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A review of international sources for road safety measures assessment

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Abstract

The efficiency assessment of road safety measures is considered to be an extremely useful tool in decision making; in particular, cost-benefit and cost-effectiveness analyses are carried out in several countries, in a more or less systematic way. The objective of this paper is to present findings from a review of current practices for road safety assessment worldwide gathered in various handbooks, manuals, research projects and other international reports. This review comprises the preliminary results of the work carried out in the framework of the on-going Working Group on the assessment of the effectiveness of road safety measures, of the Joint Transport Research Centre (JTRC) of the Organisation for Economic Cooperation and Development (OECD) and the International Transport Forum (ITF). In particular, the most important international initiatives for providing standardized and accurate methods or tools for the estimation of safety effects of road safety measures are presented. Furthermore, the procedural and technical limitations of these methodologies are discussed in this paper, as is the lack of knowledge and data on the safety effects of road safety measures but also the potential for transferability of the assessment results. Emphasis is given to the added value of the safety assessment process and the related results to the various stages of the road safety decision making at local, regional national and international level.

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1. Introduction

Most European countries set specific quantitative road safety targets and adopt related road safety strategies towards these targets, within the priorities set and the resources available. Within this framework, the efficiency assessment of road safety measures is considered to be an extremely useful tool

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in decision making; in particular, cost-benefit and cost-effectiveness analyses are carried out in several countries, in a more or less systematic way, at national, regional or local level. These studies are based on some estimate of the safety effects of the examined measures, in terms of accidents or casualties reduction following the implementation of the measure. However, a more widespread or fruitful use of efficiency assessment of road safety measure is in most cases limited, apart from the various technical and institutional barriers, by a lack of knowledge and data on the safety effects of specific road safety measures.

Nevertheless, the importance of efficiency assessment in road safety is widely recognised, and the need for more knowledge and best practice examples is becoming more and more pronounced. Many countries are looking for ways to assess the effectiveness of road safety investments and infrastructure project in general. More specifically, the European Union Directive on “Road Infrastructure Safety Management” (2008/96/CE) requires that the selection of safety treatments must account for cost-benefit ration at least for Trans European Road Networks. Existing best practice recommendations may cover the whole range of the efficiency assessment process, from the selection and application of appropriate and standardised methodologies to the interpretation of results and the identification of most efficient measures, especially in case different alternative measures need to be compared and ranked. However, the most important uncertainties involved in developing such best practice recommendations concern the adoption of appropriate values for the safety effects of individual or sets of road safety measures.

In the recent years, important research efforts have been made towards the standardization of the methods for estimating the safety effects of road safety measures. The first issue examined concerns the accuracy of the estimation, so that potential bias or other confounders are eliminated; these questions mainly concern the analyses at national level. The second critical issue concerns the conditions and necessary adjustments required to allow the transferability of the safety effect estimates to different settings or countries; this question has become very important at international level, and particularly within the development of handbooks and manuals aiming to assist decision makers, researchers or other stakeholders involved in the efficiency assessment of road safety measures.

The on-going Working Group on the assessment of the effectiveness of road safety measures, of the Joint Transport Research Centre (JTRC) of the Organisation for Economic Cooperation and Development (OECD) and the International Transport Forum (ITF) aims to facilitate international collaboration to address the common need for information about effects of safety measures and to stimulate greater efficiency in the development of reliable safety effectiveness estimates and their dissemination. The objectives of the Working group are:

- To evaluate opportunities for and obstacles to international collaboration in the development of crash modification functions (CMFs)
- To develop a theoretical basis for assessing countermeasure effectiveness and a framework for assessing the confidence that can be placed on crash reduction estimates
- To examine the availability of cost-effectiveness assessments of road safety interventions, and review the quality and transferability of the estimates available
- To provide recommendations that can improve and harmonise research methods and reporting standards, and thereby increase the potential for transferability and mutually beneficial ongoing international collaboration.

As a first step, the Working Group reviewed current practices for road safety measures assessment worldwide, both at national and at international level. This paper presents the preliminary results of this review of current practices, which will be finalized at the respective final report.

