Interreg
EUROPEAN UNION
Danube Transnational Programme
RADAR

Project co-funded by European Union funds (ERDF, IPA, ENI)

Thematic Area 1 report

THEMATIC AREA 1 (TA1): ROAD SECTIONS SAFETY - GENERAL SUITABILITY OF THE ROAD SECTIONS FOR SAFETY AND MAINTENANCE UPGRADING USING SAFER ROADS INVESTMENT PLANS

RADAR – Risk Assessment on Danube Area Roads

https://www.interreg-danube.eu/radar

Internal Report Hierarchy Level			
Activity Number	4.2	Activity Title	RSEG review and assessment reports
Work Package Number	4	Work Package Title	Strategy and Action Plan
Authors (per company, if more than one company provide it together)	Jure Kostanjšek, Klemen Filipič, AMZS Marko Ševrović, EIRA-EuroRAP Olivera Djordjevic, EIRA-EuroRAP Steve Lawson, EIRA-EuroRAP Slaviša Babić, HC		
Status (F: final, D: draft, RD: revised draft):	F		
Version Number	3.0		
File Name	RADAR_project_RSEG_Safer_Roads_Investment_Plans		
Issue Date	29.07.2019		
Project start date and duration	June 1, 2018 – 36 months		

Table of Contents

1. Introduction

The long-term European goal for 2050 is zero road deaths. The intermediate European target for both deaths and serious injuries is set to be redefined for 2030 as 50% of the 2020 outturn. Legislation to strengthen vehicle and infrastructure safety is proposed. The role of network wide safety assessment and the need to assure reliable operation of vehicle technologies such as lane-keeping and intelligent speed assistance is identified.

Problems, needs and issues

The EU Commission has addressed the slow reduction of the fatality rate on the roads of the EU, which is well below the rate needed to achieve the 2020 target. Directive 2008/96/EC on road infrastructure safety management is to be strengthened as part of a drive to remedy this. The Commission's impact assessment on the proposal for amending the Directive states infrastructure improvement is a priority:

Road safety actors in the EU have reacted to the slowdown with renewed commitment to the cause, as expressed by EU transport ministers in the Valletta Declaration on road safety[1] of March 2017. In the Declaration, ministers confirmed that road safety "requires concrete and joint action by the institutions of the European Union, the Member States, regional and local authorities, industry and civil society". They undertook to "continue and reinforce measures necessary to halve the number of road deaths in the EU by 2020 from the 2010 baseline" and to set a target of halving the number of serious injuries in the EU by 2030 from the 2020 baseline. They committed, among other things, to improving "the safety of road users by developing safer infrastructure, bearing in mind the possibility of extending the application of infrastructure safety management principles beyond the Trans-European Transport Network (TEN-T) roads".

The European Commission's Explanatory Memorandum on amending Directive 2008/96/EC on road infrastructure safety management intends that a revised Directive should include the specific objective of "improving the follow-up on the findings of road infrastructure management procedures" (p2) by "introducing a network-wide road assessment, a systematic and proactive risk mapping procedure to assess the 'in-built', or inherent, safety of roads across the EU".

1.35 million road traffic deaths in the world, every year

A new report by the World Health Organization (WHO) indicates road traffic deaths continue to rise, with an annual 1.35 million fatalities worldwide. The WHO Global status report on road safety 2018 highlights that road traffic injuries are now the leading killer of children and young people aged 5-24 years in the World.

The WHO Global status report on road safety 2018 documents that despite an increase in the overall number of deaths, the rates of death relative to the size of the World population have stabilized in recent years. This suggests that existing road safety efforts in some middle and high-income countries have mitigated the situation.

In the settings where progress has been made, it is largely attributed to better legislation around key risks such as speeding, drinking and driving, and failing to use seat-belts, motorcycle helmets and child restraint systems, safer infrastructure like sidewalks and dedicated lanes for cyclists

[1] http://data.consilium.europa.eu/doc/document/ST-9994-2017-INIT/en/pdf

and motorcyclists, improved vehicle standards such as those that mandate electronic stability control and advanced braking, and enhanced post-crash care.

3-star or better standard roads by 2030

The status report also includes the Global Voluntary Performance Target for Road Safety Risk Factors that have been agreed by UN Member States to help governments measure and manage road safety. Target 3 is aimed at **ensuring the safety of all new roads by meeting a 3-star or better standard for all road users by 2030.**

The report highlights the importance of improving the safety performance for all road user groups and captures progress in the institutional management of road safety, legislation and road user behaviour, safe roads, safe vehicles and post-crash care. Results are available at a global level and a country level to help guide priorities for action. The good news is that 48 countries have reduced road deaths, but sadly 104 countries saw an increase in the number of road deaths between 2013 and 2016.

Figure 1 EU performance infographic on Sustainable Development Goals (SDGs) – Goal 3 (https://ec.europa.eu/europeaid/policies/sustainable-development-goals_en)

Higher death rates in lower income countries

The report shows that these measures have contributed to reductions in road traffic deaths in 48 middle and high-income countries. However, not a single low-income country has demonstrated a reduction in overall deaths, in large part because these measures are lacking. In fact, the risk of a road traffic death remains three times higher in low-income countries than in high-income countries.

For instance, the Danube area consists of very different countries, some of them on the border between low income to low middle-income. On one hand, the area includes Austria and parts of Germany, which have highly developed and highly traffic-laden road systems, and on the other hand there are countries that are still developing their road network like Moldova or Bosnia and Herzegovina. In general, previous EU funded projects like SENSoR have shown large parts of the Danube road network rate poorly for safety, particularly for vulnerable road-users, and death rates in many countries are higher than the EU average.

Alarming statistics: more than 7.500 people killed on roads in Danube area

According to status report of WHO, more than 7.500 people were killed on the roads of Danube area in 2016*. Many cases suggest that these numbers annually cost up to 2 % of countries GDP. Great parts of the Danube road network rate poorly for safety for vulnerable road-users also, and death rates in many countries are higher than the EU average.

Many countries lack professional capacity and approaches to the problem. Main issue in most countries across the Danube area is that road infrastructure is often inefficient or simply missing.

The project RADAR will implement learning and transnational cooperation activities to help the relevant organisations in the Danube area to identify risk on their road networks and help them reduce risk systematically by improving road infrastructure and roads' layout. RADAR addresses all road-users but pays special attention to vulnerable road users and safety on major roads near schools. It also approaches the issue of safety in a holistic way and tackles speeding as a major risk on roads.

Making changes – How to implement successful road safety improvement programme

Typically, more than 50% of all fatalities happen on less than 10% of roads and targeting high-risk roads is proven to be high-return and achievable. With the highest risk roads identified, and a plan to improve, the design and construction teams can be deployed. Key road infrastructure safety features can be included to ensure the desired safety performance for all road users. This can be done either through high priority maintenance level, or minor and major upgrades can be prioritised to meet local needs and the business case for each upgrade can be determined. Using existing budgets, or with new resources shaped by the Investment Plan or Business Case, the improvement can be funded. To achieve successful implementation of road safety upgrades some key steps need to be incorporated in process to achieve maximum impact. Typical successful RAP project is shown on figure 2.

