South East Europe Transnational Cooperation Programme

SENSOR
South East Neighbourhood Safe Routes

Programme co-funded by the European Union

Star Rating Roads for Safety

Results for Consultation with Stakeholders

EuroRAP
EUROPEAN ROAD ASSESSMENT PROGRAMME

SLOVAKIA

MAKE ROADS SAFE HELLAS · SAMS SLOVAKIA · KTI · AMZS · AMCC · AMCM · BIHAMK · ACM AUTOMOBIL CLUB DIN MOLDOVA

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About SENSOR

The road infrastructure of a country not only serves the basic need for safe transport of people and goods but is also considered vital for its growth and development. Decisions for public and private investments, related to these infrastructures must take into consideration the overall level of their safety capacity in a measurable way.

Road traffic injuries are a global, man-made and preventable epidemic with a health burden on the scale of HIV/AIDS and Malaria. According to the World Health Organization, about 1.24 million people die every year as a result of road traffic crashes, while the annual number of road deaths worldwide is projected to increase to about 2.4 million by 2030. Specifically in the European Union, more than 30.000 persons were killed and about 1,5 million persons were injured in more than 1,1 million car accidents.

On this basis, the United Nations announced in 2010 the Global Plan for the Decade of Action for Road Safety 2011-2020. The Plan encourages countries and stakeholders to implement actions that contribute to the reduction of the forecasted road fatalities rate. The categories of activities (pillars) that the Plan proposes as focusing areas are: building road safety management capacity; improving the safety of road infrastructure and broader transport networks; further developing the safety of vehicles; enhancing the behaviour of road users; and improving post-crash care. Focusing on the Infrastructure pillar, the countries should be able to assess the safety capacity of the road network for all road users and further implement infrastructure improvements through targeted investment programs. Moreover, the European Directive 2008/96/EC on Road Safety Infrastructure Management provided the requirements for safety management of the Trans-European Road Network that include Road Safety Inspection, Safety Ranking and Audits, suggesting investments on road sections with the highest number of collisions and/or the highest collision reduction potential.

Within this framework the South East Neighbourhood Safe Routes (SENSoR) project has taken safety rating to the next level – moving from measurement to action by assessing the risks that road users face from infrastructure and by identifying the potential improvements that can save the most lives for the money available. To do so, the Project Partners applied the latest tools of the International Road Assessment Programme (iRAP), a charity supporting countries and financial institutions worldwide during the UN Decade. The results give GPS-mapped sites where improvements, often as simple as barriers, school crossings or roadside hazard clearance, can make the difference.

SENSoR builds on outstanding cooperation between automobile clubs, universities and road authorities. Having been co-financed by the South East Europe (SEE) Transnational Cooperation Programme and the European Union, the 2-year project brought together 14 countries – Greece, Slovakia, Hungary, Slovenia, Republic of Moldova, Serbia, Former Yugoslav Republic of Macedonia, Bosnia and Herzegovina, Croatia, Albania, Montenegro, Bulgaria, Romania and Ukraine.

The project was launched in September 2012 and finished in September 2014. It included the road inspection, coding, analyses and reporting of RAP road safety assessments of almost 16.000 km in the above mentioned countries. The current report presents the Star Rating results for a 2,488 km part of the major road network in Slovakia. The assessment was performed by MAXNETWORK Ltd. and expert company AF-CITYPLAN who is an accredited RAP supplier.

For more information, contact the Slovak SENSOR project partner: SAMŠ (Slovak Association of Motorsport), contact person: Martin Juck, phone: +421 904 992 913, email: juck.martin@gmail.com

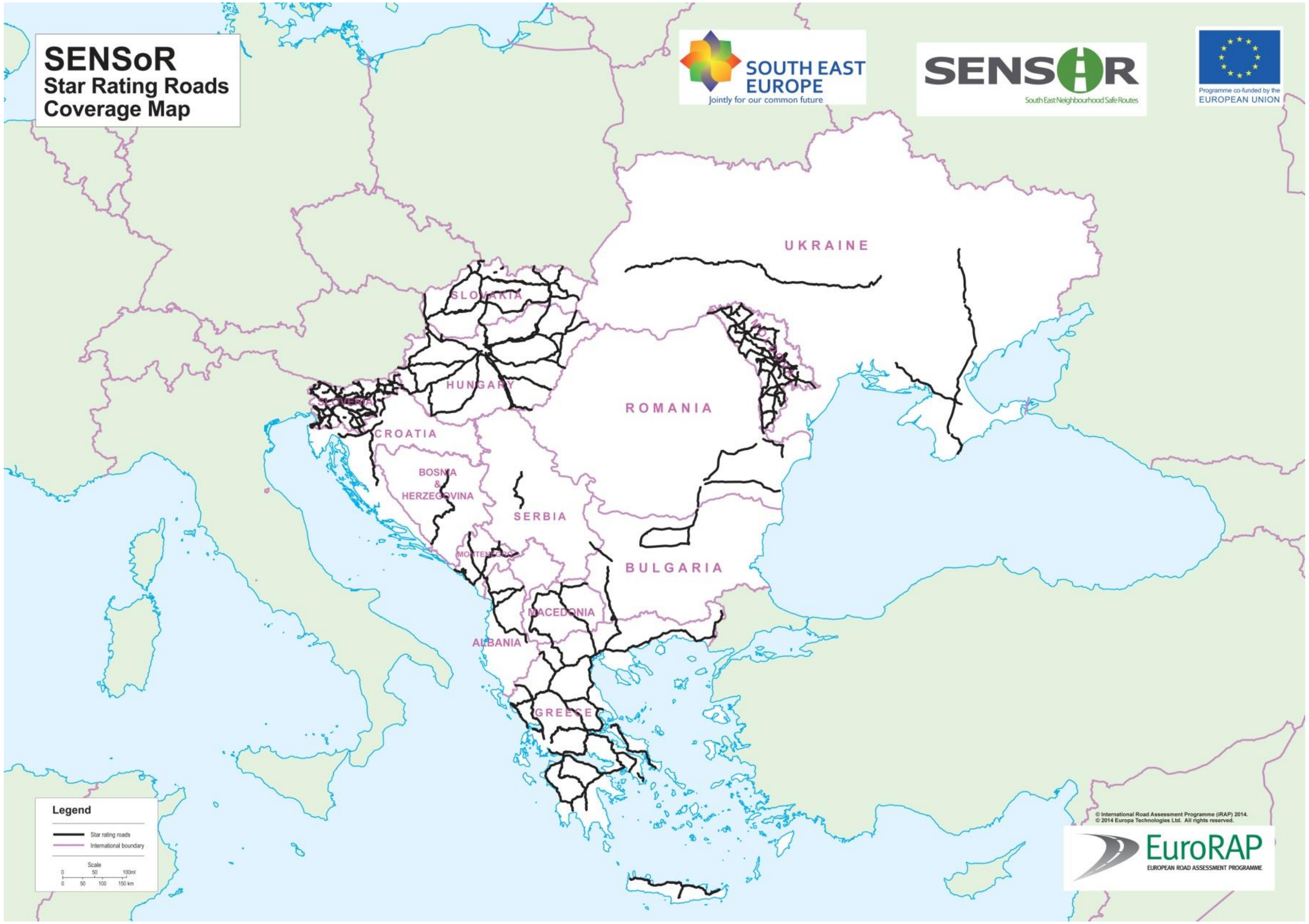

Figure 1: SENSoR Star Rating Coverage Map

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1 Introduction

1.1 Road Assessment in Slovakia

The current report presents the Star Rating results for a 2,488 km part of the major road network in Slovakia, whereby divided roads (dual carriageways) were inspected in both directions.. These results are only a part of the analysis of almost 16.000 km of the TEN-T road network in 14 countries in South East Europe, which was performed within the framework of the SENSoR Project.

In Slovakia, according to the Traffic Police Department of Slovak republic, the number of road fatalities in 2013 was 223, the number of serious injuries was 1086 and the estimated Gross Domestic Product loss due to road traffic crashes reaches the 1,4%[1]. The Road Fatalities Rate in Slovakia in 2013 was 4.12 per 100.000 people[2]. Slovakia is the 2014 ETSC PIN[3] award winner. It has made the most progress in saving lives since the EU target to halve road deaths by 2020 was set four years ago, according to analysis by the European Transport Safety Council (ETSC). Data for the period 2010-2013 reveal that Slovakia made a dramatic 37% reduction in total deaths of road users.

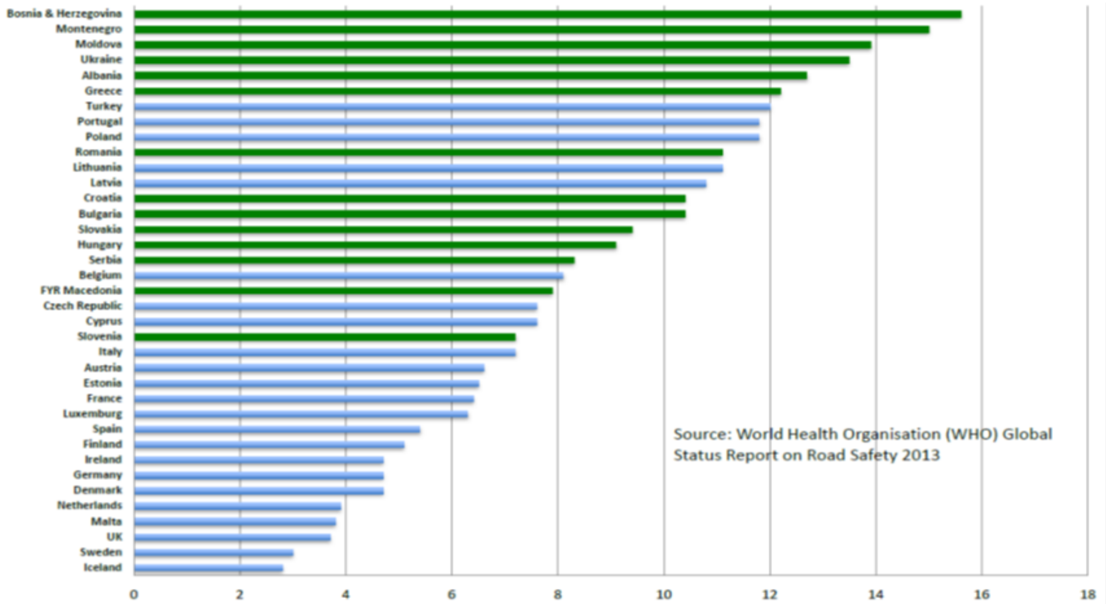

Figure 2: Road Fatalities per 100.000 people

[1] Global status on road safety, WHO 2013

[2] Statistical Office of the Slovak Republic, 09/2013

[3] ETSC Road Safety Performance Index (PIN) report is based on analysis of official data overseen by a panel of 32 road safety experts from the EU28, Norway, Switzerland, Serbia and Israel.

1.2 Results for consultation with stakeholders

This report is presented as “results for consultation with stakeholders” because the SENSoR Project Partners wish to discuss with those who influence the safety of roads and road infrastructure the detail of these surveys and the priorities and possibilities for investing to save lives and serious injuries.

The results are based upon surveys carried out between October – December 2013 and upon data collected at other times and with the support of Project Partners, government and police agencies. The SENSoR project is grateful for this support.

An outcome of the SENSoR project is that the individual participating countries now have a “Safer Roads Investment Plan” which may be used to prioritise spending on crash countermeasures. This Plan is not a “bill of works” and it and the assumptions used in the model must be carefully assessed by local engineers and others who have contributed to the work or who have a legitimate interest in the roads. In particular, they must assess such features as the value of life and injury used in the work, the data used in estimating injury savings, traffic volumes, countermeasure costs and operating speed on the network.

The data for the SENSoR surveys are held in iRAP’s ViDA software. In circumstances where the printed output differs from that held in ViDA, the material held within the software takes precedence. The printed report provides the results of the survey and also gives an entry-level guide to the software and the analysis possibilities that are available within it. Any changes in the modelling assumptions, coding corrections, minor model changes or differences in the presentation of results (such as rounding) will always be reflected in results held in the ViDA software.

1.3 The RAP Method

The protocols used here were developed by the International Road Assessment Programme (iRAP). iRAP is a registered charity dedicated to saving lives through safer roads.

iRAP provides tools and training to help countries make roads safe. Its activities include:

- inspecting high-risk roads and developing Star Ratings, Safer Roads Investment Plans and Risk Maps
- providing training, technology and support that will build and sustain national, regional and local capability
- tracking road safety performance so that funding agencies can assess the benefits of their investments.

The programme is the umbrella organisation for EuroRAP, AusRAP, usRAP, KiwiRAP and ChinaRAP. Road Assessment Programmes (RAP) are now active in more than 70 countries throughout Europe, Asia Pacific, North, Central and South America and Africa.

iRAP is financially supported by the FIA Foundation for the Automobile and Society and the Road Safety Fund. Projects receive support from the Global Road Safety Facility, automobile associations, regional development banks and donors.

National governments, automobile clubs and associations, charities, the motor industry and institutions such as the European Commission also support RAPs in the developed world and encourage the transfer of research and technology to iRAP. In addition, many individuals donate their time and expertise to support iRAP. iRAP is a member of the United Nations Road Safety Collaboration.

The main objective of the RAP method is the improvement of the road users' safety by proposing cost-effective investment plans. The most crucial point in the RAP is that engineers and planners in developed countries have for over twenty years adopted an underlying philosophy of designing a forgiving road system to minimize the chances of injuries when road users make mistakes that result in crashes. The method indicates that the severity of a road accident can be reduced through the intervention at the sequence of events happening during this 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.

The initial step for the implementation of the RAP method is the inspection and record of the infrastructure elements of a road network, which relate to the road safety. The record leads to the quantification of the safety that a road section provides to its users by awarding safety scores (Star Rating Scores). The Star Rating Scores express the safety capacity of a road section in a 5-Stars scale. This quantification aims to identifying the most appropriate countermeasures, which will increase the infrastructure's road safety score. The Safer Roads Investment Plan (SRIP) includes all the countermeasures proved able to provide the greater safety capacity and maximize the benefit over spent cost of the planned investments. Thus, the SRIPs are considered as a valuable tool for the authorities, stakeholders and investors in order to decide for the most cost-effective and efficient road infrastructure investments.

1.3.1 Measuring the road infrastructure safety

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 the 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 RSI, the Road Protection Score (RPS) is calculated. The RPS 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. For each road user type and for 100m road segmentation the respective RPS is calculated as follows:

$$RPS_{n,u}=\sum_{c} RPS_{n,u,c}=\sum_{c} L_{n,u,c} * S_{n,u,c} * OS_{n,u,c} * EFI_{n,u,c} * MT_{n,u,c}$$

where "n" is the number of 100m road segment, "u" the type of road user and "c" the crash type that the road user type "u" may be involved in. The following variables are taken into consideration: L: the Likelihood that the "i" crash may be initiated, S: the Severity of the "i" crash, OS: the degree to which risk changes with the Operating Speed for the specific "i" crash type, EFL: the degree to which a person's risk of being involved in the "i" type of crash is a function of another person's use of the road (External Flow Influence), MT: the potential that an errant vehicle will cross a median (Median Traversability).

1.3.2 The Star Rating process

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 RPS 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 RPS 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 RPS 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).

1.3.3 Developing the Safer Road Investment Plans (SRIPs)

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 F the number of fatalities that can be prevented on a time period of 20 years, given that a specific set of countermeasures is applied.

The number is related to four main factors: (1) the safety score of the specific road segment, (2) the “u” road users flow, (3) the fatality growth, which indicates the underlying trend in road fatalities and (4) 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 Fn,u,c value and the ratio of the actual number of serious injuries to the actual number of fatalities to the relevant 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 [19].

The next step in establishing the SRIPs is the identification of the most appropriate countermeasures. Countermeasures are the engineering improvements that the road authorities should take so as to reduce the fatalities and serious injuries 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 RPS 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.

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 the cost of a human life is 70 times the GDP per capita, the cost of a serious injury is the 25% of the cost 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, taking into account 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.

The SRIP is conducted for a period of 20 years and shows the list of the most cost effective improvements that are able to 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‘s maintenance and/or rehabilitation plans.

2 The inspected road network

2.1.1 Coverage and basic characteristics

The inspected network consists of 419 km of motorways + 245 km of expressways (where divided, inspected in both directions) and 1219 km of first class roads. All roads included in Slovak TEN-T were surveyed, including all motorways and expressways and selected busy and high-risk first class roads (some of them also part of the Slovak TEN-T corridors: first class roads No. 11, 18, 50, 65, 66, 68 and 73). The surveyed roads are described in the following table, and Figure 3 depicts the surveyed network graphically.