On that purpose, the most important international approaches and initiatives are analysed, concerning handbooks and manuals (NHTSA, FHWA, CEDR, etc.) but also research project results like SUPREME, ROSEBUD, PROMISING and other studies and reports (IRTAD, EC, i-cars). These comprehensive

manuals, handbooks and other tools have been developed in the recent years, aiming to gather, harmonize and improve the existing knowledge on the effectiveness of road safety measures. These sources are often used by countries within their national road safety efficiency assessment analyses, by adopting the values proposed (e.g. in terms of percentage reduction of accidents / fatalities, or CMFs), or by adjusting them to the local conditions. However, due to the important gaps in the knowledge concerning the transferability of such values across countries, several countries have developed their own methods and values for assessing the effectiveness of road safety measures. The review of all these international initiatives has led to a number of lessons, useful to the researchers and practitioners in assessing the effectiveness of road safety measures but also to the decision makers in order to implement evidence based road safety policies, programmes and measures.

2. Handbooks, manuals and toolkits

2.1. The handbook of road safety measures - Elvik et al (2009)

The handbook aims to provide a systematic overview of current knowledge regarding the effects of road safety measures, by presenting state-of-the-art summaries of current knowledge regarding the effects of 128 road safety measures. The types of measures that are included are road design and road equipment, road maintenance, traffic control, vehicle design and protective devices, vehicle and garage inspection, driver training and regulation of professional drivers, public education and information, police enforcement and sanctions, post-crash care and general purpose policy instruments.

More specifically, the handbook aims to answer questions related to the type measures that can be used to reduce the number of traffic crashes or the severity of injury in such crashes, the crash problems and types of injury that may be affected by the different measures, the effects on crashes and injuries of the various road safety measures, as well as their related effects on mobility and the environment. Moreover, the costs of road safety measures are examined, and the potential for cost-benefit evaluations of the measures is demonstrated.

It is also demonstrated that the safety effect of a measure may vary from place to place, depending on the design of the measure, the number of crashes at the spot, any other measures that have been implemented, etc. An attempt has been made to identify sources of variation in the findings of different studies and to try to form as homogeneous groups as possible when presenting estimates of the effects of measures on road safety.

In particular, the handbook seeks to develop objective knowledge about the effects of road safety measures by relying on an extensive and systematic search of literature and by summarising this literature by means of formal techniques of meta-analysis that minimise the contribution of subjective factors that are endemic in traditional, narrative literature surveys. A systematic framework has been used to assess the validity of the studies that are quoted. Moreover, the need to develop crash modification functions in order to describe systematic variation in the effects of road safety measures is stressed.

The criteria of study quality that have been applied to assess the road safety evaluation studies referred to in this handbook are to a great extent based on the validity framework of Cook and Cambell (1979). According to this framework, the quality of a study can be assessed in terms of four types of validity:

- Statistical conclusion validity; sampling technique, sample size, reporting of statistical uncertainty in results, measurement errors. Specification of crash or injury severity Second point.
- Theoretical validity; identification of relevant concepts and variables, hypotheses describing the relationships between variables, knowledge of causal mechanisms.
- External validity; generalisability of the results of a study.

- Internal validity; basis for inferring a causal relationship between treatment and effect; statistical association between treatment and effect, clear direction of causality, dose-response pattern, specificity of effect, control of confounding factors.

2.2. *The Highway Safety Manual*

The Highway Safety Manual (HSM) aims to introduce a science-based technical approach and to provide tools for conducting quantitative safety analyses, allowing for safety to be quantitatively evaluated alongside other transportation performance measures such as traffic operations, environmental impacts, and construction costs. In particular, the HSM provides a method to quantify changes in crash frequency as a function of cross-sectional features. With this method, the expected change in crash frequency of different design alternatives can be compared with the operational benefits or environmental impacts of these same alternatives.

The HSM provides the following tools:

- Methods for developing and evaluating a roadway safety management program, including the identification of hazardous sites, the diagnosing of conditions at the site, the evaluation of evaluating conditions and the identification of potential treatments, the prioritization and programming of the treatments, and subsequently the evaluation of the effectiveness of reducing crashes of the programmed treatments;
- A predictive method to estimate crash frequency and severity;
- A catalogue of crash modification factors (CMFs) for a variety of geometric and operational treatment types, developed using before/after studies that account for regression to the mean;

The HSM is organized into four parts:

Part A explains the relationship of the HSM to planning, design, operations, and maintenance activities. Part A also includes fundamentals of the processes and tools described in the HSM.