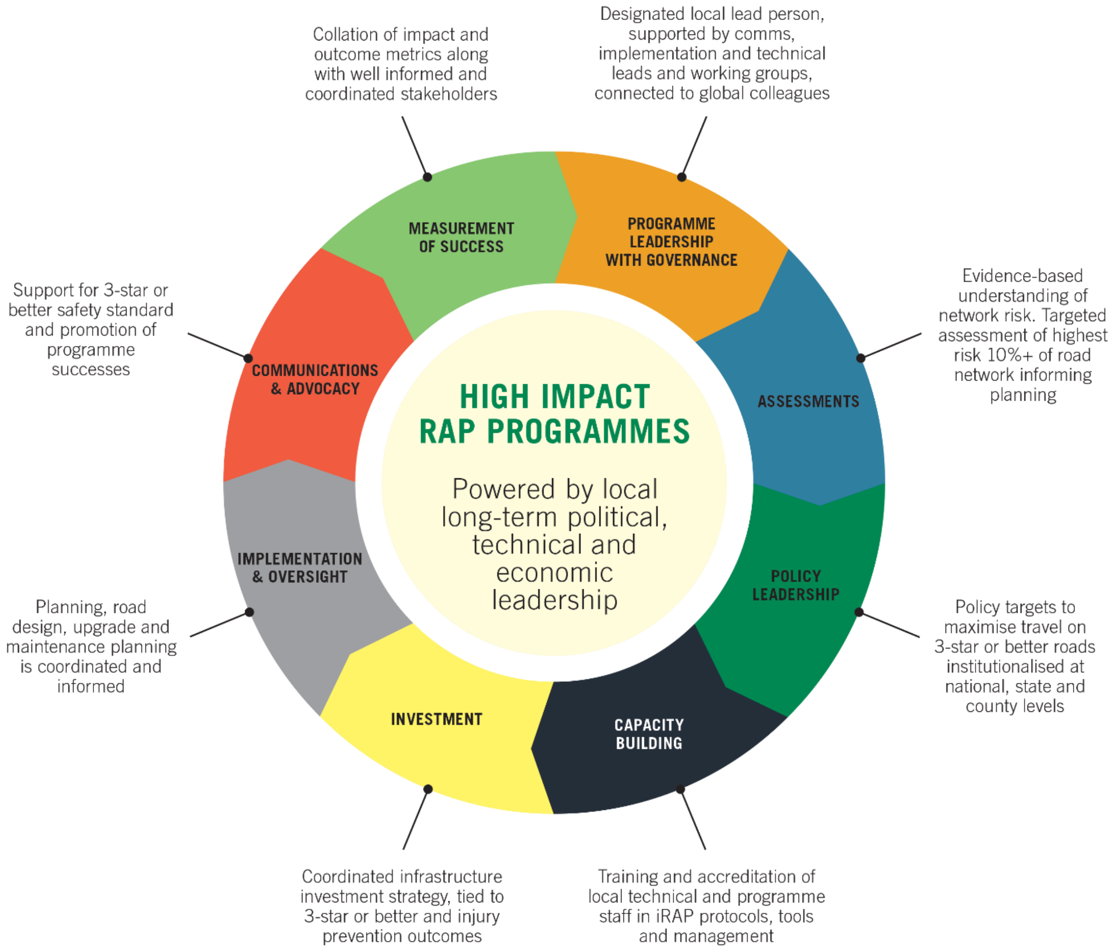

Figure 2 Successful Road Assessment programmes building blocks

About this document

This document is based on RADAR Road Safety Expert Group - Thematic Area 1 meeting, discussion, inputs and experts' feedback, as Thematic Area 1 "*General suitability of the road sections for safety and maintenance upgrading using safer roads investment plans*" report.

This document is going to be used further as a basis for two of RADAR project main outputs:

- Danube Infrastructure Road Safety Improvement Strategy (DIRSIS),
- Country-specific action plans. (DIRSISAP)

This work is about understanding, sharing and making proposals on how to improve national road authorities' procedures and organisation. This document aims to steer road authorities and help them:

- arrange their road safety governance and make arrangements to reduce casualties,
- assess the safety of their roads and make priorities for casualty reduction,
- have policy leadership and plans.

In addition to that, this document aims to raise the:

- question on what capacity they have to implement change,
- question on what arrangements there are for road safety investment,
- question on how improvements are implemented and what oversight there is of that,
- question on how the success of that work is measured, monitored and communicated.

Inputs to this document were provided by Road Safety Expert Group Members prior to the RSEG TA1 Meeting in Ljubljana (March 2019) and the final report was consolidated including comments and conclusions from the meeting (Thematic report on the review activity done within the RSEG for Danube wide road section safety and maintenance upgrading using SRIP – D4.2.1.)

2. Thematic Area 1 (TA1) topics and focus

TA 1 - Thematic area 1 is oriented into optimisation of using of limited road upgrade investment funds and road safety investment funds, by supporting most cost-benefit effective engineering solutions at the most appropriate locations / road sections.

Financial limitations are expected, which suggests that not all good, worthy or necessary projects will be able to receive funding. Hence, a method which would single out a high-priority programs and/or projects is a necessity. Furthermore, since quite a lot of possibilities for addressing a risk are available, it is essential to comprehend which of these possibilities offer highest safety cost-benefit ratio. Economic evaluations are a valuable tool for comparison, prioritization and selection of the interventions in the field of road safety and it can be a method of identification of measures which offer highest economic and social returns over a selected period of time.

Safer Roads Investment plans (SRIPs), based on relevant input data, such as road inspections or road surveys, road data coding and road assessment, provide a set of available and cost-effective proven countermeasures for improving infrastructure road safety, in terms of preventing potentially dangerous situations, prevention of road crashes and in event of road crash, reducing seriousness of injuries for accident participants.

SRIP is the concept, that was one of the outputs of the SENSoR project and is used in iRAP (International Road Assessment Programme) methodology, which foresees the selection of infrastructural countermeasures with a cost-benefit analysis, considering losses generated by fatal or serious injuries, to produce implementation-ready investment plans of high return measures. Therefore, TA1 focuses on:

- Relevant information for specific challenges:
  - problem identification,
  - available solutions,
  - issues, efficiency, implementation, assessment of implementation,
  - alternative measures.
- Selected themes for discussion:
  - linkage of solutions with partner countries specific / current road safety situation/infrastructural need for road safety improvement,
  - review of methods /means for ranking hot spots / crash clusters,
  - role of network scale action plans to treat crash sites with common features,
  - rising of road safety on entire road routes.

3. Review of methods /means for ranking hot spots / crash clusters

Ranking of high accident "risk" locations or high concentration sections implies a method to identify, analyse and rank sections of the road network which have been in operation for more than three years and upon which a statistically higher number of fatal accidents in proportion to the traffic flow have occurred, compared to the network average.

Different countries use different analytical-statistical or GIS oriented techniques for analysis and identification of clustering or road accidents of the same type. These techniques can be divided in two main groups:

- Based on real accident data:
    - hot spot analysis,
    - dangerous sections identification using road safety indicators – i.e. iRAP Risk rating procedures,
    - number of accidents of the same type,
    - density of accidents,
    - accident rate (number of accidents in regard to vehicles-km),
    - other methods of clustering identification.

  These methods result in the identification of single independent locations, wider "high risk" stretches or even dangerous sections identification.

- Based on current road condition, road alignment and road/roadside equipment, as the assessment of road condition – identifying possible locations for improvements:
    - i.e. iRAP Star Rating procedures.
    - RSIA/RSA/RSI procedures
- BSM – Black spot management procedure (2008/96/EC)

3.1. State of the art in Danube countries: Review of methods and/or means for ranking hot spots and/or crash clusters

Methods of tracking road infrastructure risk used in participating countries vary from non-systematic visual identification of high risk areas to systematic use of iRAP Risk Mapping and Star Rating procedures. With the exception of only a few countries, all of them are to some extent familiar with iRAP procedures, at least as a result of participation in an international project. In addition, hot spots management is reported to be present in about half of them, mostly for many years now and using different methods of identifying such spots.

Where iRAP methodology is not in use, the risk is mostly calculated/assessed on the basis of number and rate of road accidents/injuries, including their spatial distribution, and some measure of vehicle flow/AADT.

In general, all countries have AADT data available. However, the range, accuracy and keeping the data up-to-date can be a challenge.

Reported accuracy of the existent road accident databases mostly depends on type of the accident and/or injury. In some countries it is described as quite accurate and in others as not. Accidents with more serious consequences are less prone to underreporting. The location accuracy also varies, however it is improving with time and use of new technologies (GPS). The scope of crash type information, where existent, is in general reported as adequate.

In clear majority of countries, either the Ministry of interior directly or Traffic Police is responsible for keeping the database. In a few cases, some data is held at institutions, dealing with statistics.

In general, and where existent, only limited amount of data is publicly available. More data for the road safety stakeholders is available on request.

A few challenges regarding accuracy and sharing of the data as well as hopes for the future improvement are reported.

4. EC Directive 2008/96/EC implementation

Directive 2008/96/EC on road safety infrastructure management introduces the general principle of safety impact assessment (RSIA) at pre-design stage, of safety audit (RSA) at the design stage, regular inspections (RSI) at operation stage and the ranking of high accident concentration sections, and establishes a comprehensive system of road infrastructure safety management (NSM). The Directive aims to ensure that these four procedures are integrated in all phases of planning, design and operation of the road infrastructure in the TEN-T road network. Also, the Directive encourages Member States to apply its provisions to the rest of the network constructed using EU funding in whole or in part.

Example: In Slovenia, there are over 30 licensed road safety auditors. Motorway authorities use their road safety audit/inspection procedures primarily on sections, with worst iRAP road safety score. Plan for 2019: to implement road safety audit/inspection procedures also on lower ranked roads (not only TEN-T corridors).

4.1. RSA - road safety audit

"Road safety audit" means an independent detailed systematic and technical safety check relating to the design characteristics of a road infrastructure project and covering all stages from planning to early operation.

4.2. RSI - road safety inspection

"Safety inspection" means an ordinary periodical verification of the characteristics and defects that require maintenance work for reasons of safety.

Complete analysis of the existing road safety level on the observed road network sections is usually performed according to the RSI methodology consisting of the following steps:

- collecting input data needed to create a complete and comprehensive database,
- encoding and processing of collected data,
- analysis of the collected input data to determine the existing road safety levels on the observed road sections,
- proposing the countermeasures,
- countermeasures prioritisation.