Road No.	Road Description	Length (km)	Cway type
D1	Bratislava/Petržalka - Senec	28	Dual
D1	Senec - Trnava	23	Dual
D1	Trnava - Piešťany	34	Dual
D1	Piešťany - Nové Mesto nad Váhom	22	Dual
D1	Nové Mesto nad Váhom - Nemšová	32	Dual
D1	Nemšová - Sverepec	27	Dual
D1	Ivachnová - Liptovský Peter	27	Dual
D1	Liptovský Peter - Važec	18	Dual
D1	Važec - Lučivná	12	Dual
D1	Prešov - Košice	21	Dual
D1	Považská Bystrica - Dolný Hričov	12	Dual
D1	Sverepec - Považská Bystrica	10	Dual
D1	Lučivná - Spišský Štvrtok	27	Dual
D1	Svinia - Prešov	8	Mixed
D1	Spišské Podhradie- Beharovce	8	Mixed
D1	Beharovce - Hendrichovce	14	Mixed
D2	Bratislava/Lamač - Bratislava/Čuňovo	26	Dual
D2	Záhorie (vojenský obvod) - Bratislava/Lamač	26	Dual
D2	Brodské - Záhorie (vojenský obvod)	29	Dual
D3	Dolný Hričov - Žilina	9	Dual
D4	Bratislava/Jarovce – junction D2xD4	2	Dual
D4	Záhorská Bystrica - Stupava	5	Single
R1	Nitra - Čaradice	41	Dual
R1	Čaradice - Bzenica	30	Dual
R1	Budča - Banská Bystrica	15	Dual
R1	Trnava - Nitra	39	Dual
R1	Bzenica - Lehôtka pod Brehmi	9	Dual
R1	Lehôtka pod Brehmi - Žiar nad Hronom	8	Dual
R1	Žiar nad Hronom - Budča	14	Dual
R1A	junction R1xR1A - Nitra	7	Dual
R2	Figa - Tornaľa	13	Single
R2A	Košice – Šaca	11	Dual
R3	Oravský Podzámok - Horná Lehota	5	Single
R3	Trstená - Tvrdošín	8	Single
R4	Svidník	5	Single
PR3	Vajkovce - Košice	14	Dual
I/11	Krásno nad Kysucou - Žilina	23	Single
I/11	Svrčinovec - Krásno nad Kysucou	15	Single
I/12	Svrčinovec - Skalité	15	Single
I/18	Makov - Bytča	30	Single
I/18	Bytča - Žilina	16	Single

I/18	Žilina - Martin	26	Single
I/18	Martin - Kraľovany	19	Single
I/18	Kraľovany - Ivachnová	26	Single
I/18	Ivachnová - Liptovský Mikuláš	21	Single
I/18	Liptovský Mikuláš - Važec	33	Single
I/18	Važec - Poprad	24	Single
I/18	Poprad - Levoča	22	Single
I/18	Levoča - Spišské Podhradie	19	Single
I/18	Spišské Podhradie - Chminianska Nová Ves	29	Single
I/18	Chminianska Nová Ves - Kapušany	21	Single
I/18	Kapušany - Soľ	29	Single
I/18	Soľ - Strážske	24	Single
I/18	Strážske - Michalovce	16	Single
I/50	Drietoma - Svinná	31	Single
I/50	Svinná - Nováky	37	Single
I/50	Nováky - Handlová	25	Single
I/50	Handlová - Žiar nad Hronom	24	Single
I/50	Podkriváň - Lučenec	27	Single
I/50	Lučenec - Rimavská Sobota	25	Single
I/50	Rimavská Sobota - Tornaľa	29	Single
I/50	Tornaľa - Brzotín	31	Single
I/50	Brzotín - Turňa nad Bodvou	32	Single
I/50	Turňa nad Bodvou - Košice/Juh	35	Single
I/50	Košice/Juh - Dargov	31	Single
I/50	Dargov - Michalovce	30	Single
I/50	Michalovce - Vyšné Nemecké	35	Single
I/50	Budča - Podkriváň	33	Single
I/65	Žiar nad Hronom - Kremnica	14	Single
I/65	Kremnica - Turčianske Teplice	18	Single
I/65	Turčianske Teplice - Martin	31	Single
I/65	Nitra - Čaradice	35	Single
I/65	Bzenica - Ladomerská Vieska	14	Single
I/66	Šahy - Hontianske Nemce	33	Single
I/66	Hontianske Nemce - Zvolen	37	Single
I/66	Podbrezová - Polomka	26	Single
I/66	Polomka - Šumiac	24	Single
I/66	Šumiac - Vernár	12	Single
I/66	Zvolen - Podbrezová	44	Single
I/67	Vernár - Poprad	25	Single
I/68	Košice/Juh - Milhosť	18	Single
I/68	Mníšek nad Popradom - Ľubotín	34	Single
I/68	Ľubotín - Sabinov	24	Single
I/68	Sabinov - Prešov	20	Single
I/68	Prešov - Košice/Staré Mesto	35	Single
I/73	Stročín - Vyšný Komárnik	26	Single
I/73	Lipníky - Stročín	34	Single

Table 1: The inspected road network in Slovakia

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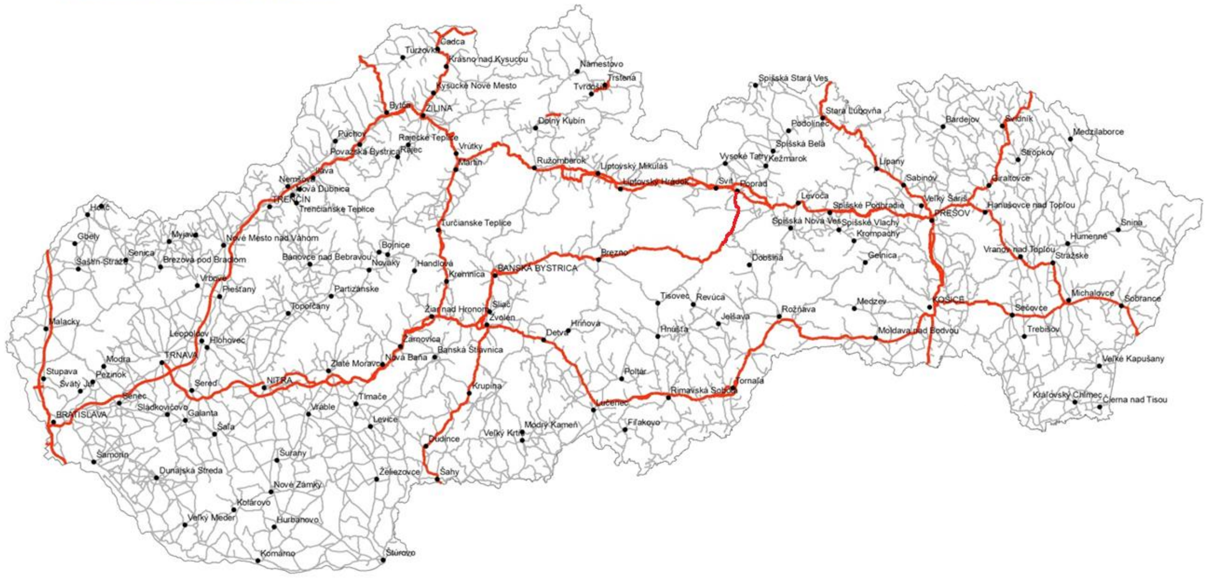

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data source: Slovak Road Administration, Road network length in the Slovak Republic as at 1.1.2013, http://www.cdb.sk/
cartographic base: © GEOMATIKA Ltd., Tekovská 9, 82109 Bratislava

Figure 3 – SENSoR surveyed network in Slovakia

2.1.2 Details of the recorded road attributes

On the basis of the analysis of the inspection's data the following Table presents details of the inspected network.

Vehicle flow (AADT)	Km	%
1000 - 5000	247.7	10.0
5000 - 10000	962.1	39.0
10000 - 15000	514.3	21.0
15000 - 20000	496.7	20.0
20000 - 40000	264.8	11.0
40000 - 60000	2.0	0.0
Area type	Km	%
Rural / open area	2,024.5	81.0
Urban / rural town or village	463.1	19.0
Bicycle observed flow	Km	%
None	2,436.2	98.0
1 bicycle observed	48.4	2.0

2 to 3 bicycles observed	2.7	0.0
4 to 5 bicycles observed	0.3	0.0
Bicycle peak hour flow	Km	%
None	1,227.7	49.0
1 to 5	1,259.9	51.0
Bicycle star rating policy target	Km	%
Not applicable	2,487.6	100.0
Vehicle occupant star rating policy target	Km	%
Not applicable	2,487.6	100.0
Carriageway label	Km	%
Carriageway A of a divided carriageway road	636.4	26.0
Carriageway B of a divided carriageway road	625.6	25.0
Undivided road	1,225.6	49.0
Centreline rumble strips	Km	%
Not present	2,428.2	98.0
Present	59.4	2.0
Curvature	Km	%
Straight or gently curving	2,300.8	92.0
Moderate	133.0	5.0
Sharp	44.1	2.0
Very sharp	9.7	0.0
Delineation	Km	%
Adequate	2,130.5	86.0
Poor	357.1	14.0
Quality of curve	Km	%
Adequate	114.9	5.0
Poor	74.1	3.0
Not applicable	2,298.6	92.0
Facilities for bicycles	Km	%
Off-road path with barrier	0.1	0.0
Off-road path	0.1	0.0
On-road lane	1.9	0.0
None	2,485.2	100.0
Shared use path	0.3	0.0
Facilities for motorised two wheelers	Km	%
None	2,487.6	100.0
Grade	Km	%

>= 0% to <7.5%	2,459.7	99.0
>= 7.5% to <10%	10.1	0.0
>= 10%	17.8	1.0
Intersection type	Points	%
Merge lane	839	3.0
Roundabout	91	0.0
3-leg (unsignalised) with protected turn lane	235	1.0
3-leg (unsignalised) with no protected turn lane	1433	6.0
3-leg (signalised) with protected turn lane	23	0.0
3-leg (signalised) with no protected turn lane	11	0.0
4-leg (unsignalised) with protected turn lane	60	0.0
4-leg (unsignalised) with no protected turn lane	296	1.0
4-leg (signalised) with protected turn lane	47	0.0
4-leg (signalised) with no protected turn lane	1	0.0
None	21816	88.0
Railway Crossing - passive (signs only)	0.3	0.0
Railway Crossing - active (flashing lights / boom gates)	0.7	0.0
Median crossing point - formal	1.4	0.0
Intersecting road volume	Points	%
>=15,000 vehicles	7	0.0
10,000 to 15,000 vehicles	33	0.0
5,000 to 10,000 vehicles	198	1.0
1,000 to 5,000 vehicles	651	3.0
100 to 1,000 vehicles	1358	5.0
1 to 100 vehicles	813	3.0
None	21816	88.0
Intersection channelisation	Points	%
Not present	24187	97.0
Present	689	3.0
Intersection quality	Points	%
Adequate	1450	6.0
Poor	1610	6.0
Not applicable	21816	88.0
Land use - driver-side	Km	%
Undeveloped areas	785.3	32.0
Farming and agricultural	1,102.9	44.0

Residential	430.0	17.0
Commercial	102.6	4.0
Educational	2.2	0.0
Industrial and manufacturing	64.6	3.0
Land use - passenger-side	Km	%
Undeveloped areas	624.1	25.0
Farming and agricultural	1,274.2	51.0
Residential	419.4	17.0
Commercial	97.9	4.0
Educational	2.5	0.0
Industrial and manufacturing	69.5	3.0
Lane width	Km	%
Wide (>= 3.25m)	2,272.0	91.0
Medium (>= 2.75m to < 3.25m)	194.6	8.0
Narrow (>= 0m to < 2.75m)	21.0	1.0
Median type	Km	%
Safety barrier - metal	838.9	34.0
Safety barrier - concrete	361.2	15.0
Physical median width >= 20.0m	0.9	0.0
Physical median width >= 10.0m to < 20.0m	1.8	0.0
Physical median width >= 5.0m to < 10.0m	5.3	0.0
Physical median width >= 1.0m to < 5.0m	13.6	1.0
Physical median width >= 0m to < 1.0m	10.7	0.0
Continuous central turning lane	3.0	0.0
Flexipost	9.8	0.0
Central hatching (>1m)	70.0	3.0
Centre line	1,152.5	46.0
Safety barrier - motorcycle friendly	0.1	0.0
One way	14.2	1.0
Wide centre line (0.3m to 1m)	5.6	0.0
Motorcycle %	Km	%
1% - 5%	2,487.6	100.0
Motorcycle observed flow	Km	%
None	2,467.0	99.0
1 motorcycle observed	19.9	1.0
2 to 3 motorcycles observed	0.7	0.0

Motorcycle star rating policy target	Km	%
1% - 5%	2,487.6	100.0
Number of lanes	**Km**	**%**
One	1,168.8	47.0
Two	1,180.7	47.0
Three	94.3	4.0
Four or more	2.0	0.0
Two and one	38.3	2.0
Three and two	3.5	0.0
Operating speed (85th percentile)	**Km**	**%**
40km/h	3.8	0.0
50km/h	16.5	1.0
55km/h	284.7	11.0
65km/h	27.8	1.0
75km/h	122.2	5.0
85km/h	43.0	2.0
95km/h	870.7	35.0
110km/h	55.2	2.0
120km/h	5.5	0.0
130km/h	1,058.2	43.0
Operating speed (mean)	**Km**	**%**
35km/h	3.8	0.0
40km/h	16.5	1.0
50km/h	284.7	11.0
60km/h	27.8	1.0
70km/h	122.2	5.0
80km/h	43.0	2.0
90km/h	870.7	35.0
100km/h	55.2	2.0
110km/h	5.5	0.0
130km/h	1,058.2	43.0
Paved shoulder - driver-side	**Km**	**%**
Wide (>= 2.4m)	21.4	1.0
Medium (>= 1.0m to < 2.4m)	148.3	6.0
Narrow (>= 0m to < 1.0m)	2,156.3	87.0
None	161.6	6.0

Paved shoulder - passenger-side	Km	%
Wide (>= 2.4m)	241.8	10.0
Medium (>= 1.0m to < 2.4m)	904.0	36.0
Narrow (>= 0m to < 1.0m)	1,180.4	47.0
None	161.4	6.0
Shoulder rumble strips	Km	%
Not present	1,835.5	74.0
Present	652.1	26.0
Pedestrian crossing facilities - inspected road	Points	%
Grade separated facility	205	1.0
Signalised with refuge	31	0.0
Signalised without refuge	51	0.0
Unsignalised marked crossing with refuge	69	0.0
Unsignalised marked crossing without a refuge	904	4.0
No facility	23616	95.0
Pedestrian crossing facilities - intersecting road	Points	%
Grade separated facility	2	0.0
Signalised with refuge	16	0.0
Signalised without refuge	19	0.0
Unsignalised marked crossing with refuge	9	0.0
Unsignalised marked crossing without a refuge	484	2.0
Refuge only	1	0.0
No facility	24345	98.0
Pedestrian crossing quality	Points	%
Adequate	738	3.0
Poor	522	2.0
Not applicable	23616	95.0
Pedestrian fencing	Km	%
Not present	2,466.1	99.0
Present	21.5	1.0
Pedestrian observed flow across the road	Km	%
None	2,441.2	98.0
1 pedestrian crossing observed	14.9	1.0
2 to 3 pedestrians crossing observed	2.9	0.0
4 to 5 pedestrians crossing observed	27.8	1.0
6 to 7 pedestrians crossing observed	0.5	0.0

8+ pedestrians crossing observed	0.3	0.0
Pedestrian observed flow along the road driver-side	Km	%
None	2,417.2	97.0
1 pedestrian along driver-side observed	33.3	1.0
2 to 3 pedestrians along driver-side observed	29.9	1.0
4 to 5 pedestrians along driver-side observed	4.2	0.0
6 to 7 pedestrians along driver-side observed	1.3	0.0
8+ pedestrians along driver-side observed	1.7	0.0
Pedestrian observed flow along the road passenger-side	Km	%
None	2,402.9	97.0
1 pedestrian along passenger-side observed	32.3	1.0
2 to 3 pedestrians along passenger-side observed	39.6	2.0
4 to 5 pedestrians along passenger-side observed	9.3	0.0
6 to 7 pedestrians along passenger-side observed	1.2	0.0
8+ pedestrians along passenger-side observed	2.3	0.0
Pedestrian peak hour flow across the road	Km	%
0	1,361.7	55.0
1 to 5	535.0	22.0
6 to 25	577.9	23.0
26 to 50	13.0	1.0
Pedestrian peak hour flow along the road driver-side	Km	%
0	1,314.5	53.0
1 to 5	297.2	12.0
6 to 25	875.9	35.0
Pedestrian peak hour flow along the road passenger-side	Km	%
0	1,241.9	50.0
1 to 5	304.5	12.0
6 to 25	941.2	38.0
Pedestrian star rating policy target	Km	%
Not applicable	2,487.6	100.0
Property access points	Km	%
Commercial Access 1+	230.3	9.0
Residential Access 3+	90.4	4.0
Residential Access 1 or 2	60.5	2.0
None	2,106.4	85.0

Road condition	Km	%
Good	1,641.1	66.0
Medium	791.1	32.0
Poor	55.4	2.0
Roads that cars can read	Km	%
Does not meet specification	2,487.6	100.0
Roadside severity - driver-side distance	Km	%
0 to <1m	1,441.3	58.0
1 to <5m	805.0	32.0
5 to <10m	64.9	3.0
>= 10m	176.4	7.0
Roadside severity - driver-side object	Km	%
Safety barrier - metal	987.2	40.0
Safety barrier - concrete	373.4	15.0
Aggressive vertical face	5.6	0.0
Upwards slope - rollover gradient	19.6	1.0
Deep drainage ditch	0.5	0.0
Downwards slope	5.4	0.0
Cliff	20.5	1.0
Tree >=10cm dia.	482.1	19.0
Sign, post or pole >= 10cm dia.	211.0	8.0
Non-frangible structure/bridge or building	69.4	3.0
Frangible structure or building	34.7	1.0
Unprotected safety barrier end	125.2	5.0
Large boulders >=20cm high	0.2	0.0
None	152.8	6.0
Roadside severity - passenger-side distance	Km	%
0 to <1m	313.5	13.0
1 to <5m	1,741.5	70.0
5 to <10m	192.7	8.0
>=10m	239.9	10.0
Roadside severity - passenger-side object	Km	%
Safety barrier - metal	704.5	28.0
Safety barrier - concrete	51.7	2.0
Safety barrier - motorcycle friendly	1.3	0.0
Aggressive vertical face	7.0	0.0

Upwards slope - rollover gradient	80.0	3.0
Deep drainage ditch	11.9	0.0
Downwards slope	14.6	1.0
Cliff	23.2	1.0
Tree >= 10cm dia.	627.7	25.0
Sign, post or pole >=10cm dia.	269.3	11.0
Non-frangible structure/bridge or building	106.4	4.0
Frangible structure or building	108.1	4.0
Unprotected safety barrier end	301.4	12.0
Large boulders >= 20cm high	1.9	0.0
None	178.6	7.0
Roadworks	Km	%
No road works	2,443.5	98.0
Minor road works in progress	32.4	1.0
Major road works in progress	11.7	0.0
School zone crossing supervisor	Points	%
School zone crossing supervisor not present	25	0.0
Not applicable (no school at the location)	24851	100.0
School zone warning	Points	%
School zone static signs or road markings	22	0.0
No school zone warning	3	0.0
Not applicable (no school at the location)	24851	100.0
Service road	Km	%
Not present	2,243.4	90.0
Present	244.2	10.0
Sidewalk - driver-side	Km	%
Physical barrier	5.0	0.0
Non-physical separation >= 3.0m	3.3	0.0
Non-physical separation 1.0m to <3.0m	26.2	1.0
Non-physical separation 0m to <1.0m	95.1	4.0
None	2,356.4	95.0
Informal path >= 1.0m	0.6	0.0
Informal path 0m to <1.0m	1.0	0.0
Sidewalk - passenger-side	Km	%
Physical barrier	6.8	0.0
Non-physical separation >= 3.0m	20.8	1.0