Part B presents suggested steps to monitor and reduce crash frequency and severity on existing roadway networks. It includes methods useful for identifying improvement sites, diagnosis, countermeasure selection, economic appraisal, project prioritization, and effectiveness evaluation. Several new network screening performance measures are introduced to shift the safety analysis focus away from traditional crash rates, in order to deal with the major limitation associated with crash rate analysis i.e. the incorrect assumption that a linear relationship exists between traffic volume and the frequency of crashes.

Part C provides a predictive method for estimating expected average crash frequency of a network, facility or individual site, and it introduces the concept of safety performance functions (SPFs). The methods are provided for road segments and intersections for different facility types (rural two-lane roads, rural multilane highways, urban and suburban arterials).

Part D provides Crash Modification Factors (CMFs), allowing to quantify the change in expected average crash frequency as a result of geometric or operational modifications to a site that differs from set base conditions. These concern roadway segments, intersections, interchanges, special facilities and road networks. These CMFs are claimed to be readily applicable to any design or evaluation process where optional treatments are being considered.

The HSM Incorporates many, but not all geometric features. Moreover, the proposed models (SPFs) cannot explain crash causes. For instance, weather and driver behavior are not explicitly addressed in these models. Finally, in several cases the proposed models are very sensitive to the availability and quality of the necessary data.

2.3. *The CEDR Report*

The Conference of European Directors of Roads (CEDR) has been promoting collaboration and exchange of information and expertise amongst its members since 1998. In particular, it aims to: provide support to the activities of the Road Directors and their national road administrations, to promote a high level of common information and give assistance to the European Commission in the preparation of reports concerning the development of the Trans European Road Network (TERN).

The source of CEDR measures is the Final report of «Best Practice on Cost Effective Road Safety Infrastructure Investments», April 2008 (Yannis et. al., 2008). According to the report, five most promising investments were identified (as results of preliminary assessment and related ranking of investments) and were selected for further analysis (in-depth analysis) analyzing existing literature in conjunction with the results of Questionnaire 2 of the CEDR task group O7 (Road safety). These investments are concerning the following measures categories: roadside treatment; speeding; junction layout; junction traffic control; traffic calming.

2.4. *The FHWA Clearinghouse CMFs*

The CMF Clearinghouse is home to a Web-based database of CMFs along with supporting documentation to help transportation engineers identify the most appropriate countermeasure for their safety needs. Using this site, one can search to find CMFs or submit their own CMFs to be included in the clearinghouse. CMFs are rated using a four star system for quality. A CMF with four stars is of a quality to be included in the HSM. Stars are applied based on review for five criteria: Study Design; Sample Size; Standard Error; Potential Bias; and Data Source.

2.5. *The Cochrane reviews*

Cochrane Reviews are systematic reviews of primary research in human health care and health policy. They investigate the effects of interventions for prevention, treatment and rehabilitation. They also assess the accuracy of a diagnostic test for a given condition in a specific patient group and setting.

The Cochrane Injuries Group has been preparing Cochrane Reviews on the effectiveness of interventions for road safety, including slowing traffic speed, wearing helmets, and driver education. The findings of these Cochrane Reviews provide guidance on the effectiveness of interventions for road safety in the hope that governments, urban planners, and individuals will be encouraged to improve road safety as a matter of urgency.

2.6. *Countermeasures that work: A Highway Safety Countermeasure Guide For State Highway Safety Offices - 5th Edition (2010)*

This Guide is intended to be a key reference to assist State Highway Safety Offices (SHSOs) in the USA selecting effective, evidence-based traffic safety countermeasures for major road safety problem areas. The Guide describes strategies and countermeasures that are relevant to SHSOs, summarizes their use, effectiveness, costs, and implementation conditions and includes references to the most important publications (research summaries and individual studies) in the field.

The Guide includes countermeasures related to the following road safety problems and research areas: alcohol-impaired driving; seat-belt use and child restraints; aggressive driving and speeding; distracted and fatigued driving; motorcycle safety; young drivers; older drivers; pedestrians; bicycles.