In order to collect the additional data needed to determine the existing road traffic safety levels on the observed road sections, a field visit of the critical road sections needs to be performed. Field survey and road mapping is primarily performed by a specially equipped survey vehicle and secondary by investigation of the immediate surroundings by walking on locations where it is necessary to collect the additional data about the relevant characteristics of the existing road infrastructure and facilities present in the road environment that significantly affect the accident rate and cannot be observed from the driver's perspective. During the road survey of the observed road sections, characteristic potential hot spots, as well as the elements of existing road infrastructure and roadside hazards need to be photographed. Also, on the critical locations of the observed road sections places and elements that are not visible directly from the georeferenced video files, such as the depth and shape of drainage channels along the road, slopes and heights of the road embankment, safety barriers elements, etc., need to be additionally photographed in order to obtain a comprehensive and complete picture of the existing road safety level in the road environment.

EuroRAP/iRAP procedures represent sophisticated methods and procedures of safety assessment and ranking, measures proposals and evaluation of road infrastructure, through following procedures:

- SRS – Star Rating Scoring protocol,
- RRM – Road Risk Mapping protocol.

The assessment of the road safety requires the Road Safety Inspections of the road network sections and the assignment of a safety score to them. The inspection is conducted by visual observation and record of the road infrastructure elements which are related -directly or not- to road safety and have a proven influence on the likelihood of an accident or its severity. The RAP uses two types of inspection; the drive-through and the video-based inspection. During the first one, the record of the infrastructure's elements is performed manually, with help of specialized software, while during the second, a specially equipped vehicle is used, so as the recorded video to be used for a virtual drive-through of the network and an automated identification of the infrastructure's elements. Following the Road Survey, the Star Rating Score (SRS) is calculated. The SRS is a unit-less indicator, which depicts the infrastructure's safety capacity for each road user type and it is calculated for 100m road segments. Road user types are considered the car occupants, the motorcyclists, the bicyclists and the pedestrians, who may be involved in road accidents.

The aim of the Star Rating process is the award of the "n" 100m road segments with Stars, depicting the safety offered to each of the "u" road users' types. The Star Rating system uses the typical international practice of recognising the best performing category as 5-star and the worst as 1-star (5 stars scale), so that a 5-star road means that the probability of a crash occurrence, which may lead to death or serious injury is very low. The Star Rate is determined by assigning each SRS calculated to the Star Rating bands. The thresholds of each band are different for each road user and were set following significant sensitivity testing to determine how SRS varies with changes in road infrastructure elements. The assignment procedure leads to the development of a risk-worm chart, which depicts the variation of the SRS score in relation to the position (distance from the beginning) on the road under consideration. The final output of the Star Rating is the Star Rating Maps, in which the "n" road sections are shown with different colour, depending on their Star award (5-star green and 1-star black).

4.3. Network-wide Safety Assessment

The ranking of high accident concentration sections is a method to identify, analyse and rank sections of the existing road network upon which a large number of accidents in proportion to the traffic flow have occurred. In addition, the network wide safety ranking is a method to identify, analyse and classify parts of the existing road network according to their potential for safety development and accident cost savings.

4.4. State of the art in Danube area countries: EC Directive 2008/96/EC implementation

Directive 2008/96/EC is mostly fully implemented, in some partner countries only partially. Where reported, implementation is usually made as incorporation into national legislation or through relevant institutions.
Where implemented, different institutions are reported as responsible for the implementation of the Directive, namely relevant Ministries (Transport, Infrastructure), Road safety agencies or Road authorities.
With exception of Montenegro and Bosnia and Hercegovina, there are reported exact numbers of Licensed Road Safety Auditors per each participating country that vary greatly between 3 and about 500.
Licensed Road Safety Auditors are trained in various institutions, ranging from Universities and Ministries to accredited companies and organisations. In some cases, trainings and exams can be held at different institutions. Where reported, accredited training programs are available, with the exception of Montenegro.
As a general rule, most widely performed protocol between the participating countries is RSA followed by RSI and RSIA. Network-wide safety assessment is reported to be somewhat less frequently used. Where reported, the protocols are mostly performed on request of Road authorities by independent/external auditors, sometimes even international ones and in a few cases by relevant Ministry.
With exception of a handful of countries, protocols are in general performed on the TEN-T road network, whereas on other roads protocols are performed sporadically and in a limited scope.

4.5. State of the art in Danube area countries: EC Directive 2008/96/EC implementation

The Road Infrastructure Safety Management Directive 2008/96/EC (RISM Directive) was adopted in 2008 to ensure that road safety considerations are at the forefront of all phases of the planning, design and operation of road infrastructure. RISM Directive introduces the general principle of safety impact assessment (RSIA) at pre-design stage, of safety audit (RSA) at the design stage, regular inspections (RSI) at operation stage and the ranking of high accident concentration sections, and establishes a comprehensive system of road infrastructure safety management.

The Directive aims to ensure that these four procedures are integrated in all phases of planning, design and operation of the road infrastructure in the TEN-T road network. Also, the Directive encourages Member States to apply its provisions to the rest of the network constructed using EU funding in whole or in part. However, there are big differences in the way the Directive has been implemented by Member States, with many high-performing countries going beyond the requirements of the Directive, and other countries lagging behind.

The communication of 20 July 2010 from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions entitled 'Towards a European road safety area: policy orientations on road safety 2011-2020' stated the strategic objectives of the Union to halve the number of road deaths by 2020 compared to 2010 and to move close to zero fatalities by 2050. However, progress towards achieving those objectives has stalled in recent years. A new interim target of halving the number of serious injuries by 2030 compared to 2020 was endorsed by Council in its conclusions of 8 June 2017 on road safety, endorsing the Valletta Declaration of March 2017. Greater efforts are therefore needed to attain both those targets. Based on this conclusions, Directive 2019/1936/EC Of The European Parliament and of The Council of 23 October 2019 has been adopted amending Directive 2008/96/EC on Road Infrastructure Safety Management

The general objective of the amended directive is to reduce road fatalities and serious injuries on EU road networks by improving the safety performance of road infrastructure. The specific objectives include:

- improving the follow-up on the findings of road infrastructure safety management procedures;
- fostering harmonisation and knowledge sharing between Member States on these procedures and requirements;
- protecting vulnerable road users;
- improving the deployment of new technologies; and
- working towards a consistently high level of road safety across Member States, using the limited financial resources efficiently.

The revised Directive aims to achieve these objectives by introducing the following main changes:

- mandating transparency and follow-up of infrastructure safety management procedures;
- introducing a network-wide road assessment, a systematic and proactive risk mapping procedure to assess the 'in-built', or inherent, safety of roads across the EU;
- extending the scope of the Directive beyond the trans-European transport network (TEN-T) to cover motorways and primary roads outside the network as well as all roads outside urban areas that are built using EU funds in whole or in part;
- setting general performance requirements for road markings and road signs to make it easier to roll out cooperative, connected and automated mobility systems; and
- making it mandatory to systematically take vulnerable road users into account in all road safety management procedures.

4.5.1. Network-wide Road Assessment Candidate methodologies – 2019/1936 compliant

In order to fulfill the requirements, set out by the Directive 2008/96/EC and the amended Directive 2019/1936/EC the consultant has perform the state-of-the-art desktop research of existing road safety assessment methodologies that are in use in EU and worldwide.

Based on the research the following methodologies have been identified:

EU based and applied methodologies:

- **iRAP/EuroRAP** – The program is based on four protocols that, together, provide consistent safety ratings of roads across European borders, increasing recognition and understanding of the sources of risk and indicating priorities for network improvement. Nationally, EuroRAP protocols enable the identification of the most dangerous roads, the ability to track performance over time, and therefore where action is appropriate. Internationally, they enable comparisons between road safety performance within and between countries. To ensure that stakeholder organizations are in a position to draw maximum benefit from the detailed road condition report generated through ViDA, Star Ratings and Safer Road Investment Plans, EuroRAP offers ongoing support and training on the use of the customised RAP software. Crash Risk Maps use detailed crash data to illustrate the actual number of deaths and injuries on a road network . Star Ratings provide a simple and objective measure of the level of safety provided by a road's design. Safer Roads Investment Plans draw on approximately 90 proven road improvement options to generate affordable and economically sound infrastructure options for saving lives. Performance Tracking enables the use of Star Ratings and Crash Risk Maps to track road safety performance and establish policy positions. The Star Rating methodology is explained in a series of more than 50 factsheets . Star Ratings are based on road inspection data and provide a simple and objective measure of the level of safety which is 'built-in' to the road for vehicle occupants, motorcyclists, bicyclists and pedestrians. The focus is on identifying and recording the road attributes which influence the most common and severe types of crash, based on scientific evidence-based research. Five-star roads are the safest while one-star roads are the least safe. iRAP considers more than 90 proven road safety countermeasure options to generate affordable and economically sound Safer Road Investment Plans (SRIP) that improve a road's Star Rating and will save lives. Because each road – and the community it serves – is unique, every Safer Road Investment Plan is different. By assessing and optimizing the key attributes that are universal to all roads, we arrive at a clear network-level plan that will maximize the lives saved per unit of investment based on the road users on that road network. The investment plans consider the existing road features, the speed and volume of traffic, the expected fatalities and injuries before and after treatment, the hierarchy of treatments, the expected economic benefits of investing in that treatment, the benefit to cost ratio and the internal rate of return. In this way the road owner can have a full appreciation of the investment business case and have confidence that the interventions will deliver results.
- **ETSC PIN ratings** - The ETSC's Road Safety Performance (PIN) Index is policy instrument to help EU Member States in improving road safety. Started in June 2006, the Index covers several areas of road safety including road user behavior, infrastructure and vehicles, as well as road safety policymaking. To facilitate the collection of accurate data from all 27 EU Member States, as well as Norway, Switzerland and Israel, ETSC has set up a the PIN Panel of national focal points comprising 30 high level national experts from ETSC's network of member organisations and other organizations. PIN to date has concentrated on final outcomes - the fall or otherwise in road deaths - as well as intermediate outcomes for speed, seatbelt wearing and drink driving. No details are provided if PIN has set up a infrastructure rating methodology according to the 2019/1936/EC.