Non-physical separation 1.0m to <3.0m	40.8	2.0
Non-physical separation 0m to <1.0m	101.4	4.0
None	2,315.4	93.0
Informal path >= 1.0m	1.0	0.0
Informal path 0m to <1.0m	1.4	0.0
Sight distance	Km	%
Adequate	2,227.4	90.0
Poor	260.2	10.0
Skid resistance / grip	Km	%
Sealed - adequate	1,188.8	48.0
Sealed - medium	1,283.1	52.0
Sealed - poor	15.7	1.0
Speed limit	Km	%
<30km/h	3.8	0.0
40km/h	16.5	1.0
50km/h	284.7	11.0
60km/h	27.8	1.0
70km/h	122.2	5.0
80km/h	43.0	2.0
90km/h	870.7	35.0
100km/h	55.2	2.0
110km/h	5.5	0.0
130km/h	1,058.2	43.0
Motorcycle speed limit	Km	%
<30km/h	3.8	0.0
40km/h	16.5	1.0
50km/h	284.7	11.0
60km/h	27.8	1.0
70km/h	122.2	5.0
80km/h	43.0	2.0
90km/h	868.9	35.0
100km/h	55.2	2.0
110km/h	5.5	0.0
130km/h	1,060.0	43.0
Truck speed limit	Km	%
<30km/h	3.8	0.0

40km/h	18.2	1.0
50km/h	284.7	11.0
60km/h	26.2	1.0
70km/h	125.5	5.0
80km/h	68.3	3.0
90km/h	1,950.1	78.0
100km/h	8.8	0.0
130km/h	2.0	0.0
Differential speed limits	Km	%
Not present	1,397.8	56.0
Present	1,089.8	44.0
Speed management / traffic calming	Km	%
Not present	2,469.7	99.0
Present	17.9	1.0
Street lighting	Km	%
Not present	2,017.1	81.0
Present	470.5	19.0
Upgrade cost	Km	%
Low	1,090.5	44.0
Medium	274.1	11.0
High	1,123.0	45.0
Vehicle parking	Km	%
Low	2,322.7	93.0
Medium	109.8	4.0
High	55.1	2.0

Table 2: Details of the inspected road network in Slovakia

About half of the inspected carriageway length is undivided, whereas the other half belongs to dual-carriageway roads. Roughly 80% of the inspected roads are in rural areas, and only 5-7% of all roads are equipped with sidewalks for pedestrians. Total of 14% roads were recorded with poor delineation. 66% of roads ware considered as having good surface, 32% have medium surface condition, and 2% of roads were recorded as having poor road surface. Total 3060 intersections were recorded more than half of which were rated as “poor quality”. Total 1260 pedestrian crossings were identified, 522 of them were considered as poor. Metal or concrete barriers were recorded on 8% of the network on driver side, and on 11% on passenger side. Trees with a diameter of more than 10cm were recorded on almost one quarter of the network length on both sides. Very common dangerous roadside objects are also poles and posts, unprotected safety barrier ends, aggressive vertical faces and cliffs.

3 Data collection and coding

3.1 Road Survey

The road survey was carried out in two phases: 25^{th} October – 29^{th} October 2013 and 25^{th} November - 3^{rd} December 2013 on the previously defined network. The process was carried out in accordance with the iRAP standards. Weather conditions were satisfying for the survey, and no major technical difficulties were experienced. The first phase of the survey was carried out with a single camera, for the second phase another camera was added to the system. The survey team consisted of Ing. Imrich Tóth and Ing. Štefan Pusztai from MAXNETWORK Ltd. and Ing. Lubomír Tříska and Ing. Jiří Landa from the expert company AF-CITYPLAN. All team members were on the board for the entire time of the survey. The survey was completed in a smooth and timely fashion without facing any major issues.

3.1.1 Road Survey Equipment

The inspection system, developed by the expert company AF-CITYPLAN consists of one or two GoPro cameras attached to the roof of the inspection vehicle in special waterproof cases, and connected to a PC built in the trunk of the car. The cameras are controlled by a tablet in the hands of the vehicle passenger using a remote desktop system. For geo-referencing purposes a GPS probe was used connected also to the built-in PC. The SABS software, also developed by the expert company AF-CITYPLAN was used to combine the video footage with the GPS data at the same time.

The system was mounted into the specifically modified inspection vehicle Škoda Yeti. The vehicle was painted in yellow colour and equipped with prescribed logos for presentation purposes. The vehicle proved to have perfect size and characteristics for such inspection, providing enough space for the inspection team, their luggage and also the inspection system both in operational and non-operational state.

Figure 4: The inspection vehicle

3.1.2 Coding Team

The road coding team for the Slovakian network consisted of fifteen coders working 12 hours per day in two shifts (maximum 6 hours per day for one coder).

Coders working on the Slovakian network:

- Václav Majer
- Kateřina Peštová
- Marta Podnecká
- Jan Zalabák
- Lucia Kukurová
- Kryštof Holeyšovský
- Milan Červeňák
- Soňa Korbelová
- Igor Miltner
- Petr Jezdinský
- Jiří Snížek
- Viliam Liedl
- Michal Kubo
- Matej Kubo
- Imrich Tóth

The coding team was being continuously managed and controlled by experienced and certified engineers to ensure sufficient quality and homogeneity of the coding. The team was led by Ing. Lubomír Tříska. The team of engineers consisted of:

- Ing. Matěj Malý
- Ing. Pavel Suntych
- Ing. Bc. Karel Kocián
- Ing. Jiří Hofman
- Ing. Dagmar Tothová
- Ing. Petr Šatra
- Bc. Tomáš Sysala
- Dr. Zoltán Bojar
- Ing. Marek Roth
- Ing. Martin Juck

All of the above mentioned professionals have vast experience with road safety audits and inspections on various types of roads, and were ready to assist the coders in case of any unclarities during the whole process.

3.2 Data coding

After the completion of the road inspection phase, the process of coding of video material took place. Coding represents the process of determining specific road attributes, for each of the 100 meters interval of the inspected roads, according to the RAP-SR-2.1 Star Rating and Investment Plan – Survey and Coding Specification and the RAP-SR-2.2 Star Rating coding manual.

The quality assurance process was the next important phase of the coding process and assessed whether the road attributes captured in the road inspection had been rated correctly. It was an important validation step prior to calculation of Star Ratings, data interrogation and further consultation with stakeholders.

A requirement of the RAP method, according to the RAP-SR-2-4 – Road Coding Quality Assurance Guide, is the external review of a minimum 10% of the data coded from road inspections. It is recommended that this external review is carried out at three key stages of the process – after completion of 25%, 50% and 100% of the coding. This enables issues to be resolved early thus reducing the amount of recoding required.

The Quality Assurance of the specific dataset was performed by RACC Spain and Road Safety Foundation UK, which are accredited RAP suppliers and were commissioned by the SENSOR project to perform the QA task.

The basic assumptions used regarding the traffic volume, the pedestrian and bicycle volume, the operating speed, the crash data the countermeasure costs and the economic data on which the made during the coding phase are presented in the following paragraphs.

3.2.1 *Traffic Volume*

Traffic volume data is used in the iRAP model as a multiplier to estimate the number of deaths and serious injuries that could be prevented on the roads.

To get the traffic volume distribution of whole network, the official Slovak data were used, provided by the Slovak Road Administration and based on traffic-flow census 2010 (see http://www.ssc.sk/sk/Rozvoj-cestnej-siete/Dopravne-inzinierstvo/Celostatne-scitanie-dopravy-2010.ssc), re-calibrated according to the Methodical Directive 01/2006, issued by Ministry of Transport of Slovak Republic about „Traffic Flow Forecasting on the Slovak road network up to 2040". Data re-calibrated for 2011 were taken into account. Due to limited sensitivity of the ViDA software to slight changes in AADTs, the 2011 values are accurate enough for the purpose of the project. In case of missing data (newly built roads), the Slovak National Motorway Company was contacted to provide actual data, which was answered positively.

The share of motorcycles on the total AADT was constantly set to < 5% for the entire Slovak road network.

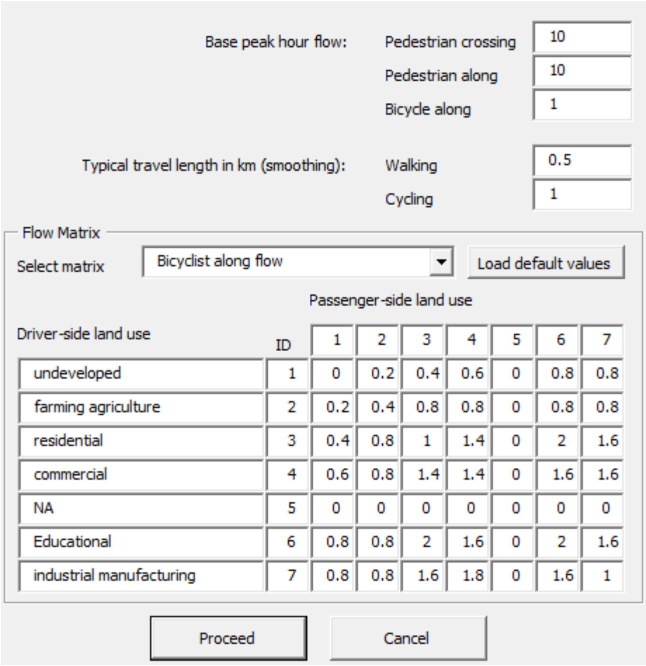
3.2.2 *Pedestrian and Bicycle volume*

The ViDA model requires also inputting four types of flows for each 100m section of the surveyed network:

- Pedestrian peak hour flow across the road
- Pedestrian peak hour flow along the driver-side
- Pedestrian peak hour flow along the passenger-side
- Bicyclist peak hour flow along the road

These types of data are difficult to obtain as there are no relevant measurements. To overcome this issue, appropriate estimations were made using the RAP pre-processor tool. This tool estimates the pedestrians and bicyclists flows based on the coded attributes like Land use, Area type, Pedestrian crossing facilities, Sidewalk provision etc.

The basic flows and the multiplier matrix for various land use along the road are displayed in Figure 5. The matrix is the same for all four types of flows.



Driver-side land use	ID	1	2	3	4	5	6	7
undeveloped	1	0	0.2	0.4	0.6	0	0.8	0.8
farming agriculture	2	0.2	0.4	0.8	0.8	0	0.8	0.8
residential	3	0.4	0.8	1	1.4	0	2	1.6
commercial	4	0.6	0.8	1.4	1.4	0	1.6	1.6
NA	5	0	0	0	0	0	0	0
Educational	6	0.8	0.8	2	1.6	0	2	1.6
industrial manufacturing	7	0.8	0.8	1.6	1.8	0	1.6	1

Figure 5 – Basic pedestrian and bicyclists flows

In addition, number of conditions was applied to better estimate the real pedestrian and bicyclist flows. In particular:

- In sections where pedestrians/bicyclists were observed, the minimum base flow multiplier was set to 1. Where more than 8 pedestrians/bicyclists were observed, the minimum base flow multiplier was set to 1,5.
- On dual carriageway roads with a median barrier (without pedestrian crossing facility) the pedestrian crossing flow was set to 0.
- Where pedestrian crossing facility is present, the minimum base flow was set to 1, and the pedestrian crossing flow is multiplied by 1,5.
- Where an intersection is present, the base pedestrian crossing flow is multiplied by 1,25.
- It is assumed that pedestrians do not walk in medians on dual carriageway roads
- Where a sidewalk facility is present, the minimum pedestrian base flow multiplier along the road is set to 1.
- Where vehicles park either on one or both sides of the road (including bus stops), the minimum pedestrian base flow multiplier is set to 1.
- In all rural areas, the values are multiplied by 0,1 for the passengers along, and bicyclists along flows. The pedestrian crossing flow is multiplied by 0,2.
- On rural dual carriageway roads all flows are set to 0.

3.2.3 Operating Speed

The level of risk of death or serious injury on a road is highly dependent on the speed at which the traffic travels. The RAP method indicates that risk assessments must be performed using the ‘operating speed’ on a road. Operating speed is defined as being the greater of the legislated speed limit or the measured 85th percentile speed.

Only a few speed measurement data on the Slovak motorways and expressways were obtained from the National Motorway Company (NDS). In order to get more familiar with the speed behaviour of local drivers, speed measurement data from AF-CITYPLAN’s previous project was used. In this previous project, couple of measurements along the roads I/66 and II/564 were made for a significant amount of time (3 days to 1 week). Details on the measurements are provided in Annex 2.

Based on these measurements, the experience of the survey team, and also consultation with local engineers, an assumption was made that the speed behaviour of the drivers in Slovakia, the Czech Republic and Hungary is very similar. Another assumption is that the key variable affecting the operating speed is the speed limit. Given these assumptions and the measurements made, Table 3 was created in order to determine the mean and the 85th percentile speeds based on the posted speed.

Speed limit [km/h]	30	40	50	60	70	80	90	100	110	120	130
85th - percentile speed	40	50	55	65	75	85	95	110	120	130	130
Mean speed	35	40	50	60	70	80	90	100	110	120	130

Table 3 – Operating speeds

Due to lack of real speed data on the whole network scale, this table was used for the entire surveyed network and shall be sufficient estimation of the real driving behaviour of the local drivers.

Estimated operating speeds across the surveyed network were measured in a series of counts in the particular project countries, where it was possible to obtain it from road authorities and other stakeholders. Other estimates were provided from the survey vehicle travelling as a “floating vehicle” in the traffic stream (see comments in the “Moving Car Observer” technique (Wardrop and Charlesworth (1954))[4].

3.2.4 Crash Data

The crash number, the death person number and the serious injured person number for all roads are used to support the countermeasure selection and economic analysis.

The Slovak traffic crash data for the years 2010 - 2013 were provided by the Traffic Police Department of Slovak Republic (see http://www.minv.sk/?dopravne_informacie), who is the official supplier of this data in Slovakia. The used data are including following details:

[4] Wardrop J. G. and Charlesworth G. (1954). A method of estimating speed and flow of traffic from a moving vehicle. *Proc. Inst. Civil Eng. part II, 3, 158-171.*

	2010	2011	2012	2013
Total deaths in road traffic Slovakia	345	324	296	223
pedestrians	113	75	66	65
cyclists	21	18	25	16
motorcyclists	26	27	27	19
car occupants	185	204	178	123

Table 4 – Fatalities on Slovakian road network

For the past years, there were 81 fatalities per year recorded on the surveyed network. This means that the model assumes that without action there would be 17,800 fatal and serious injuries over 20 years.

3.2.5 Countermeasures costs

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.

Within SENSoR, these costs were determined using a common approach followed by all project partners. This approach was based on a research implemented by the SENSOR project partner AMZS Slovenia, and are presented in Annex 3. The costs are in EURO. The countermeasure costs data used output should be considered as model patterns; however the ViDA online software allows calibrating the countermeasure costs according to exact data, given by the particular national road authorities. In some cases a low countermeasure cost has been assumed in order to enable the model to consider all suitable candidate sites for that measure.

3.2.6 Economic data

1. **Analysis period**

The number of years over which the economic benefits of the Safer Roads Investment Plan is calculated. The value for this project is set to **20 years**.

2. **Gross Domestic Product**

The key figure for the Safer Road Investment Plan is the GDP per capita in local currency. As the source of this figure the IMF World Economic Outlook Database of October 2013 was used. The GDP per capita in Slovakia for 2014 is **14,041.04 EUR**

3. **Discount rate and minimum attractive rate of return**

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. In SENSoR, a figure of 12% has been used in many countries, whereas in others, after local consultation, 9% and 4% has been used. 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. In Slovakia a discount rate of 12% has been used in this consultation report. The minimum attractive rate of return has been 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.

4. Value of life

This figure reflects the social cost of one fatality on the road. In this project the iRAP recommendation of GDP x 70 was used (see McMahon and Dahdah (2008) http://www.irap.org/en/about-irap-3/research-and-technical-papers?download=45:the-true-cost-of-road-crashes-valuing-life-and-the-cost-of-a-serious-injury-espaol). Thus, the value of life was estimated as **982,872.80 EUR**.

5. Value of serious injury

This figure reflects the social cost of one serious injury on the road. In this project the iRAP recommendation of Value of life x 0.25 (see McMahon and Dahdah) was used. Thus, the value of serious was estimated as **245,718.20 EUR.**

4 Star Rating Results

Based on the coded and supporting data, the ViDA online software produces star rating of the surveyed network. The star rating is based on individual relative risk for four user groups – vehicle occupants, passengers, motorcyclists and bicyclists. Therefore, four different star ratings were produced. The software is also capable of smoothing the data in order to eliminate random star rating differences over short sections of road.

4.1 Overall Star Ratings Results

The Star Ratings results for the entire road network analysed are presented in the next figures for each user group.

	Vehicle Occupant		Motorcycle		Pedestrian		Bicycle	
Star Ratings	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent	Length (kms)	Percent
5 Stars	40.2	2%	4.3	0%	2.7	0%	6.0	0%
4 Stars	188.6	8%	79.8	3%	9.7	0%	25.9	1%
3 Stars	932.9	38%	311.5	13%	49.7	2%	215.3	9%
2 Stars	658.2	26%	468.9	19%	70.3	3%	181.3	7%
1 Star	656.0	26%	1,611.4	65%	1,111.3	45%	824.7	33%
Not applicable	11.7	0%	11.7	0%	1,243.9	50%	1,234.4	50%
Totals	2,487.6	100%	2,487.6	100%	2,487.6	100%	2,487.6	100%

Figure 6 – Star Rating results for the inspected network

As seen from the previous figure, only 2% of the Slovakian surveyed network was awarded 5 stars, and 8% was awarded 4 stars for the vehicle occupants. On the other hand one quarter of the network gained only 1 star. The rating for motorcyclists is worse when 65% of the network length belongs to the one-star high-risk category.

Pedestrians' and bicyclists' results are distorted by the fact that about half of the inspected network was not star rated for pedestrians and bicyclists. This is due to non-existent pedestrian and bicyclist flow on these sections. Most of the time, they are dual-carriageway, rural highways. Nevertheless, it is evident that the rated road sections for the vulnerable road users were awarded poor rating, especially the pedestrians' safety rating turned out to be very low.