Each section starts with a brief literature review on the road safety problem (e.g. the reader is often referred to the Cochrane reviews), followed by a presentation of the related strategies and countermeasures. More than 115 individual countermeasures are examined and typically one page is devoted to each countermeasure. In each case, the countermeasures are ranked in terms of their effectiveness on the basis of a rating in stars, whereas the use, costs and time needed for implementation are also assessed.

More specifically, effectiveness is measured by reductions in crashes or injuries:

- 5 stars: the measures are demonstrated to be effective by several high-quality evaluations with consistent results;
- 4 stars: Demonstrated to be effective in certain situations;
- 3 stars: Likely to be effective based on balance of evidence from high-quality evaluations or other sources;
- 2 stars: Effectiveness still undetermined; different methods of implementing this countermeasure produce different results;
- 1 star: Limited or no high-quality evaluation evidence;

The use of the measures is ranked between High (i.e. more than two-thirds of the States, or a substantial majority of communities), medium and low (i.e. less than one-third of the States or communities). The implementation costs are ranked between high (i.e. requires extensive new facilities, staff, equipment, or publicity, or makes heavy demands on current resources), medium and low (i.e. can be implemented with current staff, perhaps with training; limited costs for equipment, facilities, and publicity). Finally, the time to implementation is ranked between long (i.e. more than one year), medium and short (i.e. three months or less). A 'varying' option for the above rankings is also used in several cases.

2.7. Austroads Road Safety Engineering Toolkit (www.engtoolkit.com.au)

The Road Safety Engineering Toolkit is a reference tool for road engineering practitioners in state and local governments in Australia and New Zealand. It outlines best-practice, low cost, high return road environment measures to achieve a reduction in road trauma. The Toolkit seeks to reduce the severity and frequency of crashes involving road environment factors. The Toolkit draws together existing road safety engineering knowledge as far as possible into one Toolkit for easy access by practitioners. The presented knowledge has been updated with recent experience from local and state government agencies, and with the results of comprehensive road safety research reviews. The Toolkit is considered a 'living' document including updates and revisions, so that more recent safety 'wins' are captured and disseminated.

2.8. International Road Assessment Programme (iRAP) Road Safety Toolkit (<http://toolkit.irap.org/>)

The Road Safety Toolkit provides information on the causes and prevention of road crashes that cause death and injury. Building on decades of road safety research, the Toolkit helps engineers, planners and policy makers develop safety plans for car occupants, motorcyclists, pedestrians, bicyclists, heavy vehicle occupants and public transport users. It is aimed primarily at users in developing countries. It has been translated into French, Spanish and Chinese.

3. Research projects

3.1. *The PROMISING project*

The PROMISING project aimed at developing measures that reduce the risk of injury to vulnerable and young road users as much as possible in a non-restrictive way. It was commissioned by the European Union and was coordinated by the SWOV Institute for Road Safety Research.

The source of PROMISING project measures come from the WP5 «Cost-benefit analysis of measures for vulnerable road users», July 2001. Cost-benefit analysis was carried out for a number of measures.

3.2. *The ROSEBUD thematic network*

ROSEBUD (Road Safety and Environmental Benefit-Cost and Cost-Effectiveness Analysis for Use in Decision-Making) is a thematic network funded by the European Commission to support users at all levels of government (European Union, national, regional, local) with road safety related efficiency assessment solutions for the widest possible range of measures.

ROSEBUD examined the factors affecting the quality of the efficiency assessment of a safety measure, which in turn depends on the quality of the available values of safety effect. The latter were found to depend on a number of factors, including the availability of values, the validity of the data, the variability of the effect, the local versus general effects, the changeability of the effect etc.

Within the activities of the Rosebud thematic network, a handbook titled «Examples of assessed road safety measures - a short handbook», was issued on July 2006, as the main outcome of the Rosebud project. The handbook includes information about various assessed road safety measures. The assessment methods used are cost effectiveness analysis (CEA) or cost-benefit analysis (CBA). In CEA, the costs of a measure are confronted with its effects; the effects of the measures are not expressed in monetary terms. On the contrary, in CBA the result of the evaluation is obtained by comparing costs with benefits. An economic evaluation will help in identifying whether a proposed change will increase economic welfare to ensure that resources are distributed in a way which provides maximum level of utility.