- **The models developed within the research project PRACT** (funded by CEDR) – and the related international repository of Accident Prediction Models (APMs) and Crash Modification Factors (CMFs) . No information of 2019/1936/EN compliance available.
- **"Empfehlungen für die Sicherheitsanalyse von Straßennetzen (ESN)"**, which is a risk rating approach based on crash costs developed in Germany and partially adopted in Austria - does not include the kind of assessment of 'in-built' safety as required by Directive 2019/1936/EC. Federal Ministry of Transport, Building and Urban Development (BMVBS) has recommended that the "Recommendations for the Safety Analysis of Road Networks" (German abbreviation ESN) published by the Road and Transportation Research Association (German abbreviation FGSV) be adopted (ARS 27/2003). The adoption of this ESN meets the requirements of EU Directive 2008/96/EC concerning safety management for road infrastructure. In addition to individual federal states in Germany, the BASt has already successfully adopted the ESN to the federal trunk road network. This experience has been fed into the ESN revision process currently taking place. In addition, information for the IT-supported application is also included in the revision. In detail information about the background and specifications of the methodology could not be obtained in this desk research and its compliance to 2019/1936/EN could not be determined.
- **Work-related safety ratings in Sweden** - Swedish trade unions in cooperation with environmental and road safety organizations have developed a ranking system for heavy goods transport. This ranking system is called Q3 and is modelled on Euro NCAP. It is based on working environment, environmental and road safety requirements (http://www.q3.se/). While the system has limited coverage to date, it is becoming well accepted and is considered a worthwhile initiative. No information of 2019/1936/EN compliance available.
- **ECF – ECS** (European Certification standard) - The certification has been designed as a multiple-step process relying on the collection, compilation and analysis of publicly available data. The certificate will be awarded by the ECF after finishing this process. The steps of the certification are all to be performed together. There is no option just to perform some of the tasks and aim for the certification anyway. The certification can only be initiated by a consortium of the relevant partners along the route (National EuroVelo Coordination Centres or Coordinators and their regional or national partners).
    - The ECF should be informed about the certification process before it commences. The request should clearly indicate the itinerary and the partners should provide the funding. The certification can only be performed by inspectors authorized by the ECF. Trainings for route inspectors will be provided by the ECF. A list of authorized experts will be made available on the EuroVelo.org website.
    - After data collection and the evaluation is finished, the leader of the consortium should submit a request including all relevant information to the ECF for the issuing of the official certificate.
    - The ECF will issue the certificate either for the whole route or for its major section – at least 300 km long, with clearly defined origins and destinations, e.g. major cities or attractions. The validity for any certification is five years. Within this period, the members of the above-mentioned consortium are responsible for updating information relevant on the trans-national level in the EuroVelo.org database. After five years, the field work should be repeated.
    - No information of 2019/1936/EN compliance available.

5. Selection of road sections to be reconstructed / upgraded

Road, as a part of the safe system approach, is characterized by numerous factors including the characteristics of the road alignment, technical features, pavement condition, roadside equipment, lighting, intersection characteristics, effects of side barriers and level of maintenance of the road. Traffic accidents are not uniformly distributed along the entire length of the road, certain parts of the road have a higher risk rate than the other. The frequency of accidents in certain parts of the road depends largely on its shortcomings.

Based on the determined accident rate, it is possible to determine which roads require significant improvements to increase existing road network safety level. The countermeasures implementation process can then be performed according to the priorities determined, based on the determined risk levels of the individual road sections on the observed road network. This then enables the development of optimal investment plan which assures the investment of available funds into critical road network elements in order to achieve maximum cost-effective results: improved overall road traffic safety level and reduced possibility of serious and fatal traffic accident occurrence on the observed road network together with significant reductions in social and external costs in the overall road traffic system. However, AADT values on each individual road section must also be taken into account in order to ensure that appropriate roads are selected for countermeasure implementation process.

Road accident data and analysis as input for decision-making considers following indicators:

- number of fatal and serious crashes,
- traffic flow volumes,
- determined accident rates,
- the distribution of major crash types,
- number of fatal and serious crashes by road type,
- determined average accident rate by road type.

Analysis at individual road section level provides in-depth information on trends on specific routes. There are many possible variations. The most common output includes:

- improved roads: sections that have shown a decrease in the accident rate of fatal and serious crashes between data periods,
- persistently higher risk roads: sections where risk has remained high between data periods.

Statistical filters are used to select road sections that represent the most reliable improvement over time, using factors known to have an impact on the reliability of crash numbers in the observed data period. Individual road sections are omitted from the improved roads listing using the following criteria:

- Length: Sections less than 5km in length in either data period are omitted from analysis. Intersection crashes can be assigned to corresponding sections or intersection risk rating can be done as a separate analysis
- AADT: Sections with an AADT of less than 2,000 vehicles per day are excluded from analysis.

- Crash density: Sections with a density of less than 1 fatal and serious crash per kilometre are omitted in the first data period. An alternative approach is to analyse the distribution of crash density across the network and choose an appropriate level, such as the 50th percentile as a threshold value.
- Crash numbers: It is good practice to explore the distribution of crash numbers across the dataset in order to set an appropriate threshold for analysis. It is common to exclude roads where crash numbers fall below the 50th percentile.
- Statistically significant improvement in crash numbers at the 98% confidence level: Statistical test is performed on each individual section to identify the significance of the change in crash numbers over time.

5.1. State of the art in Danube area countries: Road infrastructure asset management system

Road infrastructure asset management system is present in majority of participating countries; additionally, some of them are in a process of implementation of such a system. Ownership varies from road authorities to State institutions. Data is generally collected by road authorities. The amount (and quality) of available data decreases along with the level of the road. Accessibility to stakeholders differs from country to country and is reported as being available upon request on one side and as usually not accessible on the other.

Where present, databases in general do hold infrastructure condition information, however the data can differ from database to database within the same country when there are multiple databases present. Moreover, not all information is held in the same database as there can be different databases for different types of infrastructure information.

The most commonly used key performance indicators are: International roughness index, number of road accidents and traffic volume, followed by different combinations of single variables and iRAP SRS score and Risk rate.

As reported, except in Montenegro, KPIs do at least to some extent influence on prioritisation of reconstruction/upgrade of road infrastructure in all participating countries.

6. Selection of counter-measures, locations and priority ranking

Based on most common accident types and detailed analysis of road crashes, respective measures must be selected and implemented. Sustainable long-term increase in road safety is a process, requiring planning, resources, legal background and implementation. In many cases, proven and fast implementing measures are available as low-cost measures.

Basic requirement of safe road infrastructure is a safe system for all road user types. Challenging task for road authorities is to select problematic road sections, where effects of implemented measurers are highest possible, due to limited funds. Appropriate measures must be evaluated and roads sections for upgrade prioritised in order to select and rank most appropriate actions.

Procedures of road safety assessment enables road authorities, to detect road sections with highest savings potential and where road investments have highest benefit-cost ratio. In that case, limited funds are most effectively invested.

Distribution of countermeasures on the network/location's selection and priority:

- due to funds available,
- due to traffic volumes,
- due to high accident density, accident rate, severity,
- other…

Ranking the priority of countermeasures:

- due to high accident density, accident rate, severity,
- due to traffic volumes,
- due to road class (motorways, national roads, regional roads, local roads),
- other.