The total length adds up to 2488km, due to the fact that dual carriageway roads were surveyed in both directions.

Figure 6 shows the Slovak Star Rating raw data, before smoothing. The next figures (7-11 and 13) show Star Rating maps after smoothing.

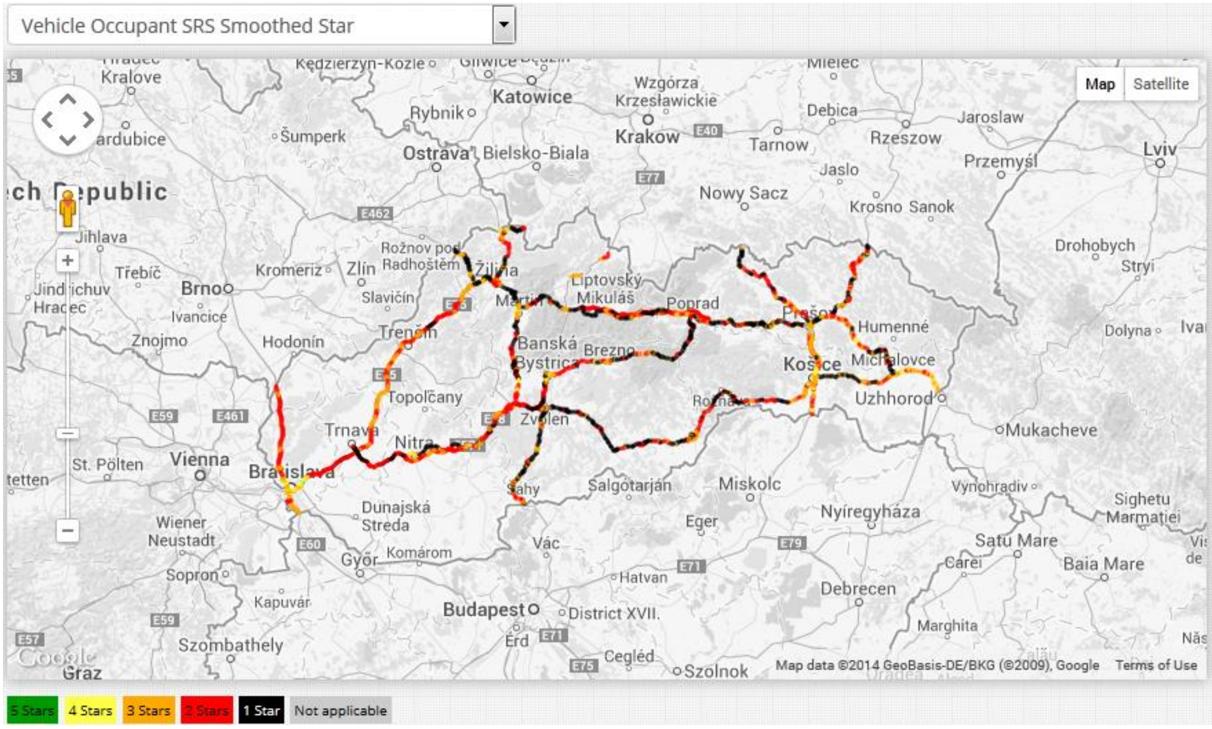


Figure 7 – Star Rating map for vehicle occupants

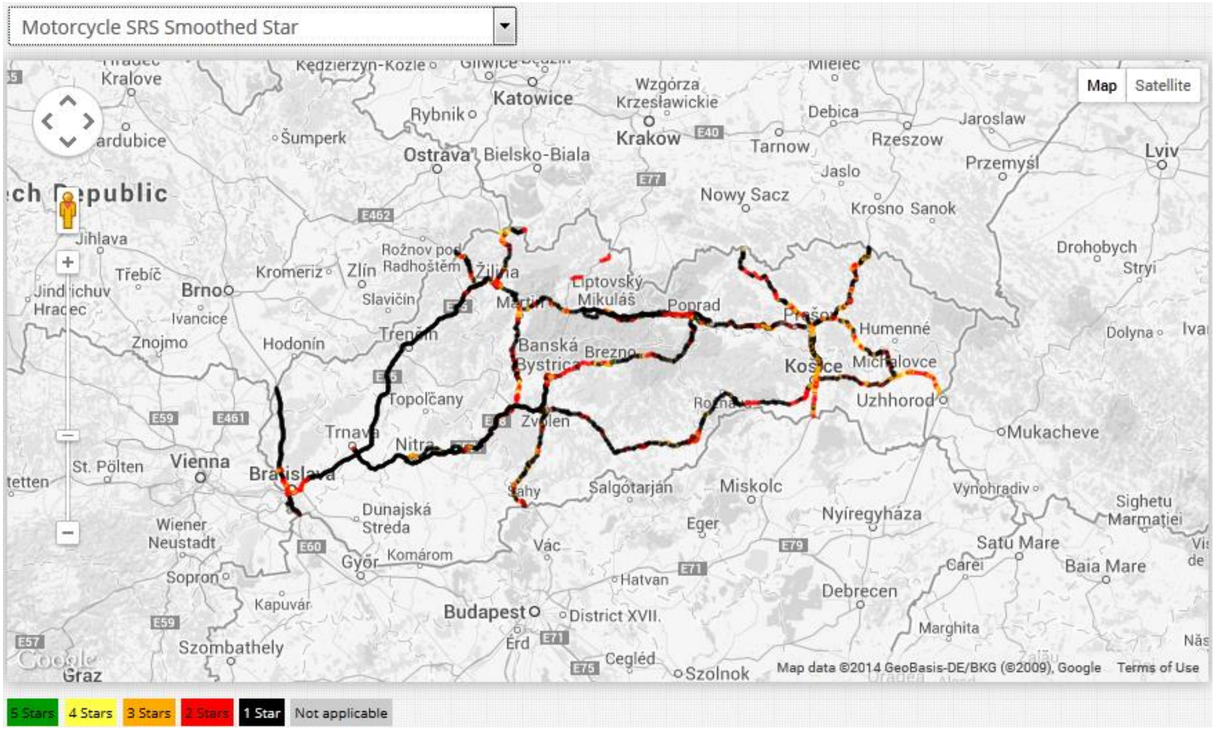


Figure 8 – Star Rating map for motorcyclists

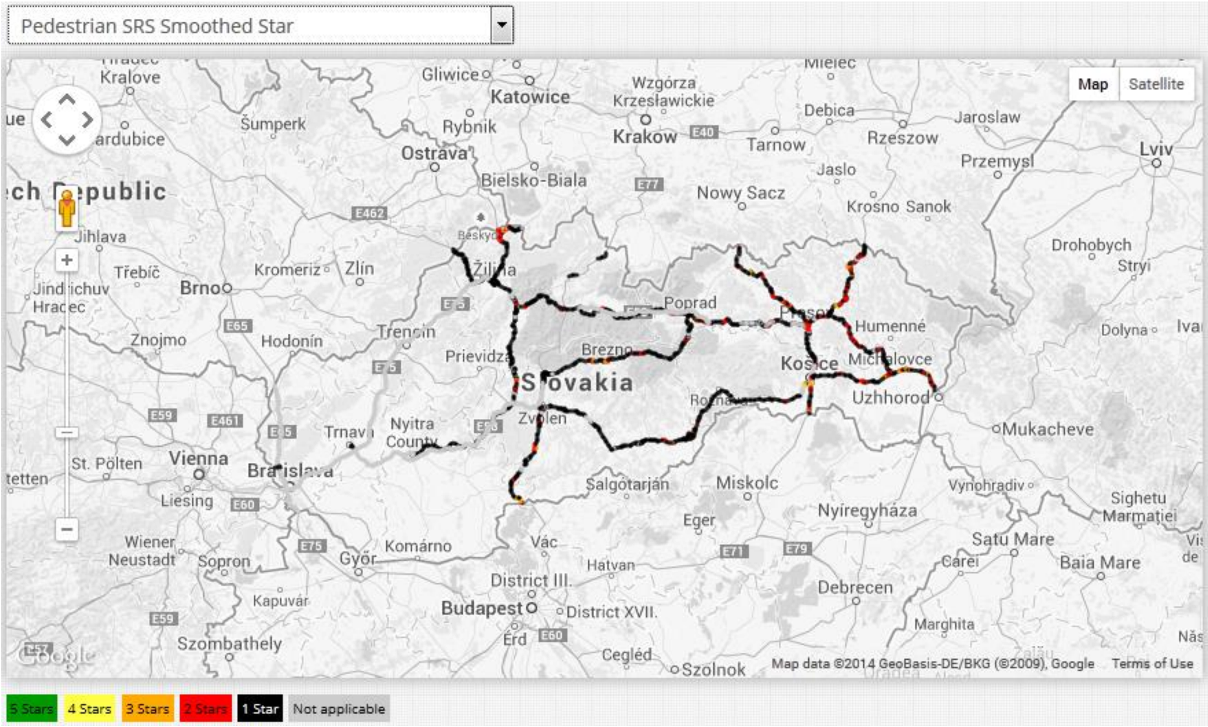


Figure 9 – Star Rating map for pedestrians

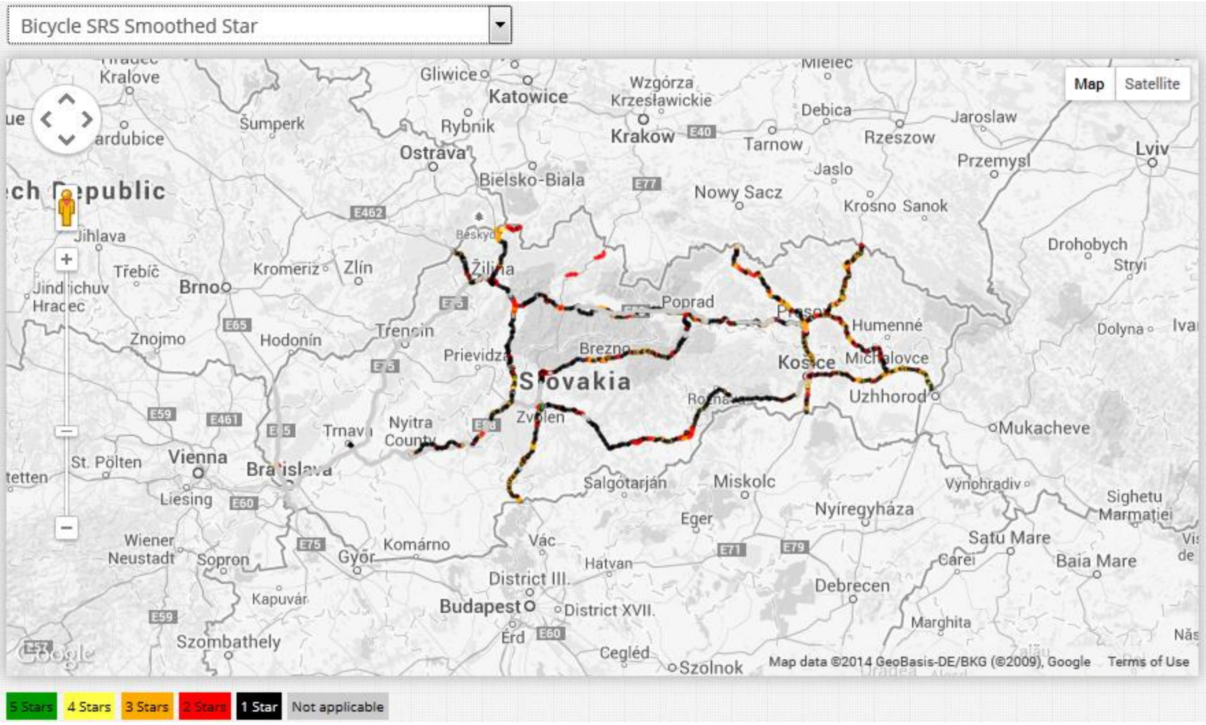


Figure 10 – Star Rating map for bicyclists

4.2 Detailed Star Ratings Results

In the next chapters, few road sections were chosen to demonstrate the Star Rating results in detail, and to explain the reasons behind the overall poor rating. These sections can be understood as case studies where the most common road safety deficits are identified, and their risk to the road users is explained.

4.2.1 I/18 Road, border crossing Makov/Velké Karlovice (SK/CZ) – Bytča

The I/18 road is one of the busiest and most dangerous first class roads in Slovakia, maintaining the east-western connection. This particular section starts at the Czech-Slovakian border crossing Makov/Velké Karlovice, and continues through a 30km long valley to the town of Bytča where it meets the I/61 road. The recorded traffic flow on this road section in 2011 was 4973 vehicles per 24 hours. It is a single carriageway road. Total number of 9 fatalities and serious injuries was recorded at this section in the time period 2009-2011.

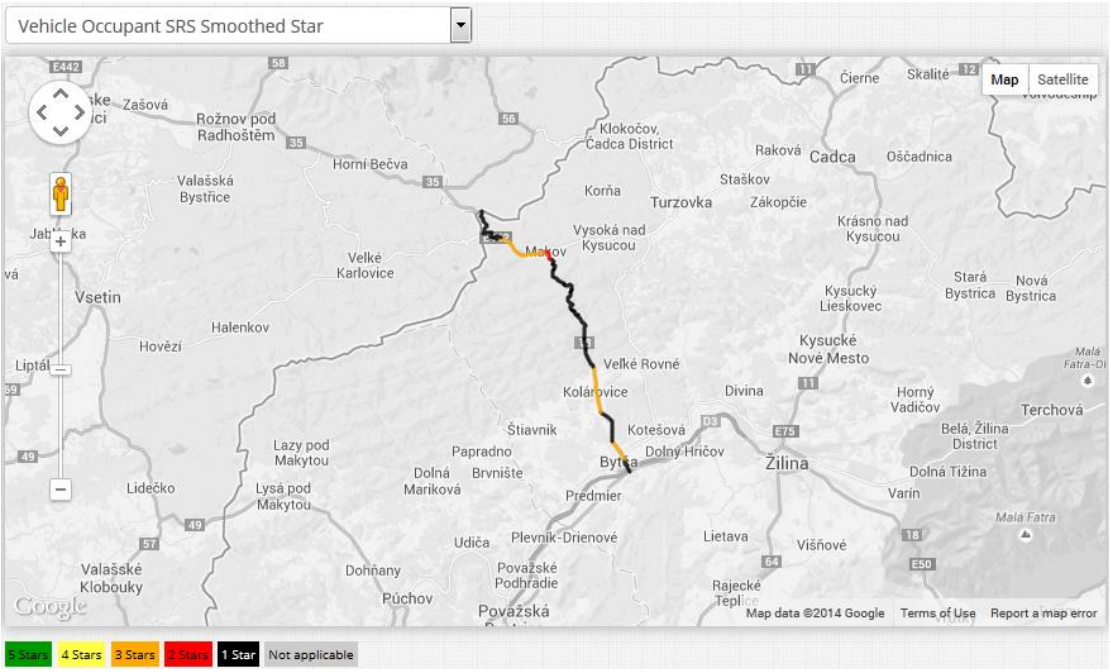


Figure 11 – Star Rating map for the Makov-Bytča section

The Star Rating results for this particular section are quite poor. 58% of its length is rated as 1-star for vehicle occupants. For pedestrians, 95% of the section's length is awarded only 1 star. To illustrate the risk distribution along the road, specific ViDA tool can be used – the Risk Worm. The Risk Worm helps to quickly identify the locations of high risk. The "spikes" in the graph are usually connected to intersections, sharp curves, or similar single factors which increase the risk significantly. The Risk Worm for the Makov-Bytča section is depicted in Figure 12. The graph shows the risk distribution before smoothing, that's why some short sections of the road fall in the 4-stars or even 5-stars category.

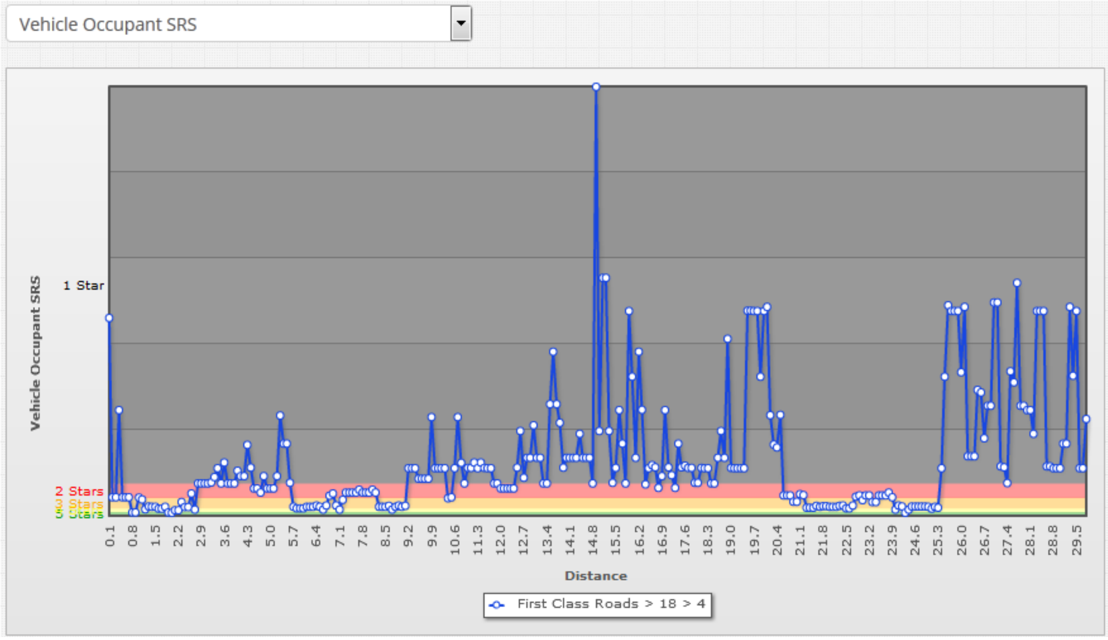


Figure 12 – Risk Worm for the Makov-Bytča section

When looking at the statistics of coded attributes along this section, the reason for the overall poor safety rating can be identified. 83% of the section length was recorded with 'medium' surface condition. The delineation was coded as poor for the entire section. Paved shoulder on both sides is either narrow (up to 1m) in about 80% of cases, or non-existent. There are 15 intersections at this section, mostly unsignalised 3-leg with no protected turn lane, only one of them was coded as 'adequate quality'. The road often leads through or along urban areas which generates pedestrian and bicyclists flows, however, only five pedestrian crossings are present. Roadside severity objects are another major cause of the poor rating. Unprotected trees are present on 40% of the section on one side, and on 60% on the other side. Only 8km, respectively 3km of the road is protected by safety barrier. Signs, poles and posts are also very common, as well as unprotected safety barrier ends. Examples of the above stated safety deficits are shown in the following pictures.