Economic evaluation of road safety measures using cost-benefit analysis is based on the costs incurred as a result of road crashes. Avoiding such costs represents the economic benefit of road safety measures. The benefit-cost ratio represents the economic advantage of the safety measures. According to the Benefit-Cost ratio, measures are ranked as poor, acceptable and excellent. Measures from Rosebud consist of user related, vehicle related and infrastructure related measures.

The recommendations of the ROSEBUD project include ways to systematize the values of safety effects, mainly by documenting the effects on the basis of either a meta-analysis or traditional literature surveys, and by providing for theoretical effects based on known relationships between risk factors and crashes. They also include criteria for examining the local findings on safety effects of road infrastructure improvements.

3.3. *The SUPREME project*

The SUPREME research project was funded by the European Commission and its goal was to collect, analyse, summarise and publish best practices in road safety in the Member States of the European Union as well as in Switzerland and Norway. The target audiences of the project are decision and policy makers at all levels, from European to local, as well as the scientific community and practitioners in the field. The aim was to provide the user specific information on outstanding safety measures with a view to implementation in other countries or at the European level.

SUPREME measures come from the final report (that consists of 14 parts) and mainly from the Parts C, D "Handbook for measures at the Country level" and "Handbook for measures at the European level", June 2007 respectively. The evaluated safety measures described are ranked as best, good and promising practices at the following areas: licensing; policy; enforcement; campaigns; infrastructure interventions; safety equipment; data analysis; post impact care.

The measures within the SUPREME research project were collected through a questionnaire sent to experts working for international or European organisations, NGOs, interest groups and industries. The information collected through the questionnaires was supplemented by additional research from the authors.

According to the SUPREME project, "best practice" measures are scientifically proven to lead to a reduction of road crashes and/or deaths and serious injuries, have a positive cost-benefit ratio and are expected to lead to effects' sustainability and/or to public acceptance. Measures are rated as "good" when the available information on the above criteria was not sufficient to assess if they were the best practice in their category because there is a clear lack of systematic evaluations of implemented measures. Measures that have not yet been implemented at the European or international level but have proven to be successful in one or several Member States were rated as "promising".

3.4. *The RANKERS project*

RANKERS (RANKing for European Road Safety) is a research project co-funded by the European Commission designed to gain new knowledge by performing research and empirical studies of the road's interaction with the driver and his vehicle in order to identify optimal road recommendations and predict their impact on safety. The main output of the project includes an index used for assessing and monitoring road safety and a comprehensive catalogue of road infrastructure safety recommendations ranked according to their cost-effectiveness.

A Road Safety Index is proposed for the evaluation of road safety in road sections, which assesses the actual status of road infrastructure and its relationship with road safety. The index is separately estimated for in six infrastructure topics: road alignment, junctions, overtaking, roadside, pavement and road layout consistency. The index provides a general safety mark for each road section and six particular road safety marks for each category in each road section. The safety marks are provided each 1,5 – 2 km of the road network and are divided in four categories, ranging from "1. It is urgent to take remedial measures to solve this infrastructure safety topic" to "4. No action is necessary".

After having identified the road safety deficiencies of road infrastructure, an eBook - Ranking of Recommendations offers the most cost - effective solutions. This catalogue is structured according to different accident scenarios and may thus provide adequate solutions for different road safety problems. The countermeasures included in the catalogue are ranked according the ratio between their costs and effectiveness. As the effectiveness information is not always available, a methodology has been developed that allows calculating the ratios between the countermeasures of the same scenario. It does not provide absolute ratios but within a set of countermeasures it provides which are more cost - effective compared to others.

4. Other Reports

4.1. *The IRTAD Annual Reports*

The source of IRTAD measures is the «IRTAD -Road Safety Annual Report 2009» that includes road safety data from 27 countries-members. This report summarizes the recent road safety measures (2007-

2009) as well as the National Road safety targets and Strategies without always indicating their effectiveness.

4.2. EC Technical Assistance for the Road Safety Action Programme 2011-2020

Within the technical assistance of the European Commission in support of the preparation of the European road safety action programme 2011-2020 several road safety measures and their impact were examined (COWI, 2011). The main sources of this report are ERSO, ETSC, EuroRAP, The Global Status Report on Road Safety of WHO, IRTAD and national sources.