It is necessary to determine the most appropriate countermeasures for individual road network elements. Countermeasures are the engineering improvements that the road authorities should take to reduce the fatality and serious injury rates. Each countermeasure is characterized by its trigger sets and its effectiveness for each of the 100m road segments. Each trigger set describes all the cases in which this certain countermeasure can be used. The effectiveness is calculated according to the number of fatalities and serious injuries that can be prevented in this segment and the SRS of this segment before and after the application of the countermeasure. It is important to mention that in the case that multiple countermeasures act on a certain road segment, the total effectiveness is not the simple sum of each countermeasure's effectiveness. Instead, a reduction factor should act, which calibrates the total effectiveness.

In order to achieve further improvements in the overall traffic safety level on the observed traffic network in future periods, it is necessary to conduct periodical road inspections and risk rate analysis as well as comparative analysis of determined risk levels between relevant time periods. Dangerous locations need to be upgraded by taking appropriate countermeasures in order to achieve predicted improvements in traffic safety.

The procedure of selecting the most appropriate countermeasures is the basis for the techno-economic analysis of the investment plan and aims to the calculation of the Benefit-Cost ratio (BCR) for each countermeasure. The economic benefit is considered as the benefit of preventing a death or a serious injury. The calculations are conducted following the assumption that statistical value of life is 70 times the GDP per capita, the statistical value of a serious injury is 25% of the statistical value of a human life and the ratio of 10 serious injuries for 1 death, if more accurate information is not available. The countermeasure cost includes all the construction costs, the maintenance costs over a 20-year period and/or probable reconstruction costs. All the benefits/costs should reflect the actual local prices, considering the economic life of each countermeasure and the discount rate. The outcome of this procedure is the BCR calculation for each countermeasure applied to a specific road segment.

6.1. State of the art by countries: Selection of road sections to be reconstructed / upgraded

Countermeasures to be implemented on crash prone locations are mostly selected by a group of experts, often in collaboration with other subjects and on the basis of crash analysis. Economic effectiveness is not widely used.

In general, there is an official statistical value of life calculated in almost every participating country, however even where existent, it is not always used in benefit cost analysis.

The cost of countermeasures is mainly calculated on the basis of costs of materials and work, needed to implement the countermeasure and their life-time. It is generally locally defined and often based on previous similar investments.

Benefit to cost ratio in countermeasure selection process is not widely used in participating countries.

Since the benefit to cost ratio in countermeasure selection process is not widely used in participating countries, benefits are also usually not calculated.

A typical upgrade project differs from country to country and where reported, a description can be seen in detail in each country's individual report.

7. Safer Roads Investment Plans and countermeasure benefit-cost ratio

Safer Roads Investment Plan is the final output of the road assessment procedures, based on video inspection, coding of road attributes and star-rating of road sections. The SRIP presents all the countermeasures proved able to provide the greater safety capacity and maximize the benefit over cost spent on the selected countermeasures. The cost of each countermeasure is compared to the statistical value of life and serious injuries that could be saved and Benefit to Cost Ratio (BCR) is calculated for each countermeasure proposed. Analysis of costs and benefits is country-specific, depending on country's statistical value of life and the countermeasure costs.

In certain situations, it is easy to identify ways to increase traffic safety to achieve a minimum acceptable SRS rating. The basic categories of remedial measures that can significantly increase the SRS rating values for different road user groups, which were applied in other EuroRAP and iRAP studies to enhance road infrastructure safety, include:

- installing a safety barrier,
- extending paved shoulders on the left side of the road (driver's side) between the traffic lane and safety barrier,
- upgrading left-turn lanes at intersections,
- constructing roundabouts,
- marking horizontal signalization (including curves),
- paved road shoulders (especially if they include a cyclist area),
- constructing a sidewalk,
- implementing traffic calming measures.

7.1. State of the art by countries: Safer Roads Investment Plans and countermeasure cost-benefit ratio

There are only a few reported experiences with financial institutions on road safety related projects and they are described as positive.
Where reported, planning network scale investments is either done by road authorities or other relevant institution on a basis of undefined procedures.
Similar to reported experiences with financial institutions on road safety related projects reported comments mainly describe those positive experiences.
A handful of reported best practice examples can be seen in detail in each country's individual report.

7.2. CEDR approach

CEDR issued “Best practice for cost-effective Road Safety Infrastructure measures” full report, 2008. CEDR formed task to group to understand, identify and disseminate best practices to ensure cost - effectiveness on road safety investments, as part of a broader Strategic Plan which defines the priorities and aims to assist and guide for more efficient National Road Authorities.

The goal was an identification of best practice on cost-effective infrastructure related road safety investments, resulting in 55 examined road safety investments. Both the implementation costs and the safety effect of each investment are ranked as "high" or "low".

In general, an investment combining a high safety effect with a low implementation cost is considered to be the most preferred. As infrastructure-related road safety initiatives usually have high implementation costs and as budgets for road safety policies worldwide are limited, decisions have to be taken about the best possible use of these budgets. The criteria used in most countries when deciding on policies and budgets are mainly suitability, lawfulness, and/or legitimacy.

However, in recent years, efficiency has also been frequently cited as a primary criterion for a good policy, and its assessment may contribute to greater rationality in the selection and application of road safety measures, preventing these from becoming merely routine decisions.

The choice of an investment or a series of investments should always be based on a road safety study, conducted by specialists. Therefore, knowledge of the relative cost-effectiveness of road safety infrastructure investments can be very useful in the selection of appropriate solutions for different road safety problems, but only when a thorough analysis on a case-specific basis is also performed.

Road safety related assessment tries to enable a selection of the optimal road safety measure. This may be achieved through the application of two widely used efficiency assessment tools, the Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA), which enable decision making and choice of the policy with the highest return in monetary terms.

The most common form of a safety effect is the percentage of accident reduction following the treatment. In order to estimate the number of accidents that can be expected to be prevented per unit of implementation of a safety investment, two components need to be calculated: the number of target accidents expected to occur per year for a typical unit of implementation of the investment, and the safety effect of the investment on target accidents.

7.3. EBRD approach

The EBRD has committed over €7.5 billion into more than 90 road projects since 1991 and road and traffic safety are embedded into the Bank's Environmental and Social Policy under Performance Requirement (PR) 4 – Health and Safety. This requires all projects to identify, assess and monitor the potential traffic and road safety risks, as well as implementing measures to control any risks. EBRD also requires any road project they invest in to take into consideration relevant EU road and traffic safety management standards.

Projects undergo road safety audits to identify road safety measures and incorporate technically road safety measure into the road design to mitigate potential road safety impacts on all road users – motorised and non-motorised.

EBRD recognised also infrastructural deficiencies that increase the risk of a crash occurring: Poor road design, poorly executed roads and inadequate road maintenance can also cause crashes and increase the severity of injury. Roads need to be designed with the needs of all road users in mind – including pedestrians, non-motorised road users and local communities and businesses.

Roads should assist road users to keep safe – encouraging appropriate speeds, ensuring good visibility, providing warnings to drivers of potential hazards. A 'forgiving road' can assist safe road user behaviour and prevent or reduce injuries.

Road design standards are quite outdated in many of the countries where the EBRD works, coupled with a lack of engineering knowledge in international best practice, safe road design and the overall process, including hot spot management, road safety audits or inspection requirements.

Funding for road safety activities is often limited due to economic constraints. Thanks to the generous support of the donors, the EBRD has been able to support priority countries via the Bank's Shareholders Special Fund (SSF). Generally, EBRD is achieving around 75% of recommendations in road safety audits being implemented into the final detailed design of road projects.

8. Road authorities' budgets

In the south-east European region, there are usually no specific "roads safety budgets" available, but only general road authorities' budgets, intended for routine and winter maintenance, for upgrades/reconstruction and for new roads construction.

8.1. State of the art by partner countries: Road authorities' budgets

Financing road safety related infrastructure upgrades is done from different sources, most commonly road authority's budget. Some projects are funded by the EU or IFIs. In the majority of participating countries there is no dedicated road safety fund or budget present or the funds are not used for infrastructural improvement. Where present, there is no specific report of implementation. About half of participating countries do use EU funding for road infrastructure safety upgrades at the moment. A single comment on possibility for improvement regarding road safety level in Czech Republic with dispersing the budget from existing single countermeasure implementation policy.

9. Conclusions and recommendations

Benefit-cost analysis of infrastructure projects is often calculated in the view of alternatives comparison and/or comparison of alternative(s) against "do nothing" scenario - usually basic user costs, in the field of infrastructure project typically over many years. Costs and benefits, that are included in "classic" assessment, are construction costs and user costs, such as value of time, congestions and environment impacts, vehicle usage costs and similar.

Having added statistical value of life, costs of fatal and serious injuries saved or even costs of property damage accidents reduced, more comprehensive benefit-costs analysis is enabled. Even more, if upgrades of existing roads in operation are in question.