Example 1 Makov/Bytča section – Frequent poles, trees, together with missing paved shoulder and missing shoulder lane

Example 2 Makov/Bytča section – Unprotected barrier ends, unprotected rocks and cliffs, poor road condition and delineation, missing paved shoulder

Example 3 Makov/Bytča section – Pedestrian crossing to a bus stop without any sidewalks, refuge or lighting

Example 4 Makov/Bytča section – Intersection without proper road signing, and sight for drivers on both merging roads

4.2.2 D2 motorway, border crossing Bratislava-Čuňovo/Rajka (HU/SK) – border crossing Kúty/Brodské (SK/CZ)

The D2 motorway is one of the oldest and most important motorways in Slovakia. It connects the Czech border at Kúty with the Hungarian border at Bratislava-Čuňovo, passing through (ordered north to south) Malacky, Bratislava (capital) and Jarovce. It is part of the European routes E65 and E75 and of the Pan-European TEN-T corridor IV. The construction started in April 1969, with the first section from Bratislava to Malacky, which was open in November 1973. In 1974, construction also started on the Czech side from Brno, with the two ends of the motorways joining on 8 November 1980, a day, when also the D1 motorway in the Czech part of Czechoslovakia was completed, joining the three most important cities in the country (Prague, Brno and Bratislava). A new planned segment from Bratislava to the Hungarian border was added in 1987. Construction continued with the building of the Lafranconi bridge in Bratislava and the junction with D1 motorway and temporary end in Petržalka in the years 1985 - 1991 and after its opening, construction stopped for five years. Construction resumed in 1996, with the sections from the temporary end to Hungary and Austria (all opened in 1998) and with the 8.5 km segment from D2xD4 junction to the Hungarian border being widened in 2002. Today, the motorway is complete, with the last 3 km in Bratislava opened on 24 June 2007. This section contained the only tunnel on the D2 entire length, the Sitina tunnel (Bratislava).

The motorway is 80km long. The carriageway direction Hungary → Czech Republic was selected here to demonstrate the common safety deficits on Slovakian motorways. The traffic volume in 2011 was about 5,500 vehicles per day in the northern part (Czech Republic – Malacky), and 14,500 in the southern part (Malacky – Hungary) in one direction.

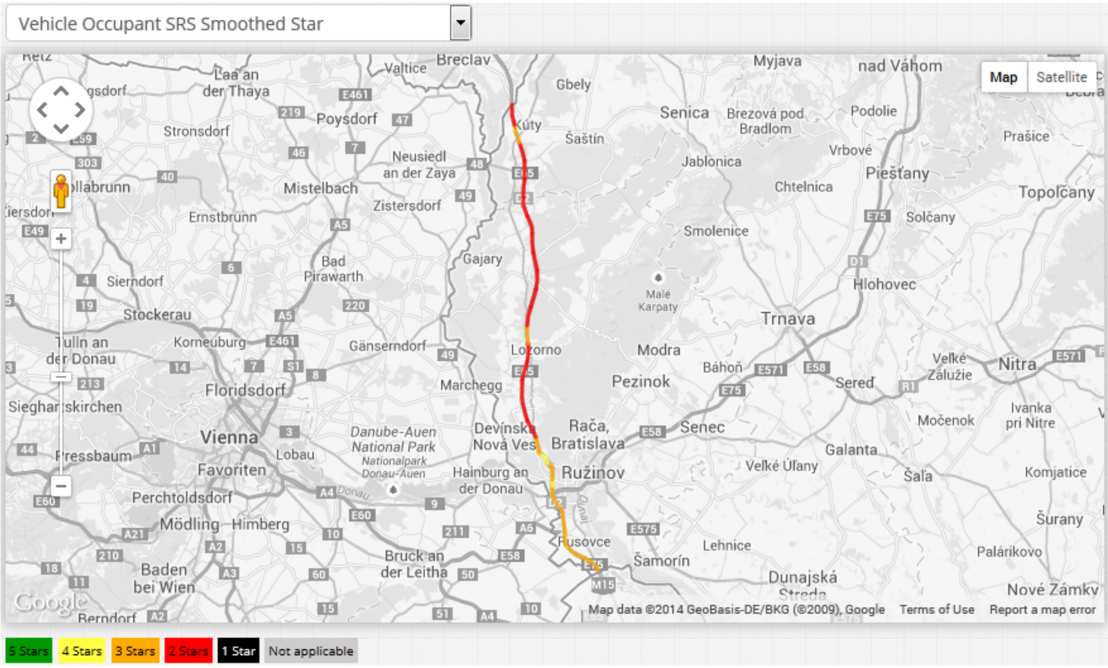


Figure 13 – Star Rating map for the D2 motorway (direction Hungary)

The vehicle occupants’ safety rating on the D2 motorway is relatively poor for motorways which generally carry much better rating. The Star Rating is higher in the Bratislava area. This is partly caused by better condition of the roads around the capital, but more importantly – by lower speed limits on the inter-urban part of the motorway (90km/h). Nevertheless, almost 90% of the section’s length is awarded two-or-three stars for vehicle occupants before smoothing. For motorcyclists, the percentage is even higher – 86%. The motorway was not rated for pedestrians and cyclists. The Risk Worm for the whole section is depicted in Figure 14.

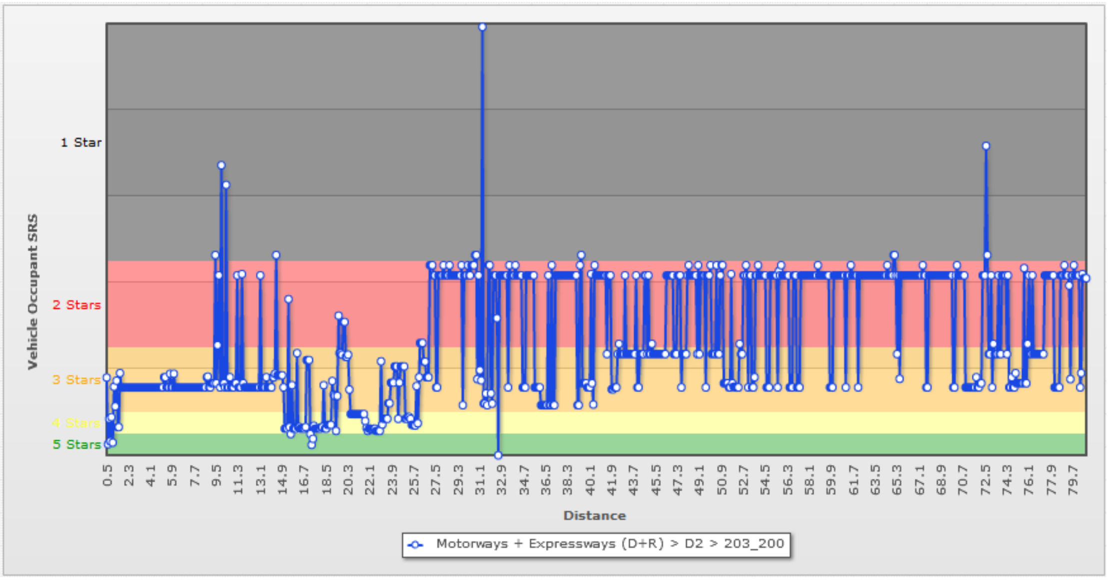


Figure 14 – Risk Worm for the D2 motorway (direction Hungary)

Once again, reasons behind the poor safety rating can be partly identified from the statistics of coded attributes. The decisive factors are missing road safety barriers (passenger side) and various hazardous objects along the road on the same side. In 22% of cases there are signs, posts or poles present, in 17% of cases trees, and on 13% of the entire length unprotected barrier ends represent significant safety deficits. In addition, there is narrow paved shoulder (up to 1m) on the driver side on the entire length. On the passenger side, the paved shoulder is mostly 1m – 2,4m wide, in 12% of cases the shoulder is narrow as well. These attributes together with high traffic volumes and operating speeds resulted in the overall poor rating for vehicle occupants and motorcyclists as a run-off crash on this motorway may have fatal consequences. In case of motorcyclists paradoxically the classic metal road safety decreases the rating. Metal barriers are generally very dangerous for motorcyclists, and require special adjustments – addition of another guard strip – to protect motorcyclists from serious injury. Examples of the above stated safety deficits are shown in the following pictures.

Example 1 D2 motorway – Frequent unprotected safety barrier ends, both metal and concrete ones

Example 2 D2 motorway – Unprotected trees in a deep slope along the passenger side of the road

Example 3 D2 motorway – Sign with non-frangible post

Example 4 D2 motorway – Narrow paved shoulder on the driver side is present on the entire stretch of the motorway

5 Safer Roads Investments Plan (SRIP)

The basic output of the RAP method, as described in paragraph 1 is the Safer Roads Investment Plan. The SRIP presents all the countermeasures proved able to provide the greater safety capacity and maximize the benefit over spent cost of the planned investments. The cost of each countermeasure is compared to the value of life and serious injuries that could be saved and Benefit to Cost Ratio (BCR) is calculated for each countermeasure proposed. The minimum threshold BCR for each 100m section was set to 1 and subsequently 3. Examples on parts of the network in subsequent report sections consider all economically justifiable measures and therefore a threshold BCR of 1.

5.1 Overall SRIP Results

The implementation of SRIP for the entire surveyed network in Slovakia would save 9,730 fatalities and serious injuries over the analysis period of 20 years assuming a threshold BCR=1. The cost of these countermeasures adds up to approximately 520 million EUR.

The total BCR of the entire investment plan is 2. Figure 15 presents the top 10 countermeasures of the SRIP in terms of saved lives and serious injuries (FSI).

In Figure 15a every 100m must achieve a BCR of 3 to be included. The latter of course achieves a more targeted saving and higher BCRs

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
9,790	1,144,391,734	542,818,817	55,400	2

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Duplication with median barrier	339.6 km	1,740	203,425,517	117,951,520	67,722	2
Roadside barriers - passenger side	938.7 km	1,490	174,028,525	71,402,280	47,921	2
Roadside barriers - driver side	552.6 km	820	96,010,334	42,308,610	51,469	2
Shoulder rumble strips	1,095.9 km	770	90,755,514	30,421,650	39,151	3
Skid Resistance (paved road)	277.5 km	650	76,181,815	57,121,530	87,575	1
Footpath provision passenger side (adjacent to road)	725.4 km	640	75,548,214	44,717,100	69,132	2
Footpath provision driver side (adjacent to road)	723.0 km	640	75,130,969	44,132,110	68,607	2
Additional lane (2 + 1 road with barrier)	267.0 km	550	65,165,915	31,243,810	55,998	2
Shoulder sealing driver side (>1m)	1,194.5 km	440	51,453,954	19,332,170	43,883	3
Road surface rehabilitation	277.9 km	420	49,798,189	12,809,130	30,043	4

Figure 15: Top 10 countermeasures for the entire road network

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
7,580	886,285,493	178,475,190	23,520	5

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Roadside barriers - passenger side	468.1 km	1,220	143,511,888	35,194,590	28,643	4
Shoulder rumble strips	1,142.8 km	960	112,568,201	11,963,690	12,413	9
Roadside barriers - driver side	242.5 km	620	72,667,170	18,397,560	29,570	4
Footpath provision driver side (adjacent to road)	338.1 km	500	59,026,898	19,125,950	37,845	3
Road surface rehabilitation	277.0 km	490	58,270,179	7,169,120	14,370	8
Footpath provision passenger side (adjacent to road)	328.8 km	490	57,681,761	18,602,530	37,667	3
Shoulder sealing driver side (>1m)	689.4 km	400	47,820,185	8,556,530	20,899	6
Shoulder sealing passenger side (>1m)	608.7 km	380	45,381,413	7,687,930	19,786	6
Clear roadside hazards - passenger side	384.0 km	300	35,641,820	1,959,620	6,422	18
Central hatching	459.4 km	270	32,244,175	4,975,970	18,024	6

Figure 16a: Top 10 countermeasures for the entire road network, threshold BCR=3 (unrounded data)

Roadside protection using barriers or clearance will have a good injury-saving return, as will better delineation, rumble strips, shoulder sealing, work on the road surface and footpath provision. Head-on protection with median barriers should be investigated. It is likely that further focused savings for pedestrians can be achieved by upgrading of the existing 514 (50%) pedestrian crossings on First Class Roads assessed as poor quality during the survey. The Star Rating results after adopting all the proposed countermeasures (BCR=1) are presented in the next figures.

	Vehicle Occupant			Motorcycle			Pedestrian			Bicycle		
Star Ratings	Length (kms)	Percent	Change	Length (kms)	Percent	Change	Length (kms)	Percent	Change	Length (kms)	Percent	Change
5 Stars	633.1	25%	+23%	42.6	2%	+2%	8.8	0%	±0%	6.1	0%	±0%
4 Stars	595.2	24%	+16%	484.7	19%	+16%	75.1	3%	+3%	26.8	1%	±0%
3 Stars	1,035.0	42%	+4%	632.6	25%	+12%	194.7	8%	+6%	331.3	13%	+4%
2 Stars	152.1	6%	-20%	690.5	28%	+9%	490.1	20%	+17%	589.3	24%	+17%
1 Star	60.5	2%	-24%	625.5	25%	-40%	475.0	19%	-26%	299.7	12%	-21%
Not applicable	11.7	0%	±0%	11.7	0%	±0%	1,243.9	50%	±0%	1,234.4	50%	±0%
Totals	2,487.6	100%		2,487.6	100%		2,487.6	100%		2,487.6	100%	

Figure 17 – Star Rating after implementing the SRIP

It is clear that the SRIP would improve the Slovakian road network safety significantly. For vehicle occupants, the number of 1-star high-risk roads would decrease to only 2%, whereas the 5-star roads would be present in 25% of cases. Overall number of 92% of 3-or-more-star roads is a good result. There are significant improvements in the motorcyclists' safety, as well as pedestrians' and bicyclists'. However, effect of the SRIP on these user groups is relatively lower than for the vehicle occupants.