According to the report, performance of enforcement on speed, drink driving, seat belt wearing in EU25 is provided as quantitative ranking: (good/ improving/ need to do more) and qualitative ranking (scale 0-10). Effectiveness of helmet wearing enforcement and child restraints are also provided. In addition, infrastructure interventions concerning engineering actions such as formal audits on new roads, regular inspections on existing roads, EuroRAP assessment (risk mapping or star rating) are also included.

Roads are assessed according to: separation of directions (how well the medians are treated), the design standard and frequency of intersections, how well the road sides are protected, how the edge of the carriageway is treated and the availability of fatalities for pedestrians and cyclists.

Concerning the education and campaign measures of the safety measures, this study presents the most common campaigns on speed, seatbelts, alcohol, helmets, young drivers and school children education.

As for trauma management, this study presents the performance for several countries according to the ranking proposed in the SafetyNet research project (high level, medium level, low level, relatively low level).

4.3. I-cars network, Thematic group on impact assessment measures

This work provides an overview of impacts assessment studies (all types of studies, from expert judgment to crash studies) for intelligent vehicle systems. The objective of the project is to exchange experience regarding the use of different methods of impact assessment and socio-economic evaluation with the goal of leading to more reliable methods with higher predictive validity.

5. Existing national approaches and initiatives

Members of the OECD/ITF Working Group provided information about the assessment of the effectiveness of road safety measures in their countries. Information was obtained from the following countries: Australia, Austria, Canada, Finland, Germany, Greece, Ireland, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom, and the United States.

From the review of these national initiatives it was concluded that many countries use the international handbooks within their national road safety efficiency assessment analyses. In some cases they adopt the values proposed (e.g. in terms of percentage reduction of accidents / fatalities, or CMFs), in other cases they adjust them to the local conditions. However, due to the important gaps in the knowledge concerning the transferability of such values across countries, several countries have developed their own methods and values for assessing the effectiveness of road safety measures.

6. Conclusion

This review of current global knowledge, experience and practices with CMFs provided a number of interesting lessons. Firstly, based on a review done within the framework of the ITF/OECD Working Group, it appeared that quite a few developed countries consider efficiency assessment of road safety measures as a very useful tool in decision making. Cost-benefit and cost-effectiveness analyses are carried out in several countries, in a more or less systematic way, at national, regional or local level. These studies are based on some estimate of the safety effects of the examined measures, in terms of crashes or casualties reduction following the implementation of the measure.

Furthermore, there is already a decade of efforts for gathering the results of cost-benefit analysis of road safety measures in several international scientific initiatives, which have resulted in a few comprehensive handbooks. These manuals, handbooks and other tools aim to gathering, harmonizing and improving the existing knowledge on the effectiveness of road safety measures with final objective to assist researchers and practitioners in assessing the effectiveness of road safety measures. The publication of the Highway Safety Manual (AASHTO, 2010) builds on efforts in many parts of the world and is reflective of deep interest in quantitative assessment of safety decisions utilizing CMFs. Countries often use these international handbooks, manuals and other tools within their national road safety efficiency assessment analyses, by adopting the values proposed (e.g. in terms of percentage reduction of accidents / fatalities, or CMFs), or by adjusting them to the local conditions.

However, a more widespread or fruitful use of efficiency assessment of road safety measure is in most cases limited, as several technical and institutional barriers exist. The most important barrier is the lack of knowledge and data on the safety effects of road safety measures. Furthermore, the transferability of the results from one case (e.g. region) to the other, make scientists and decision makers skeptical about the prevalence of these assessment results in their specific cases.

In the recent years, there is significant advancement of thinking about what research produces a good CMF and an important research effort has been dedicated towards the standardization of the methods for estimating the safety effects of road safety measures. Issues targeted concern mainly the accuracy of the estimation and the conditions and necessary adjustments required to allow the transferability of the safety effect estimates to different settings or countries. To this end, there is certainly need for further research, more assessment initiatives, but also the adoption at international level of standardized procedures for providing specific information that describes the countermeasure studies and for carrying out the cost-benefit assessment of road safety measures.

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