Across the Danube region procedures for improving infrastructure safety differs widely and are often not very satisfactory. Economically effective and proven measures are often not implemented due to limited budgets. A standardised and systematic approach is highly recommended in the field of improving road safety statistics to nearer or better than the EU average.

With the goal of reasonable and rational money spending/investing in road safety and most effectively reducing fatal and serious injuries on roads, an evidence based fast implementing and relatively low cost and highly cost-effective countermeasures are available. There are many experiences from world's leading and top-performing countries, which may be used as a good-practice examples, that may be adapted and implemented in the Danube region to contribute to safer road traffic.

There are also roads with high seasonal variations in traffic volumes and traffic accidents, which should be taken into consideration when performing road safety data analysis.

Slovenia approach example:

- Motorway authorities are regularly requesting AMZS as accredited iRAP supplier to deliver Risk Rating and Star rating procedures
  - Risk rating for 3-year periods 2006-2008, 2009-2011, 2012-2014, 2015-2018,
  - Star rating each year, about 100 km of reconstructed motorway or expressway sections
  - As assistance to licensed Road Safety Auditors, who in the name of Road authorities perform RSA/RSI procedures on the worst star rated and/or risk rated section

iRAP 3star or better roads policy:
WHAT COULD BE ACHIEVED IF IMPROVE 10% OF WORLD'S ROADS?

- 3.7 million lives would be saved
- 40.5 million serious injuries would be prevented
- Economic benefit $5,715 billion
- Benefit cost ratio of 8

RADAR project Thematic Area 1 (TA1): Road Sections Safety - general suitability of the road sections for safety and maintenance upgrading using Safer Roads Investment Plans

RECOMMENDATIONS SHEET

Recommendations for state governments/ministries/agencies:

- *To define a national minimal standard for existing and new roads based on internationally recognized methodology for road infrastructure safety rating*
- *to ensure certain portion of road infrastructure investments is allocated to road safety intervention,*
- *to ensure embedding of the Safe System approach into the mainstream of road design/investment and maintenance legislation and practice,*
- *to ensure trainings of road safety auditors,*
- *to transfer Safe system approach to local governments and local road authorities,*
- *to take into serious consideration also 2nd level roads, like regional roads,*
- *make knowledge transfer with demonstrations of good practices and approaches for road authorities and to regional/local governments.*

Recommendations for local governments:

- *to start systematic road safety data collection and analysis to plan interventions/investments on most critical locations,*

Recommendations for road authorities:

- *to form own special road safety funds within regular or investment funds dedicated for direct investments in road safety upgrades in terms of road safety equipment and measures at locations with most effectiveness*
- *to follow the road safety trends and good practices to plan maintenance and upgrades of existing road network in operation,*
- *to use the methodologies for selecting most critical locations with highest potential savings.*
- *to ensure public accessibility to the list of high accident concentration road sections / hot spots.*

Your Road Safety is on our RADAR.

9.1. State of the art by partner countries: Ideas and recommendations

Different and comprehensive suggestions contributed by experts from participating countries that are available in detail in each country's individual report.

Expansion of protocols from 2008/96/EC Directive to lower levels of roads, monitoring of measures, inter-ministerial coordination regarding implementation of action plans, unification of road safety assessment and enhanced use of BCR is seen as a general recommendation for all partner countries.

In the post RADAR stage, partners also recommended establishment of a specific Programme for Danube region countries

Determination of major routes across the Danube region, where the equal level of road safety is to be ensured. This implies acceptance of the RADAR project recommendations and development of common applicable policy in the Danube countries for:

- ✓ road safety assessment on these roads (under unified approach, criteria and methods);
- ✓ determination of the relevant countermeasures;
- ✓ approval of the scope of works for each country road section;
- ✓ implementation of these in the Safer Roads Investment Plans of the countries;
- ✓ provision of financial arrangements for dedicated road safety budgets;
- ✓ estimation of the achieved safety level on the Danube routes
- ✓ monitoring and ensuring constant equal level of road safety on these routes

REFERENCES

- iRAP Risk Rating Manual (2019)
- iRAP Survey Manual (2019)
- iRAP Coding manual (2019)
- iRAP: Star Ratings and Investment Plans: Data analysis and reporting specification (2014)
- European Commission Guide to Cost-Benefit Analysis of Investment Projects (2014)
- CEDR, Best practice for Cost-Effective Road Safety Infrastructure Investments (2008)
- EBRD, The EBRD approach to road safety, www.ebrd.com (2019)
- iRAP 3 star or better policy paper, (2018)
- Department for transport, Road Safety Management Capacity Review (2018)
- EC: EU's strategic road safety action plan (2018)
- WHO Global status report on road safety (2018)

APPENDIX 1

Example of SRIP

Total FSI's saved	Total PV of Safety Benefits (EUR)	Estimated cost (EUR)	Cost per FSI saved (EUR)	Program BCR
1,820	86.5 m	13.7m	7,485	6

Countermeasure	Length/ Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	BCR
Roadside barriers – passenger side	66.9 km	730	34.8m	5.1 m	6,917	7
Roadside barriers – driver side	45.4 km	310	14.8m	3.1 m	10,063	5
Improve curve delineation	49.3 km	180	8.6m	0.9 m	4,746	10
Road surface rehabilitation	38.9 km	130	6.5m	1.0 m	7,155	7
Shoulder rumble strips	78.7 km	130	6.5m	0.8 m	5,979	8
Clear roadside hazards – driver side	95.1 km	85	4.1m	0.5 m	5,348	9
Clear roadside hazards – passenger side	85.2 km	76	3.6m	0.4 m	5,137	9
Shoulder sealing driver side (>1m)	26.1 km	55	2.6m	0.4 m	7,422	6
Improve delineation	17.9 km	33	1.6m	0.5 m	15,122	3
Shoulder sealing passenger side (>1)	10.0 km	27	1.3m	0.3 m	10,420	5

SRIP example table shows estimated costs for countermeasures in 20-year period, the number of predicted fatalities and serious injuries (FSIs) saved, present value of safety benefit cost per FSI saved and the program Benefit-cost ratio. At each countermeasure, a length, FSIs saved, present value of safety benefit and estimated cost, cost per FSI saved and BCR ratio are calculated. Threshold value of acceptable BCR may be set, to select most effective countermeasures.

APPENDIX 2

Most common infrastructural road safety measures – roads upgrades (toolkit.irap.org)

Most important countermeasures for improving road safety tackle the most frequent road accident types:

- head-on collisions,
- run-offs,
- side-collisions,
- accidents with pedestrians and cyclists.

Most frequently proposed countermeasures in SENSoR project (2012-2014, central & east European countries):

- roadside safety barriers,
- side slopes improvement,
- clearing roadside objects,
- shoulder sealing,
- shoulder rumble strips,
- central median barriers.

Other measures:

- Provisions for pedestrians,
- street lighting,
- pedestrian crossings,
- traffic calming,
- intersections improvements.

APPENDIX 3

Safer roads investment plan (SRIP)

The SRIP is conducted for a period of 20 years and shows the list of the most cost-effective improvements that can reduce the crash risk for all road user types. In that way the SRIP enables the road authorities to set the priorities properly when developing infrastructure maintenance and/or rehabilitation plans. The SRIP presents all the countermeasures proved able to provide the greater safety capacity and maximize the benefit over cost of the planned investments. The countermeasures listed are indicative and need to be assessed and sense-checked with local engineers. The Safer Roads Investment Plan is not a "bill of works". The cost of each countermeasure is compared to the statistical value of life and serious injuries that could be saved and Benefit - Cost Ratio (BCR) is calculated for each countermeasure proposed.

The development of the most appropriate SRIP presupposes the assessment of the number of fatalities and serious injuries that could be prevented for each 100m road segment on an annual basis when a set of countermeasures is applied. The number of fatalities is calculated as follows:

$$F_n = \sum_u \sum_c F_{n,u,c}$$

where

- "n" is the number of the 100m road segment,
- "u" the type of road user,
- "c" the crash type that the road user "u" may be involved in and
- "Fn" the number of fatalities that can be prevented on a time of 20 years, given that a specific set of countermeasures is applied.

The number is related to four main factors:

- the safety score of the specific road segment,
- the "u" road users flow,
- the fatality growth, which indicates the underlying trend in road fatalities and
- the calibration factor, which inserts the actual number of fatalities that occur in the specific road section. The calculation of this factor presupposes the existence of similar crash data.

The assessment of the number of serious injuries that could be prevented for a 100m road segment is a function of the n, u, c value and the ratio of the actual number of serious injuries to the actual number of fatalities . In case of lack of appropriate data, the competent authorities should estimate this actual number as previously, or the ratio of 10 serious injuries to 1 death is used, which is proposed by McMahon et al.

In order the Safer Road Investment Plan to be developed, the costs of various countermeasures must be estimated. This will enable the determination of the benefit-cost ratio of each proposed countermeasure. The costs must include all costs of design, engineering, materials, work, land as well as maintenance for their entire life cycle.