Figure 18 – Star Rating map for vehicle occupants after implementing the SRIP

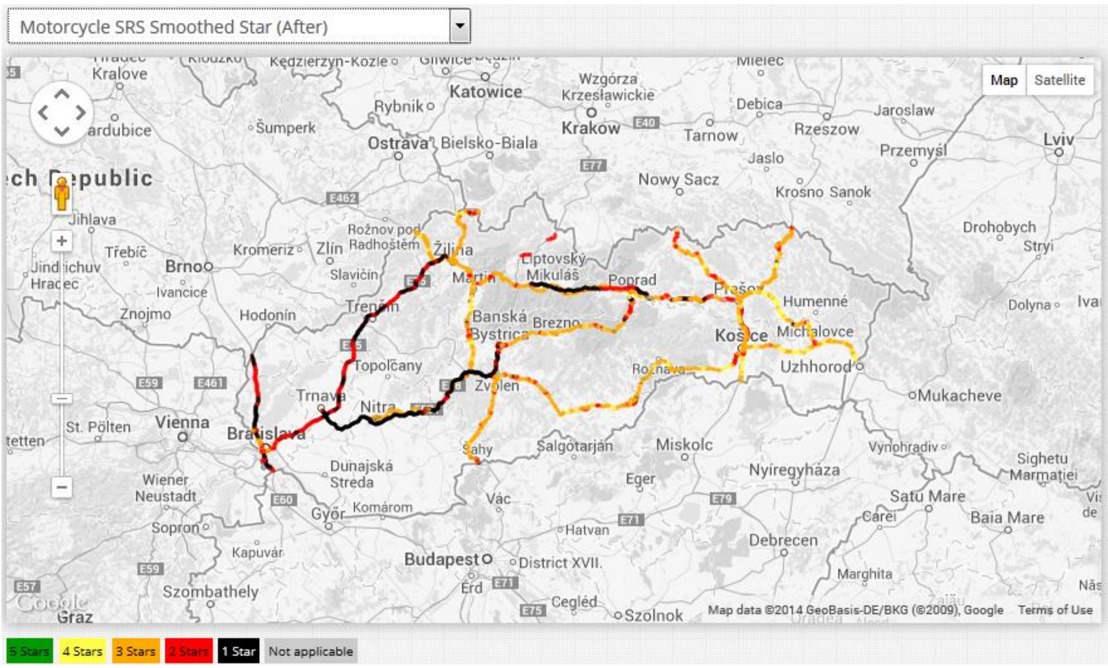


Figure 19 – Star Rating map for motorcyclists after implementing the SRIP

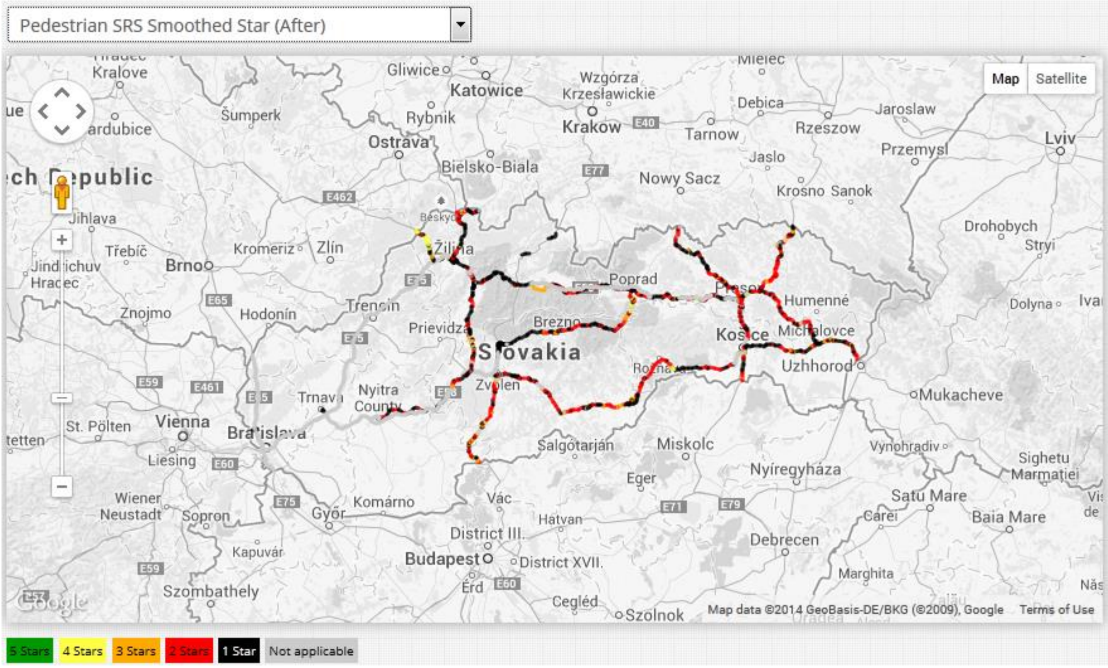


Figure 20 – Star Rating map for pedestrians after implementing the SRIP

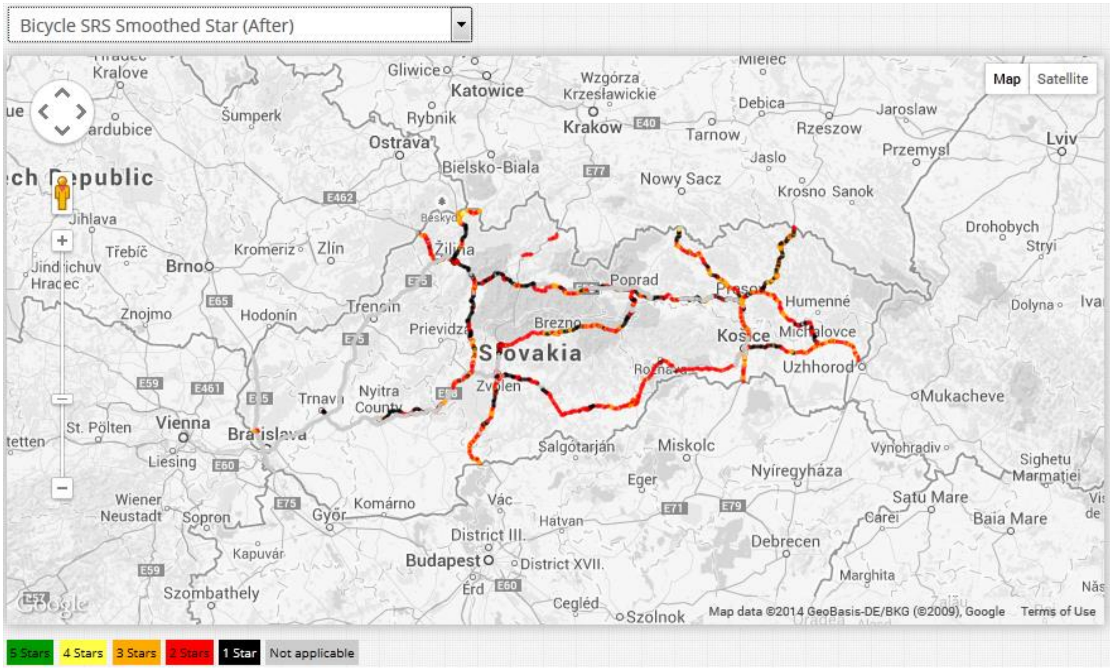


Figure 21 – Star Rating map for bicyclists after implementing the SRIP

The next figure presents the predicted casualty reductions after implementing the proposed SRIP.

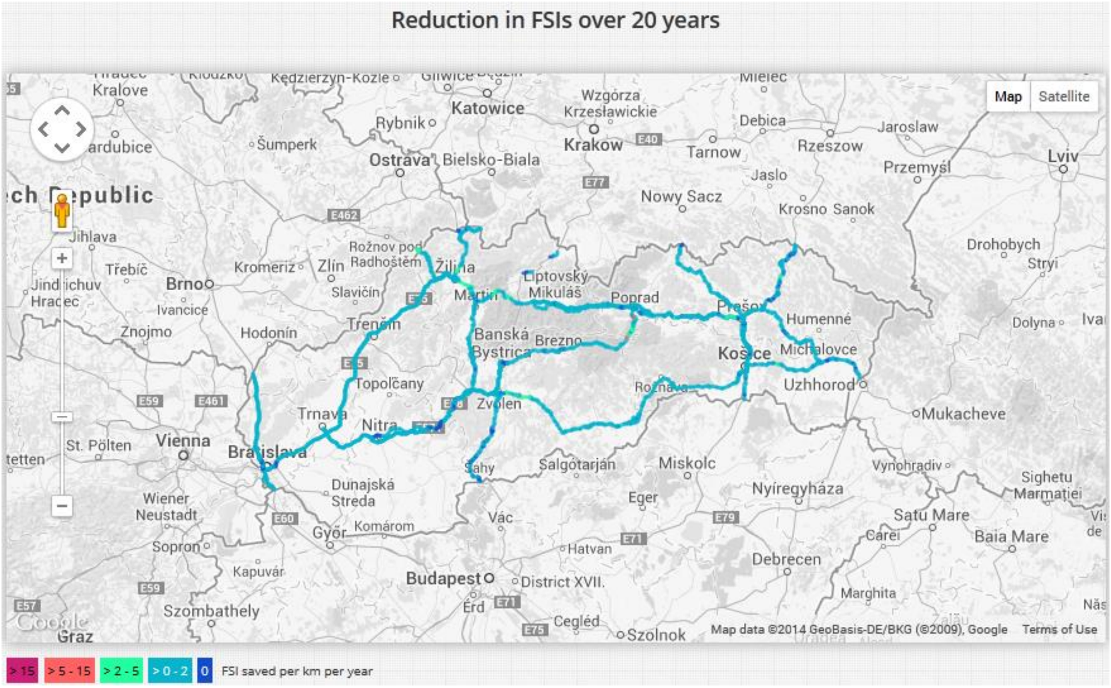


Figure 22 – Predicted casualty reduction map

This map gives a clue on where to address the countermeasures primarily to save the most lives and serious injuries. It is clear that the predicted casualty reduction is evenly spread throughout the network, with some evident 'hot spots' where focus should be put in the first place because the predicted countermeasures are expected to be most effective in those locations.

5.2 Detailed SRIP Results

The next chapters present the SRIP details for each 'case study' presented in chapter 4.2. A threshold BCR=1 is used here and some costs may have been varied to ensure fuller consideration of potential candidate sites.

5.2.1 I/18 Road, border crossing Makov/Velké Karlovice (SK/CZ) – Bytča

Figure 22 shows the details of the SRIP on this section. The table shows the top 10 countermeasures in terms of saved FSIs. The 'leading' proposed countermeasure is the provision of additional lane to build 2+1 road. This would require vast investments, evaluation of which is beyond the scope of this project. However, the possibility of implementing this countermeasure should be checked. The next proposed countermeasures are clear – improvement of the road surface, provision of safety barriers on both sides of the road, provision of footpaths, improving the sight distance to protect the pedestrians, or improving the delineation.

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
310	36,484,354	16,459,459	52,691	2

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Additional lane (2 + 1 road with barrier)	18.6 km	58	6,790,928	2,677,000	46,042	3
Skid Resistance (paved road)	12.3 km	36	4,208,456	3,294,030	91,419	1
Footpath provision driver side (adjacent to road)	21.0 km	30	3,518,562	1,916,390	63,614	2
Footpath provision passenger side (adjacent to road)	21.0 km	29	3,490,909	1,921,580	64,291	2
Sight distance (obstruction removal)	25.0 km	26	3,099,317	533,990	20,123	6
Roadside barriers - passenger side	16.5 km	22	2,668,059	1,309,280	57,315	2
Shoulder rumble strips	17.8 km	21	2,499,955	644,660	30,118	4
Roadside barriers - driver side	12.3 km	19	2,291,823	981,460	50,018	2
Improve curve delineation	5.3 km	15	1,761,407	189,990	12,599	9
Shoulder sealing passenger side (>1m)	22.4 km	14	1,667,590	420,310	29,439	4

Figure 23 – SRIP for the I/18 Makov-Bytča section

The Star Rating after implementing all proposed countermeasures at this section is the subject of the next figures. It is evident that the safety conditions would be significantly improved for all user groups. Especially the numbers for vehicle occupants and pedestrians are very positive and should be the driving force for improvements, given the high pedestrian activity along this road.

	Vehicle Occupant			Motorcycle			Pedestrian			Bicycle		
Star Ratings	Length (kms)	Percent	Change	Length (kms)	Percent	Change	Length (kms)	Percent	Change	Length (kms)	Percent	Change
5 Stars	12.1	41%	+40%	0.6	2%	+2%	3.2	11%	+11%	0.0	0%	±0%
4 Stars	7.6	26%	+22%	7.0	23%	+22%	9.6	32%	+32%	0.1	0%	±0%
3 Stars	9.1	31%	+11%	18.8	63%	+42%	4.8	16%	+15%	10.3	35%	+26%
2 Stars	0.6	2%	-14%	2.7	9%	-3%	4.9	16%	+14%	12.4	42%	+25%
1 Star	0.4	1%	-57%	0.7	2%	-64%	6.8	23%	-72%	2.7	9%	-50%
Not applicable	0.0	0%	±0%	0.0	0%	±0%	0.5	2%	±0%	4.3	14%	±0%
Totals	29.8	100%		29.8	100%		29.8	100%		29.8	100%	

Figure 24 – Star Rating of the I/18 Makov-Bytča section after implementing the SRIP

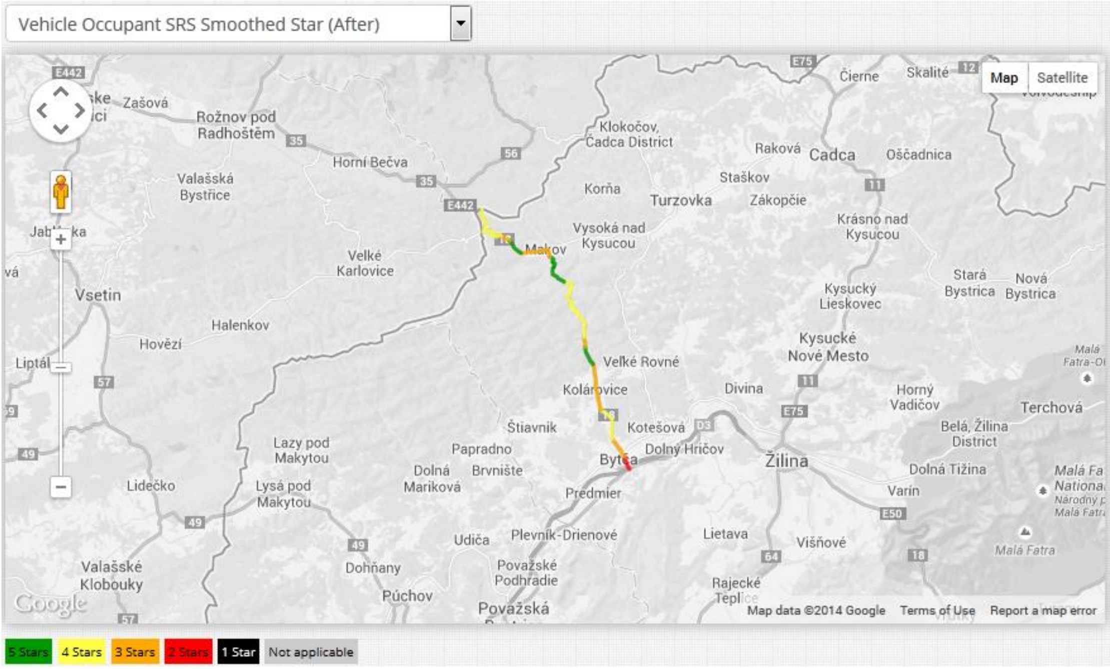


Figure 25 – Star Rating map for vehicle occupants of the I/18 Makov-Bytča section after implementing the SRIP

5.2.2 D2 motorway, border crossing Bratislava-Čuňovo/Rajka (SK/HU) – border crossing Kúty/Brodské (SK/CZ)

The next figure shows the details on the SRIP for this section. There are only 7 proposed countermeasures, but with the effect of 140 saved lives and serious injuries over the period of 20 years. As expected, the main proposed countermeasure is the roadside barriers on passenger side. The reduction of run-off accidents could be even more effective with the next countermeasure – shoulder rumble strips. The provision of wider paved shoulder on the driver side would also be justified. The remaining countermeasures have only limited effect; however, in the case of clearing roadside hazards, the low cost of this countermeasure should justify its application (BCR of 8).

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
140	16,878,955	6,248,495	43,238	3

Countermeasure	Length / Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	Program BCR
Roadside barriers - passenger side	43.4 km	93	10,957,435	3,330,080	35,496	3
Shoulder rumble strips	65.8 km	37	4,386,260	1,853,200	49,347	2
Shoulder sealing driver side (>1m)	62.0 km	11	1,398,451	985,380	82,298	1
Improve Delineation	0.7 km	1	31,326	20,110	75,008	2
Road surface rehabilitation	0.5 km	1	26,312	19,510	86,631	1
Clear roadside hazards - passenger side	0.2 km	1	11,645	1,400	14,101	8
Shoulder sealing passenger side (>1m)	2.4 km	1	67,525	38,770	67,075	2

Figure 26 – SRIP for the D2 motorway in direction of Czech Republic

The effect of the SRIP implementation on the Star Rating is evident. The high-risk sections would basically be eliminated, and the whole motorway would gain at least 3 Stars for vehicle occupants. The effect on motorcyclists' safety is very low; that is basically due to the problem with metal barriers described in previous chapter. The provision of 'motorcyclists-friendly' metal barrier is not justified due to the low motorcyclists' flows on the motorway.

	Vehicle Occupant			Motorcycle			Pedestrian			Bicycle		
Star Ratings	Length (kms)	Percent	Change	Length (kms)	Percent	Change	Length (kms)	Percent	Change	Length (kms)	Percent	Change
5 Stars	1.3	2%	+1%	0.0	0%	±0%	0.0	0%	±0%	0.0	0%	±0%
4 Stars	10.3	13%	+4%	0.4	0%	±0%	0.0	0%	±0%	0.0	0%	±0%
3 Stars	67.4	84%	+48%	4.9	6%	+2%	0.0	0%	±0%	0.0	0%	±0%
2 Stars	0.2	0%	-11%	7.7	10%	±0%	0.0	0%	±0%	0.0	0%	±0%
1 Star	1.1	1%	-42%	67.3	84%	-2%	0.0	0%	±0%	0.0	0%	±0%
Not applicable	0.1	0%	±0%	0.1	0%	±0%	80.4	100%	±0%	80.4	100%	±0%
Totals	80.4	100%		80.4	100%		80.4	100%		80.4	100%	

Figure 27 – Star Rating of the D2 motorway, direction Czech Republic after implementing the SRIP

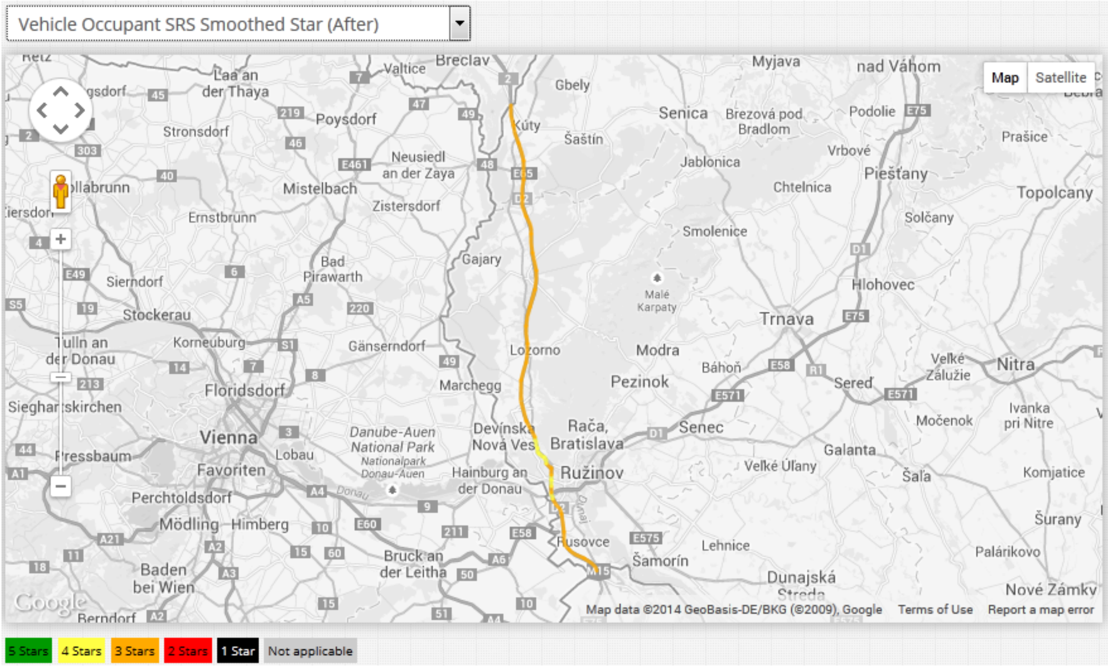


Figure 28 – Star Rating map of the D2 motorway, direction Czech republic after implementing the SRIP

6 Conclusions

As already mentioned in the Introduction, Slovakia is the 2014 ETSC PIN award winner. It has made the most progress in saving lives since an EU target to halve road deaths by 2020 was set four years ago, according to analysis by the European Transport Safety Council (ETSC). Data for the period 2010-2013 reveal that Slovakia made a dramatic 37% reduction in total deaths of road users.

However, the police statistics for the beginning of 2014 showed that the sinking almost stopped or is even changing to a slightly increasing tendency. According to the last Traffic Police statistics the number of deaths in the first half of 2014 decreased by 11, compared with the same period of 2013. It is at the moment impossible to forecast the final numbers for 2014, however it seems, that new triggers has to be find and implemented to cut the road accidents down in the next decade.

