drivers</td>
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<td>√</td>
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