The number of years over which the economic benefits of the Safer Roads Investment Plan are calculated is typically set to 20 years. The key figure for the Safer Road Investment Plan is the GDP per capita in local currency. Discounting is a technique used, among other things, to estimate costs and benefits that occur in different time periods and is used to calculate the Net Present Values (NPV) and budgets required within iRAP's ViDA software. The appropriate discount rate to use can vary by country and in many investment project modelling exercises is set in consultation with the funder. Typically, the discount rate varies from 4% to 12%, the latter figure being often used in World Bank transport projects. A sensitivity analysis conducted within the ViDA Model showed that from a practical perspective, at a 12% discount rate compared with 4%, the total Present Value of safety benefits was approximately halved, the overall estimated cost of the investment is reduced by about a third and the estimated number of fatal and serious injuries saved over 20 years is reduced by about 10%. Lists of triggered countermeasures are similar with, as expected, slightly fewer sites or lengths of road recommended for improvement when the discount rate is higher. Again, as part of the consultation process in individual countries, variations on the discount rate can be trialled. The minimum attractive rate of return is set at the decimal fraction equivalent. High discount rates and the implied zero-traffic growth assumption within the model would mean that the Benefit- Cost Ratios and estimates of casualties saved are highly conservative. In addition to aforementioned parameters the statistical value of life and serious injury need also be specified. The statistical value of life reflects the social cost of one fatality on the road and the value of serious injury the social cost of one serious injury on the road. According to the iRAP recommendations the statistical value of serious injury is calculated by dividing the statistical value of life by 4.

The range of Benefit-Cost Ratios is usually between 2 and 6 for the overall investment programmes. For individual countermeasures, the BCRs of those with greatest life-saving potential are of course higher and range in most countries between 2 and 7, but in some commonly up to and around 14.

BCRs for some countermeasures are predicted to be even higher, typically

- if costs of the measures are low (such as with delineation),
- if the risk reduction is focussed on a very limited part of the network (for example, at crossing facilities for pedestrians at a few sites of high activity), or
- if a predicted risk is precisely matched with a countermeasure (such as median barriers countering head-on crashes).

BCRs for overall country programmes or countermeasures dependent upon many elements, including the acceptance threshold that is set for matching countermeasures with risk over every 100m, the statistical value of life and the countermeasure costs selected.

The main objective of the SRIP plan development methodology is the improvement of the road users' safety by proposing cost-effective investment plans. The method indicates that the severity of a road accident can be reduced through the intervention at the sequence of events happening during traffic accident. As it is known, an injury accident results from a chain of events, starting with an initial event, probably resulting from several factors, which leads to a dangerous situation. The basic idea is to intervene at any point of this chain, in order to reduce the kinetic energy of all road users who are involved in the accident to a tolerable level. Such an intervention may not only reduce the number of accidents but also the severity of injuries

According to EuroRAP/iRAP model, a minimum acceptable star rating of the road network segments is a 3-star score (i.e. medium risk level). For example, the Dutch government is determined to achieve a minimum 3-star score on its state roads network by 2020. Similar goals have been set in road infrastructure improvement agreements by certain low and middle-income countries. The increase in star rating scores is related to the reduction in the number of traffic accidents with fatal and serious injuries, as well as the reduction of costs caused by these accidents. By increasing the star rating score by one star, the cost of the traffic accidents is almost halved. Figure shows the connection between the scores and costs of traffic accidents with fatal and serious injuries. It is evident that the costs are drastically reduced when a 2-star rating is increased to a minimum acceptable 3-star rating.

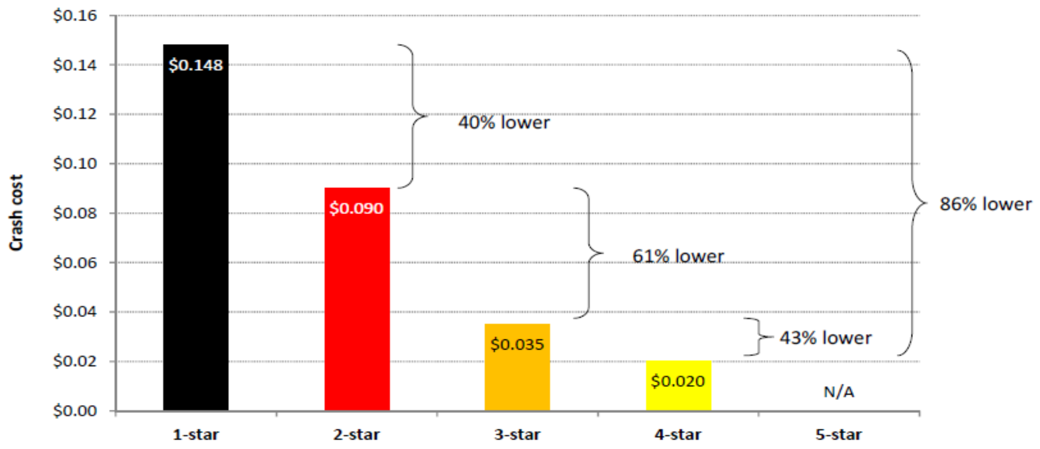

Figure: Values of road protection scores for car occupants in relation to the unit costs of traffic accidents with fatal and serious injuries per vehicle-kilometre

APPENDIX 4

CROATIA - STATE ROAD DC3 - CASE STUDY

Low volume road section used as backup route on motorway closure

ROAD SAFETY ANALYSIS OF THE SELECTED ROAD SECTIONS ON THE STATE ROAD DC3: DELNICE – ČVOR OREHOVICA

In November 2018, the Faculty of Transport and Traffic Sciences has conducted the Road Survey of the 7 selected sections on the state road DC3: Delnice - Orehovica in the Republic of Croatia with a total length of 40.2km. The Road Survey of selected DC3 road sections was conducted by a specialized vehicle equipped by iRAP accredited surveying system. The observed road section includes only one-way road segments.

Based on the conducted road safety analysis of the selected road sections on the state road DC3: Delnice - čvor Orehovica, a total of 2431 potentially dangerous locations with increased traffic accident occurrence risk were identified. The obtained results show that the largest part of the total number of identified potentially dangerous locations (23.9%), primarily include road segments with dangerous roadside environment. Dangerous objects in the road environment on high-risk road segments mainly include unprotected trees greater than 10cm in diameter, irregular rock faces, large rocks or boulders, high embankments and cliffs. Unprotected metal road safety barrier ends as well as different types of defects and deformations on metal safety barrier constructive elements were also observed on large number of road segments (14.31%). The results of the analysis also show that on relatively large number of road segments, there is a possibility of direct vehicle impact on unprotected signs, posts and poles, greater than 10 cm in diameter, present along the road. The high accident occurrence risks on the selected road sections are also caused by the fact that adequate sight distance is not provided at large number of existing intersections, property access points, pedestrian crossings and curves. The results of the performed analysis also show that the observed road sections include approximately 6 potentially dangerous locations per 100 meters, i.e. approximately 60 potentially dangerous locations per kilometre.

Based on the determined values of the traffic accidents risk rates, it is evident that 33.6% of the observed road segments (13.5km), have unacceptably high traffic accidents occurrence risk per million vehicle kilometres travelled. The acceptable value of the risk rate is determined only on 3.7% of the observed road segments. The remaining segments of the observed road sections belong to the medium-low risk (20.9% of road segments) and low risk categories (41.8% of road segments).

The results of the risk analysis performed according to the EuroRAP/iRAP SRS methodology show that only 4.46% of the DC3 state road was rated with a minimally acceptable SRS score of 3 stars (medium risk level), in the vehicle occupants category. On the other hand, the majority of the observed road sections of state road DC3 (more than 80% of road segments) gained only 1-star (high risk level), while the SRS score of 2-stars (medium-high level of risk) was determined on 12.13% of road segments. In the motorcyclists category, even higher risk levels have been determined, whereby the 96.78% of the observed road sections belong to the unacceptably high-risk categories. Similar risk levels were also found in pedestrian and cyclists categories, where the most of the observed road segments (87.38% and 96.79%, respectively) gained 1 or 2 stars (high and medium-high risk).

If the 3-star rating is accepted as the minimum acceptable level of safety, then based on the results obtained, it can be seen that virtually all (95.55%) of the observed DC3 state road sections in the vehicle occupants category belong to the unacceptable high and very high risk categories. The similar results were also obtained for motorcyclist category, where almost all the observed road sections (96.78% of road segments) gained only 1 or 2 stars. The unacceptably low SRS scores were also determined for bicyclist and pedestrians, with 87.38% and 96.79% of observed road sections awarded with only 1-star, in bicyclist and pedestrian category, respectively.