The very well-known road safety system „triangle“ identifies three basic pillars of road safety:

1. vehicle
2. driver
3. road

1) **Vehicle:** nowadays the passive and active safety level of the new vehicles in Slovakia is on a very high level. A significant impact on the road accidents decrease have had also two waves of so called „scrappage incentive“ in the year 2009, which eliminated 42,000 of vehicles older than 10 years from Slovak roads and replaced them with new, safe cars. Thanks to the EuroNCAP programme, the car manufacturers are pushed - by the public and competition as well - constantly to increase the vehicle safety by implementing the latest technologies. New vehicles are more accessible to the wide public due to attractive offers of various leasing and retail companies.

2) **Driver:** the driving behaviour in Slovakia is strongly influenced by the solid and very active performance of the Traffic Police. Partly by preventive, but mainly by repressive means is the Traffic Police Department currently one of the leaders in road accidents decrease in Slovak Republic. Moreover, in 2014 a new law about „objective responsibility“ for traffic offenses will be adopted. Through this institute even more possibilities will be available to control the traffic rules abidance. The Traffic Police is also changing their „philosophy“ in the last years - more controls are concentrated to really dangerous road sections instead to levy the fines without sense. On the other hand, obvious lacks are still in the prophylactic - educational area. The traffic education of children and adults is deeply behind the level of well developed countries as Austria or Germany. Driving schools are de-centralized, the system allows to run a driving school practically without any qualification. Children traffic education playgrounds almost disappeared, if some are in operation, they are often managed more-or-less on a lay basis. The full responsibility for this situation lies on the Government and Ministry of Education of Slovak Republic.

3) **Road:** as regards the third pillar, the road infrastructure safety remains so far beyond adequate caring of responsible authorities. The pressure on road owners and administrators, in order to convince them to pay more attention to road safety issues, is in Slovakia very flat. ***And yet here is hidden a huge potential for road accidents decrease and mitigation of fatal and serious injuries. A safe road has to be equipped with such (at least basic) road safety elements, which are able to protect the road users in case of a driving error and „forgive“ them their mistakes. A price for human failure in road traffic must not be immediately death or disability.***

That´s just why the SENSOR project is so important. Within this unique project a real-time road safety inspection on 2,500 km of the primary Slovak road network was realized. The inspection was carried out in October – November 2014 by companies MAXNETWORK and AF-CITYPLAN, using a dedicated survey vehicle and specialised technology. The entire motorway and expressway network together with busy and high-risk first class roads was inspected. Through the specific analysing software V*i*DA™ - courtesy of the project accessible for Slovak road authorities - was it possible to identify the dangerous high risk road sections. And we can see, that despite the fact that Slovakia belongs to the best performing countries in decreasing of road fatalities, the Slovak roads are still far from safe. Only 2% of the Slovakian surveyed superior road network (TEN-T) was awarded 5 stars, 8% 4 stars and 38% 3 stars for the vehicle occupants. These road sections can be considered as safe (in European terms of road safety). On the other hand one quarter of the network gained only 1 star. The rating for motorcyclists is even worse - 65% of the network length belongs to the one-star high-risk category.

Safety deficits were identified in terms of frequent hazardous objects along the roads (trees, poles, unprotected safety barrier ends), missing safety barriers (passenger side), narrow paved shoulders or poor road surface and delineation in some places. The likelihood a road accident with fatal consequences is still unacceptably high on most Slovak roads.

As the main road safety shortcomings on the inspected network were identified :

- Hazardous objects close to the road
- Lack of run-off protection
- Lack of head-on protection
- Poorly designed junctions where brutal right-angled side-impacts may occur

Tools developed by iRAP are now frequently applied to help develop “Safer roads investment plans” for national governments and financial institutions. These tools, using a standard pool of 94 proven safety measures from international practice, help evaluate how much it would cost to raise star ratings. They show too how the most lives can be saved for the money available by targeting high return safety countermeasures at locations of known high risk.

The ViDA™ software is able to calculate „bank-ready“ safe road infrastructure investment plans with a list of most effective life-saving countermeasures on particular road sections. The estimated cost of upgrading and rehabilitation along the entire length of this network is assumed to be approx. 520 million EUR and will provide a BCR of 2. The casualty reduction on the priority sections would be around 55% – around 9730 casualties saved over 20 years if the network is upgraded. Setting a threshold BCR=3 achieves a programme BCR of 5, about 7580 fatal and serious casualties saved over 20 years for a budget of about 180 million EUR.

Across the 14 countries for which there are data in the SENSoR project, the range of Benefit Cost Ratios is typically 5 or 6 for the overall investment programmes when the threshold BCR is 3. For individual countermeasures, the BCRs of those with greatest life-saving potential are of course higher and in most countries include many in the range between 5 and 10, but in some often up to and around 20.

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 value of life and the countermeasure costs selected.

These results for consultation provide a limited scenario of costs and benefits and the ViDA software offers the opportunity for local engineers and policy makers to vary the parameters to match them local circumstances and budgets.

Some of the most effective proposed countermeasures for Slovakia are (photos courtesy of iRAP) include:

- **Provision of head-on protection (2+1 road)**

  Among the median barriers recommended for Slovakian roads is the 2+1 road, a specific category of three-lane road, consisting of two lanes in one direction and one lane in the other, alternating every few kilometres, and separated usually with a steel cable barrier. Traditional roads of at least 13 metres width can be converted to 2+1 roads and reach near-motorway safety levels at a much lower cost than an actual conversion to motorway or dual carriageway In Sweden, many 13 metres wide roads have been built, especially in the period 1955–1980. These have two 3.5 metres wide lanes, and two 3 metres wide shoulders, in the beginning planned as emergency strip, due to the relative unreliability of autos of that period. Around 1990, the idea emerged to build fences in the middle of them and to have 2+1 lane. This would be a cheap way of increasing traffic safety, since these roads have had a bad safety record. The width invites high speeds. Some people were, for example, overtaking against meeting traffic, assuming meeting cars would go to the side. We can see the same practice on Slovak roads (e. g. first class road I/63, road section Bratislava - Dunajská Streda). Even when the roads are a little narrow for 3 lanes, successful pilots were realized in Sweden. After the year 2000, more than 1000 km of roads in Sweden have been converted from wide ordinary roads into 2+1-road, all with median barriers.

  Until recently, the roads had the original 90 km/h speed limit. However, many people drove at 90 km/h at 1-lane parts but 110 km/h at 2-lane parts (the same speed limit as on motorways). The speed limit has now been changed to 100 kilometres per hour with a notably smoother traffic flow.


- **Safety barriers (passenger side) with protected ends**

  They are designed to redirect the vehicle and have a lower severity than the roadside hazard they protect. There are three main types of safety barrier (but within these types there are different systems which have their own specific performance characteristics).

  Flexible barriers are made from wire rope supported between frangible posts. Flexible barriers may be the best option for minimizing injuries to vehicle occupants, however they may pose a risk to motorcyclists. These barriers deflect more than other barrier types and need to be repaired following impact to maintain their re-directive capability.

Semi-rigid barriers are usually made from steel beams or rails. These deflect less than flexible barriers and so they can be located closer to the hazard when space is limited. Depending on the impact these barriers may be able to redirect secondary impacts.

Rigid barriers are usually made of concrete and do not deflect. Rigid barriers should be used only where there is no room for deflection of a semi-rigid or flexible barrier. Rigid barriers are often utilized at high volume roadwork sites to protect road workers or other road users particularly where another barrier type is awaiting repair. Currently (depending on their height and other details) these provide the highest level of containment of heavy vehicles. In most cases following impact these barriers require little or no maintenance.

Much of the benefit from the use of barriers comes from a reduction in crash severity. Although a crash may still occur, it is likely to have a safer consequence than colliding with the object that the barrier is protecting.

Early traffic barrier designs often paid little attention to the ends of the barriers. Vehicles that struck blunt ends could stop abruptly or have steel rail sections penetrate into the passenger compartment, resulting in severe injuries or fatalities.] As a result, barrier terminals were developed that brought the end of the terminal down to ground level. While this prevented the rail from penetrating the vehicle, it could also vault a vehicle into the air or cause it to roll over, since the barrier end formed a ramp. To address the vaulting and rollover crashes, energy absorbing terminals were developed. These have a large steel impact head that engages the frame or bumper of the vehicle. The impact head is driven back along the guide rail, dissipating the vehicle's kinetic energy by bending or tearing the steel in the guide rail sections. A guide rail may also be terminated by curving it back to the point that the terminal is unlikely to be hit end-on, or, if possible, by embedding the end in a hillside or cut slope.

An alternative to energy absorbing barrier terminals are impact attenuators. These are used for wider hazards that can't be effectively protected with a one-sided traffic barrier.

- **Rumble strips**

  Rumble strips take a number of different forms, and can be produced by cutting grooves within the pavement surface, or by adding plastic bumps (or ribs) to the road.

  The most missing type of rumble strips on the inspected Slovak road network are *longitudinal rumble strips* (also referred to as raised profile edge lines or audio-tactile edge lines). They can be used to delineate the edge of a road where driver fatigue is known to cause crashes. As well as providing visual delineation, longitudinal rumble strips can also be heard and felt by drivers and riders. When a tyre runs over the rumble strips a noise and vibration is produced. This tells sleepy or distracted drivers that their vehicle is starting to leave the road.

  Longitudinal rumble strips can also be used in the centre of the road. When combined with painted centrelines, rumble strips help prevent head-on crashes and run-off-road crashes resulting from vehicles crossing into the opposing lane. Flexible posts (or flexi-posts) can also be used in the centre of the road to separate opposing flows and are an effective treatment in discouraging overtaking manoeuvres, reducing the likelihood of head-on crashes.

All the countermeasures listed are indicative and will need to be assessed and sense-checked with local engineers and road authorities.

The Safer Roads Investment Plan is not a “bill of works”, however we strongly hope, that the Slovak road owners and administrators will accept the project results not as a kind of „competition“, but as a support and the V*i*DA™ software will become a helpful tool in their daily work.

Slovak SENSOR Team, Bratislava, August 2014

Annex 1 – Traffic Volume

The next chapter presents the traffic flows used in ViDA for the particular sections. The values without any background colour were provided by Slovak Road Administration (SSC), based on traffic-flow census 2010, re-calibrated according to the Methodical Directive 01/2006, issued by Ministry of Transport of Slovak Republic about „Traffic Flow Forecasting on the Slovak road network up to 2040". Values with yellow background colour were provided by the National Highway Company, and related to the year 2013. The values with orange background colour were estimated from the flows of adjacent roads due to missing traffic flow data.

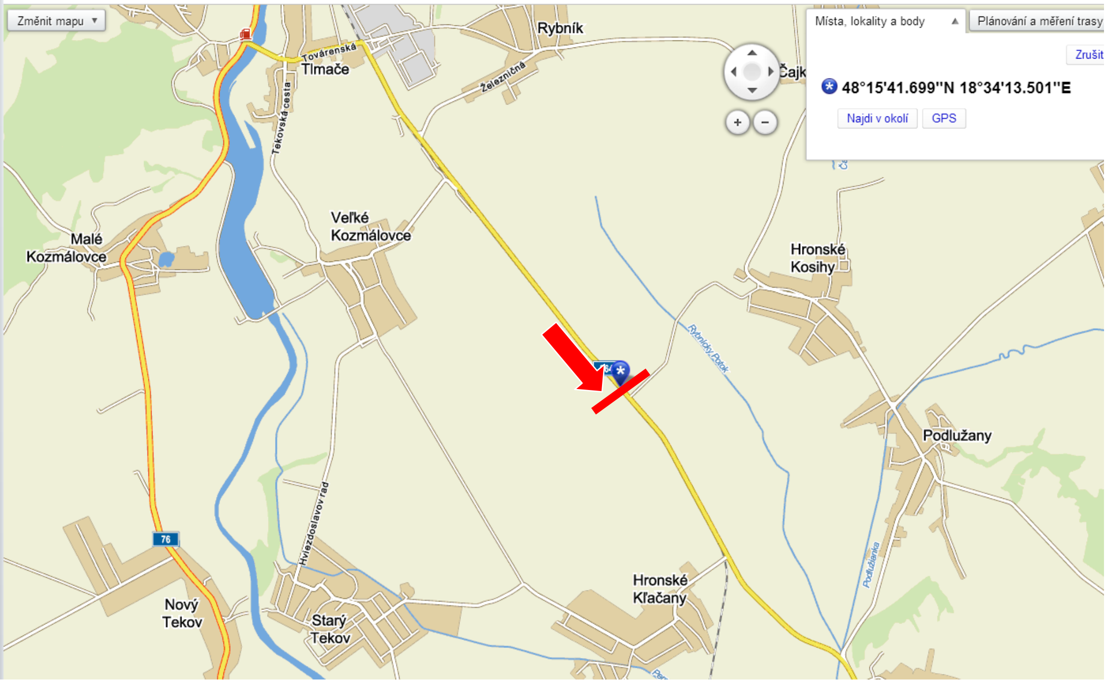
Road No.	Road Description	Carriageway type	Traffic flow [veh./24hrs]
D1	Bratislava/Petržalka - Senec	Dual	75476
D1	Senec - Trnava	Dual	55941
D1	Trnava - Piešťany	Dual	34038
D1	Piešťany - Nové Mesto nad Váhom	Dual	30014
D1	Nové Mesto nad Váhom - Nemšová	Dual	33184
D1	Nemšová - Sverepec	Dual	27681
D1	Ivachnová - Liptovský Peter	Dual	19200
D1	Liptovský Peter - Važec	Dual	14686
D1	Važec - Lučivná	Dual	14033
D1	Prešov - Košice	Dual	20352
D1	Považská Bystrica - Dolný Hričov	Dual	23608
D1	Sverepec - Považská Bystrica	Dual	18882
D1	Lučivná - Spišský Štvrtok	Dual	12911
D1	Svinia - Prešov	Mixed	10782
D1	Spišské Podhradie- Beharovce	Mixed	8623
D1	Beharovce - Hendrichovce	Mixed	11809
D2	Bratislava/Lamač - Bratislava/Čunovo	Dual	28785
D2	Záhorie (vojenský obvod) - Bratislava/Lamač	Dual	29520
D2	Brodské - Záhorie (vojenský obvod)	Dual	18005
D3	Dolný Hričov - Žilina	Dual	23153
D4	Austria – D2	Dual	12900

D4	Záhorská Bystrica - Stupava	Single	2000
R1	Nitra - Čaradice	Dual	15000
R1	Čaradice - Bzenica	Dual	14790
R1	Budča - Banská Bystrica	Dual	20662
R1	Trnava - Nitra	Dual	31908
R1	Bzenica - Lehôtka pod Brehmi	Dual	19736
R1	Lehôtka pod Brehmi - Žiar nad Hronom	Dual	19736
R1	Žiar nad Hronom - Budča	Dual	24682
R1A	R1 – Nitra	Dual	9800
R2	Figa - Tornaľa	Single	4839
R2A	Košice – Šaca	Dual	15626
R3	Oravský Podzámok - Horná Lehota	Single	7156
R3	Trstená - Tvrdošín	Single	3267
R4	Svidník	Single	4300
PR3	Vajkovce - Košice	Dual	10176
I/11	Krásno nad Kysucou - Žilina	Single	20357
I/11	Svrčinovec - Krásno nad Kysucou	Single	10396
I/12	Svrčinovec - Skalité	Single	3177
I/18	Makov - Bytča	Single	4973
I/18	Bytča - Žilina	Single	14048
I/18	Žilina - Martin	Single	27613
I/18	Martin - Kraľovany	Single	19818
I/18	Kraľovany - Ivachnová	Single	18883
I/18	Ivachnová - Liptovský Mikuláš	Single	5084
I/18	Liptovský Mikuláš - Važec	Single	6344
I/18	Važec - Poprad	Single	6312
I/18	Poprad - Levoča	Single	11443
I/18	Levoča - Spišské Podhradie	Single	13988
I/18	Spišské Podhradie - Chminianska Nová Ves	Single	6306
I/18	Chminianska Nová Ves - Kapušany	Single	19506
I/18	Kapušany - Soľ	Single	9782
I/18	Soľ - Strážske	Single	8838
I/18	Strážske - Michalovce	Single	8548
I/50	Drietoma - Svinná	Single	10912

I/50	Svinná - Nováky	Single	10976
I/50	Nováky - Handlová	Single	13452
I/50	Handlová - Žiar nad Hronom	Single	9830
I/50	Podkriváň - Lučenec	Single	10405
I/50	Lučenec - Rimavská Sobota	Single	8291
I/50	Rimavská Sobota - Tornaľa	Single	5810
I/50	Tornaľa - Brzotín	Single	5972
I/50	Brzotín - Turňa nad Bodvou	Single	7009
I/50	Turňa nad Bodvou - Košice/Juh	Single	15627
I/50	Košice/Juh - Dargov	Single	17954
I/50	Dargov - Michalovce	Single	11061
I/50	Michalovce - Vyšné Nemecké	Single	7193
I/50	Budča - Podkriváň	Single	15416
I/65	Žiar nad Hronom - Kremnica	Single	7415
I/65	Kremnica - Turčianske Teplice	Single	4496
I/65	Turčianske Teplice - Martin	Single	11266
I/65	Nitra - Čaradice	Single	15642
I/65	Bzenica - Ladomerská Vieska	Single	13805
I/66	Šahy - Hontianske Nemce	Single	4494
I/66	Hontianske Nemce - Zvolen	Single	7544
I/66	Podbrezová - Polomka	Single	6418
I/66	Polomka - Šumiac	Single	2815
I/66	Šumiac - Vernár	Single	2512
I/66	Zvolen - Podbrezová	Single	14640
I/67	Vernár - Poprad	Single	4455
I/68	Košice/Juh - Milhosť	Single	11639
I/68	Mníšek nad Popradom - Ľubotín	Single	3912
I/68	Ľubotín - Sabinov	Single	6110
I/68	Sabinov - Prešov	Single	12276
I/68	Prešov - Košice/Staré Mesto	Single	11655
I/73	Stročín - Vyšný Komárnik	Single	6438
I/73	Lipníky - Stročín	Single	6892