As part of the comprehensive road safety analysis, special consideration was given to cases where parallel sections of the A6 motorway are partially or completely closed for traffic due to unfavourable weather conditions. Thereby, transit traffic flows from the A6 motorway are redirected to the observed DC3 state road sections, causing significant changes in the relevant characteristics and structure of traffic flows within the survey area. The results of the conducted analysis show that, in the case of partial closure of parallel sections of the A6 motorway (partial traffic ban only for trucks, buses and motorcycles), traffic volumes on the observed sections of state road DC3 in the morning and afternoon peak hours increase by an additional 25-50% compared to the normal traffic conditions, when the A6 motorway is open for traffic. A significant increase in the percentage of trucks in the traffic flow was also determined. During the closure of parallel sections of the A6 motorway, the percentage of trucks is increased by an average of 28%, with a rise of up to 40% during the working days, compared to the normal traffic conditions, while during the weekend the increase of trucks percentage is slightly lower and ranges from 20-30%. On the other hand, the increase of traffic volumes and the percentage of trucks and motorcyclists in the traffic flow structure causes reduction of the operating speeds percentile values. Based on the analysis of the measured vehicle speed values it was concluded that, in the case of partial closure of the A6 motorway section, the median value of the operating speed of the vehicles in the traffic flow on the DC3 state road sections is decreased from 73 km/h to 62 km/h, while the value of 85th percentile speed is reduced from 77 km/h to 69 km/h. Results of the percentile analysis of speeds show that the increase in traffic volumes and the percentage of trucks and motorcycles in the traffic flow combined with additional external influences of unfavourable weather conditions, cause the reduction of vehicle speeds in the traffic flow in a relative amount of 10-15% in relation to the vehicle speeds measured under normal traffic conditions.

In order to increase the existing level of safety over the whole length of the observed road sections to an acceptable level (SRS rating of 3 stars), large amount of funds must be invested, due to the fact that the most parts of the observed road sections on the DC3 state road have unacceptably high risk rates and low SRS scores. Using the standard iRAP procedure for defining the SRIP investment plan in the ViDA application, the first variant of investment plan was defined, according to which a total of 6.394.297,00 € should be invested for the upgrading and reconstruction of the observed state road DC3 road section (in case if the threshold BCR value is set to 1). According to the first variant of the investment plan, it is estimated that during the 20 years, a total of 107 road accidents with fatal and serious injuries will be prevented if all defined countermeasures are implemented. Based on the conducted analysis, it is estimated that the percentage of 1-star road sections, after the implementation of all countermeasures defined in the first variant of the investment plan, will be reduced by 80% in the vehicle occupant category. On the other hand, the results of the analysis show that even after the implementation of all countermeasures defined in the first variant of the investment plan, the large percentage of road segments in vehicle occupant category would belong to medium-high risk category (SRS score of 2 stars). The most road segments in the remaining road user categories (from 53.71% to 76.49%) would still be in the very high risk category.

Based on the determined potentially dangerous locations on the observed road sections of DC3 state road, the values of obtained iRAP RRM risk rates and iRAP SRS scores, the appropriate countermeasures were selected, which if implemented, will ensure that the overall road safety will be increased to acceptable level on the majority of the observed DC3 state road sections. During the first phase of the SRIP plan development, the BCR threshold value was varied in range between 0.1 and 1, since the results of the performed analysis of existing road safety have shown that on the most road segments of the observed DC3 state road sections, a large number of potentially dangerous locations with very high risks of fatal and serious accidents occurrence have been determined, which cannot be completely reconstructed and upgraded if the investment plan considers only the implementation of cost-effective countermeasures. In other words, this means that the higher values of BCR threshold values would produce investment plans which can ensure the achievement of minimum acceptable road safety levels on relatively small number of road segments. Therefore, only lower threshold BCR values were considered in the first phase of the SRIP plan development.

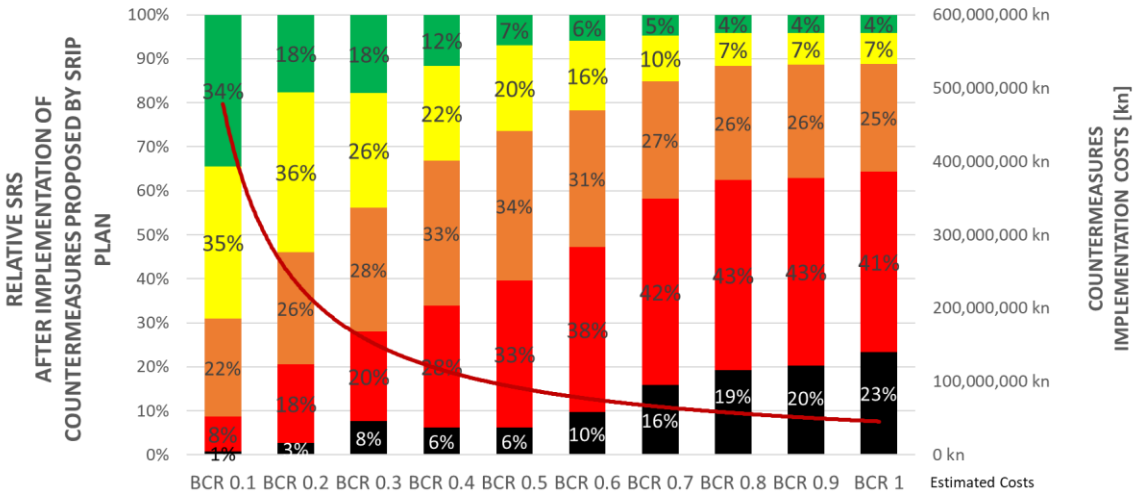

Figure: comparative overview of predicted SRS scores and estimated total costs of countermeasures implementation

The results of the performed Cost-Benefit Analysis in the first phase of SRIP investment plan development indicate that the reduction of BCR threshold value from 1 to 0.1, cause the increase in estimated countermeasures implementation costs from 47,317,801 HRK do 466,340,932 HRK, while the total present value of benefits achieved after increasing the road safety levels on the observed DC3 state road sections is in range between 141,322,757 HRK (1 HRK = 7.4 €) do 203,385,825 HRK. Thereby, if all proposed countermeasures are implemented, it is estimated that between 107 and 156 fatal and serious traffic accidents will be prevented during the 20 years of the analysis period. It was also determined that in cases when BCR threshold value is reduced below value of 0.5, the estimated countermeasure implementation costs begin to increase rapidly, whereby function of total costs show nearly exponential growth, instead linear growth observed for BCR threshold values higher than 0.5. On other hand, the function of total present value of generated benefits shows nearly linear growth, when the BCR threshold value is reduced from 1 to 0.1.

Based on the results of conducted Cost-Benefit Analysis it was also determined that the minimum BCR threshold value of 0.6 should be used in order to achieve SRS rate of 3 stars on the most of the observed DC3 state road sections. Figure above shows the graph with detailed, comparative overview of predicted SRS scores and estimated total costs of countermeasures implementation, for SRIP plans produced based on the BCR threshold values in range between 0.1 and 1.

Since the available funds intended for the implementation of countermeasures on the selected road sections of the state road DC3 were limited to only approx. 1,350,000 €, which is considerably lower amount than the costs estimated by the first variant of the investment plan, it was necessary to define a realistic alternative investment plan variant, which assumes the implementation of defined short-term and long-term countermeasures only on the critical road segments of the DC3 state road. The second variant of the investment plan was developed according to the iRAP UDIP procedure. The relevant characteristics of determined potentially dangerous locations, risk rate rate values determined according to the iRAP RRM methodology, SRS scores determined based on the iRAP SRS methodology, together with defined financial constraints (HRK 10,000,000), were used to select appropriate short-term and long-term countermeasures, which will ensure a satisfactory level of traffic safety only on the critical parts of the observed road sections of the state road DC3: Delnice - Orehovica. According to the final, optimal variant of the investment plan, a total of 141 critical road segments, 14.1 km in length, were selected for the implementation of selected short-term and long-term countermeasures. Thereby, a total of 1.346.968,00 € should be invested in the implementation of the proposed countermeasures to raise the road safety level on the critical parts of the observed road sections (34.90% of the road segments) to a satisfactory, medium risk levels (SRS rating of 3 stars), while the risk rates and SRS scores on the rest of the route would remain unaltered. The BCR ratio of the proposed optimal variant of the investment plan is 3,1. If the defined countermeasures for the upgrading and reconstruction of the DC3 state road are implemented, it is estimated that a total of 24 traffic accidents with fatal and serious injuries will be prevented in the next 20 years. The predominant proposed short-term and long-term countermeasures that are expected to produce the maximum effects are:

- Implementing or upgrading the roadside barriers, both on passenger and driver side;
- Delineation quality improvement,
- Replacement or installation of new traffic signing;
- Clearing potentially dangerous objects on both sides of the road;
- Pavement condition improvement;
- Implementation of traffic calming measures.