Annex 2 – Speed measurement details

Site 1



Road: II/564

Coordinates: N 48.260714, E 18.571340

Date: 14.3.2014 – 20.3.2014

Time of measurement: 00:00 – 24:00

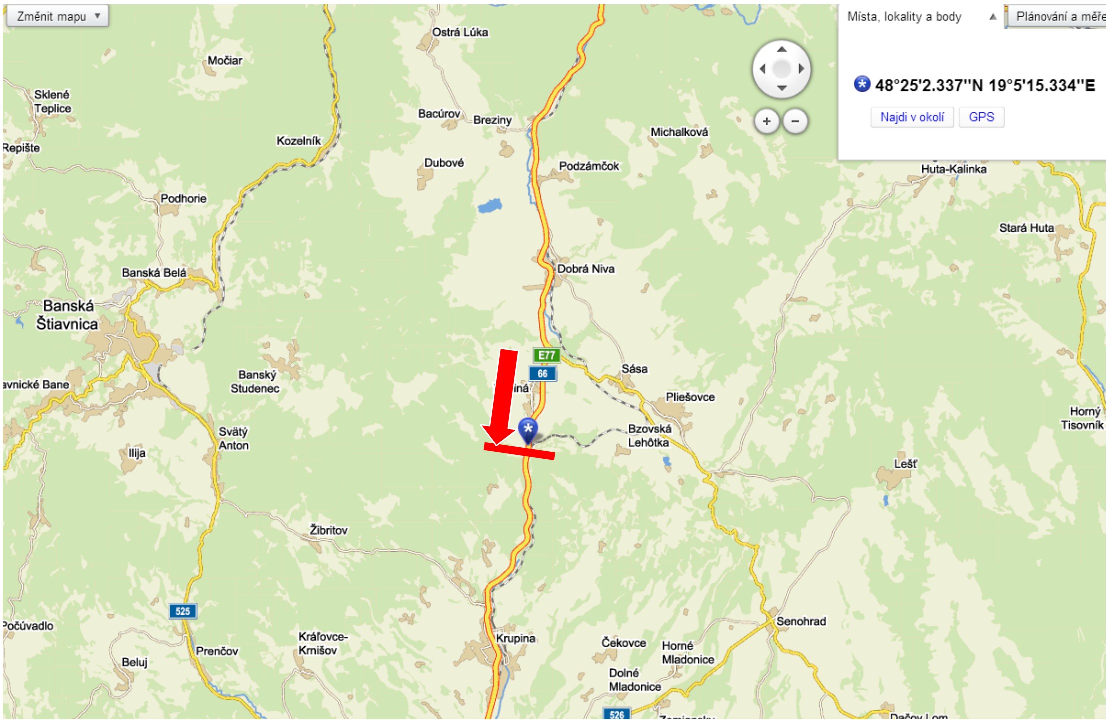
Nr. of recorded vehicles: 47 889

Speed limit: 90km/h

Measured 85th percentile speed: 96km/h

Measured mean speed: 85km/h

Site 2



Road: I/66

Coordinates: N 48.415018, E 19.086939

Date: 14.3.2014 – 17.3.2014

Time of measurement: 00:00 – 24:00

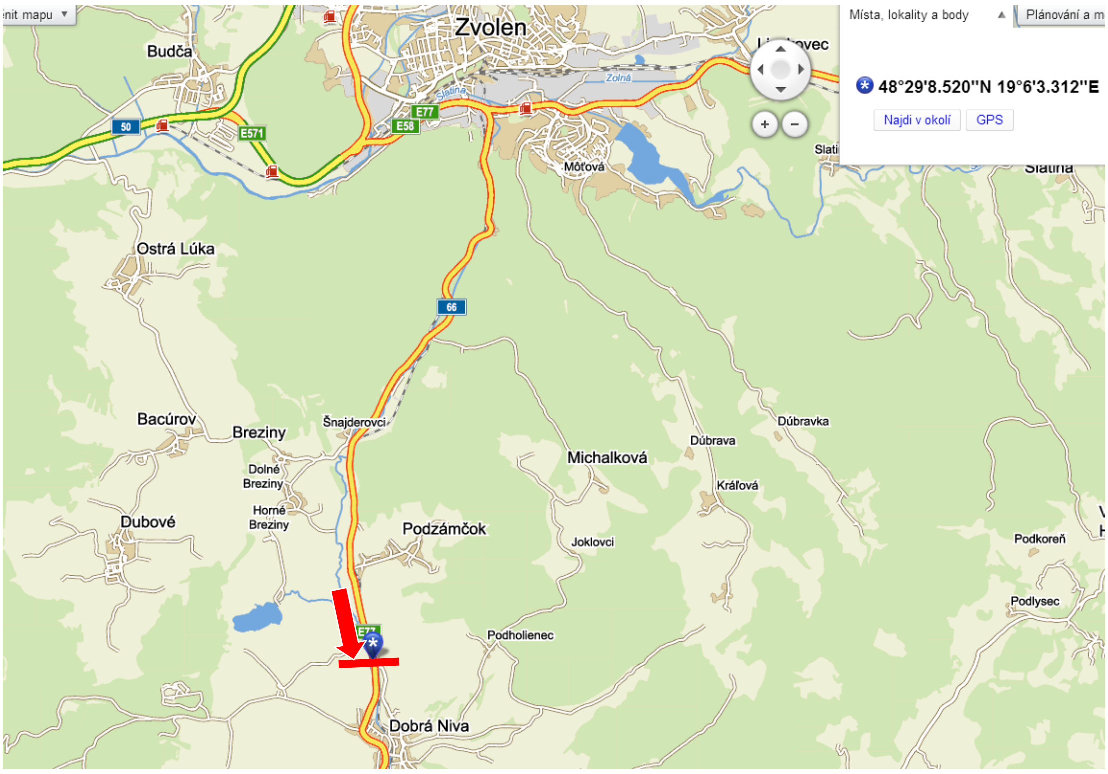
Nr. of recorded vehicles: 16 929

Speed limit: 90km/h

Measured 85th percentile speed: 105km/h

Measured mean speed: 91km/h

Site 3



Road: I/66

Coordinates: N 48.415018, E 19.086939

Date: 14.3.2014 – 20.3.2014

Time of measurement: 00:00 – 24:00

Nr. of recorded vehicles: 51 363

Speed limit: 90km/h

Measured 85th percentile speed: 98km/h

Measured mean speed: 87km/h

Annex 3 – Countermeasure costs

Countermeasure ID	Countermeasure	C'way Code	Unit of Cost	Service Life	RURAL Low Upgrade Cost	RURAL Med Upgrade Cost	RURAL High Upgrade Cost	URBAN Low Upgrade Cost	URBAN Med Upgrade Cost	URBAN High Upgrade Cost
1	Improve delineation	Individual	lane km	5	6 900	6 900	6 900	8 600	8 900	10 200
2	Bicycle lane (on-road)	Individual	per km	20	34 600	66 100	140 600	52 300	46 300	60 400
3	Bicycle lane (off-road)	Individual	per km	20	83 200	90 300	219 300	108 800	118 300	290 000
4	Motorcycle lane (painted logos only on-road)	Individual	per km	5	2 800	2 800	2 800	3 000	3 300	4 100
5	Motorcycle lane (construct on-road)	Individual	per km	20	64 200	102 200	140 200	70 800	108 300	146 300
6	Motorcycle lane (segregated)	Individual	per km	20	92 700	109 300	126 000	108 800	124 000	139 200
7	Horizontal realignment	Individual	lane km	20	145 200	191 300	285 600	252 700	345 100	533 500
8	Improve curve delineation	Individual	per carriageway km	5	9 500	9 500	9 500	10 700	10 700	10 700
9	Lane widening (up to 0.5m)	Individual	lane km	10	43 700	69 400	107 600	61 800	73 300	119 100
10	Lane widening (>0.5m)	Individual	lane km	10	83 600	163 900	252 100	118 800	137 300	197 000
11	Protected turn lane (unsignalised 3 leg)	Multi	intersection	10	30 200	127 600	457 700	36 600	164 800	438 400
12	Protected turn lane (unsignalised 4 leg)	Multi	intersection	10	30 200	138 400	418 100	41 300	218 700	488 100
13	Delineation and signing (intersection)	Multi	intersection	5	8 600	10 200	12 900	11 400	13 400	25 200
14	Protected turn provision at existing signalised site (3-leg)	Multi	intersection	10	11 000	14 300	26 600	16 200	24 700	44 900
15	Protected turn provision at existing signalised site (4-leg)	Multi	intersection	10	11 000	14 300	24 500	16 200	26 600	44 100
16	Signalise intersection (3-leg)	Multi	intersection	20	46 400	46 400	46 400	60 300	60 300	60 300
17	Signalise intersection (4-leg)	Multi	intersection	20	54 500	54 500	54 500	74 100	74 100	74 100

18	Grade separation	Multi	intersection	50	5 937 500	5 937 500	5 937 500	5 937 500	5 937 500	5 937 500
19	Rail crossing upgrade	Multi	intersection	20	76 400	161 500	522 500	76 400	161 500	522 500
20	Roundabout	Multi	intersection	20	176 300	347 300	489 800	267 900	552 900	790 400
21	Central hatching	Multi	per km	10	8 300	8 300	8 300	8 300	8 300	8 300
22	Rumble strip / flexi-post	Multi	per km	10	11 900	11 900	11 900	11 900	11 900	11 900
23	Central turning lane full length	Multi	per km	10	165 300	200 800	272 100	218 500	266 000	361 100
24	Central median barrier (no duplication)	Multi	per km	10	76 400	93 000	126 300	107 400	131 000	178 600
25	Duplication with median barrier	Undivided Only	per carriageway km	20	1 216 000	1 406 000	1 786 000	1 710 000	1 995 000	2 565 000
26	Duplicate - <1m median	Undivided Only	per carriageway km	20	881 600	995 600	1 223 600	1 159 000	1 349 000	1 729 000
27	Duplicate - 1-5 m median	Undivided Only	per carriageway km	20	972 800	1 086 800	1 314 800	1 292 000	1 482 000	1 862 000
28	Duplicate - 5-10m median	Undivided Only	per carriageway km	20	984 200	1 150 300	1 483 100	1 406 000	1 596 000	1 976 000
29	Duplicate - 10-20m median	Undivided Only	per carriageway km	20	1 185 600	1 262 700	1 464 100	1 672 000	1 835 000	2 163 300
30	Duplicate - >20m median	Undivided Only	per carriageway km	20	1 641 600	1 741 500	1 917 900	2 242 000	2 389 800	2 728 000
31	Service Road	Individual	per km	20	243 200	262 200	300 200	446 500	505 900	624 600
32	Additional lane (2 + 1 road)	Individual	per km	20	433 200	480 700	575 700	684 000	779 000	969 000
33	Implement one way network	Undivided Only	per carriageway km	20	61 800	67 700	79 600	85 500	94 900	114 100
34	Upgrade pedestrian facility quality	Individual	unit	10	8 300	8 300	8 300	8 300	8 300	8 300
35	Refuge Island	Multi	unit	10	11 900	11 900	11 900	11 900	11 900	11 900
36	Unsignalised crossing	Multi	unit	10	4 800	4 800	4 800	4 800	4 800	4 800
37	Signalised crossing	Multi	unit	20	23 800	29 700	35 600	17 800	21 400	23 800
38	Grade separated pedestrian facility	Multi	unit	50	950 000	950 000	950 000	1 068 800	1 068 800	1 068 800
40	Road surface rehabilitation	Individual	lane km	10	8 300	9 500	10 700	9 500	10 700	11 900

41	Clear roadside hazards - passenger side	Individual	per linear km	20	4 400	4 700	5 000	6 200	6 500	7 000
42	Clear roadside hazards - driver side	Individual	per linear km	20	4 400	4 700	5 000	6 200	6 500	7 000
43	Sideslope improvement - passenger side	Individual	per linear km	20	10 300	13 100	16 300	12 800	15 200	20 000
44	Sideslope improvement - driver side	Individual	per linear km	20	10 300	13 100	16 300	12 800	15 200	20 000
45	Roadside barriers - passenger side	Individual	per linear km	20	72 800	75 400	77 300	82 700	91 000	107 600
46	Roadside barriers - driver side	Individual	per linear km	20	72 800	75 400	77 300	82 700	91 000	107 600
47	Shoulder sealing passenger side (<1m)	Individual	per linear km	20	10 400	13 500	16 700	12 800	14 700	18 400
48	Shoulder sealing passenger side (>1m)	Individual	per linear km	20	10 400	14 500	18 800	12 800	14 700	18 500
52	Restrict/combine direct access points	Individual	per km	10	84 600	99 800	130 500	104 500	123 700	161 700
54	Footpath provision passenger side (adjacent to road)	Individual	per km	20	47 500	59 900	83 600	93 100	107 000	135 500
55	Footpath provision passenger side (>3m from road)	Individual	per km	20	53 300	75 000	38 000	80 800	91 300	113 000
56	Speed management reviews	Individual	per carriageway km	5	6 400	7 200	8 900	22 800	27 500	37 100
57	Traffic calming	Individual	per carriageway km	10	20 700	24 400	31 500	31 800	37 700	49 700
59	Vertical realignment (major)	Individual	lane km	20	4 750 000	4 750 000	4 750 000	4 750 000	4 750 000	4 750 000
61	Median Crossing Upgrade	Multi	intersection	10	76 000	95 000	133 000	124 100	152 300	209 900
62	Clear roadside hazards (bike lane)	Individual	per km	20	4 400	4 700	5 000	6 200	6 500	7 000
63	Sideslope improvement (bike lane)	Individual	per km	20	10 300	13 100	16 300	12 800	15 200	20 000
64	Roadside barriers (bike lane)	Individual	per km	20	72 800	75 400	77 300	82 700	91 000	107 600
65	Clear roadside hazards (seg MC lane) passenger side	Individual	per km	20	4 400	4 700	5 000	6 200	6 500	7 000
66	Sideslope improvement (seg MC lane) passenger side	Individual	per km	20	10 300	13 100	16 300	12 800	15 200	20 000
67	Roadside barriers (seg MC lane) passenger side	Individual	per km	20	72 800	75 400	77 300	82 700	91 000	107 600
68	Speed management reviews (MC Lane)	Individual	per carriageway km	5	6 400	7 200	8 900	6 400	7 200	8 900

69	Central median barrier (MC lane)	Multi	per km	10	72 800	75 400	77 300	82 700	91 000	107 600
71	Skid Resistance (paved road)	Individual	lane km	10	67 500	77 200	98 600	84 100	97 400	124 000
72	Skid Resistance (unpaved road)	Individual	per carriageway km	10	23 400	27 000	34 800	30 400	35 000	44 800
73	Pave road surface	Individual	lane km	10	99 400	121 500	166 600	125 400	153 500	210 500
74	Street lighting (mid-block)	Individual	lane km	20	109 300	126 900	162 600	142 500	166 300	213 800
75	Street lighting (intersection)	Individual	intersection	20	51 100	59 600	76 100	60 300	69 700	88 700
76	Street lighting (ped crossing)	Individual	unit	20	9 500	10 500	12 400	11 900	13 100	15 500
77	Shoulder rumble strips	Individual	per carriageway km	10	7 100	8 300	9 500	7 100	8 300	9 500
78	Parking improvements	Individual	per carriageway km	20	11 200	12 400	13 800	15 700	17 300	19 300
79	Sight distance (obstruction removal)	Individual	per carriageway km	20	14 500	16 300	19 300	20 000	22 500	27 300
80	Pedestrian fencing	Individual	per carriageway km	20	24 700	26 700	30 400	32 100	34 700	40 000
81	Side road grade separated pedestrian facility	Individual	intersection	20	950 000	950 000	950 000	1 068 800	1 068 800	1 068 800
152	Side road signalised pedestrian crossing	Individual	unit	20	23 800	29 700	35 600	17 800	21 400	23 800
153	Side road unsignalised pedestrian crossing	Individual	intersection	10	4 800	4 800	4 800	4 800	4 800	4 800
163	Footpath provision passenger side (with barrier)	Individual	per km	20	77 000	87 700	109 100	95 000	108 200	134 300
164	Footpath provision passenger side (informal path >1m)	Individual	per km	10	23 800	23 800	23 800	23 800	23 800	23 800
178	Footpath provision driver side (informal path >1m)	Individual	per km	10	10 400	13 500	16 700	12 800	14 700	18 400
177	Footpath provision driver side (with barrier)	Individual	per km	20	10 400	14 500	18 800	12 800	14 700	18 500
174	Footpath provision driver side (>3m from road)	Individual	per km	20	47 500	59 900	83 600	93 100	107 000	135 500
173	Footpath provision driver side (adjacent to road)	Individual	per km	20	53 300	75 000	38 000	80 800	91 300	113 000
171	Shoulder sealing driver side (<1m)	Individual	per linear km	20	77 000	88 100	110 200	95 000	108 400	133 900
172	Shoulder sealing driver side (>1m)	Individual	per linear km	20	23 800	23 800	23 800	23 800	23 800	23 800

182	Realignment (sight distance improvement)	Individual	lane km	20	179 000	214 600	285 900	283 100	342 500	461 200
186	Central median barrier (1+1)	Undivided Only	per km	20	174 000	188 300	216 800	217 600	235 400	270 900
187	Clear roadside hazards (seg MC lane) driver side	Individual	per km	20	4 400	4 700	5 000	6 200	6 500	7 000
188	Sideslope improvement (seg MC lane) driver side	Individual	per km	20	10 300	13 100	16 300	12 800	15 200	20 000
189	Roadside barriers (seg MC lane) driver side	Individual	per km	20	72 800	75 400	77 300	82 700	91 000	107 600
190	Wide centreline	Undivided Only	per linear km	20	6 900	6 900	6 900	8 600	8 900	10 200
191	School zone warning - signs and markings	Individual	lane km	5	8 600	10 200	12 900	11 400	13 400	25 200
192	School zone warning - flashing beacon	Individual	unit	20	8 300	8 300	8 300	8 300	8 300	8 300
193	School zone - crossing guard/supervisor	Undivided Only	unit	1	13 100	13 100	13 100	13 100	13 100	13 100

* Costs are in Euros

Annex 4 – Minimum 3-star safety rating standard

A 3-star EuroRAP/iRAP rating is a minimum target to achieve. For example, the government of the Netherlands has committed to achieving a 3-star minimum for its national roads by 2020. Similar targets are being used in some low- and middle-income countries in contracts for road improvements[5].

Increasing the Star Rating is associated with a decrease in fatal and serious injury crash costs or crash rate – about a halving in the metric by an increase of one star.

The figure below shows this and the resulting dramatic reductions in crash costs at a 3-star rating[6].

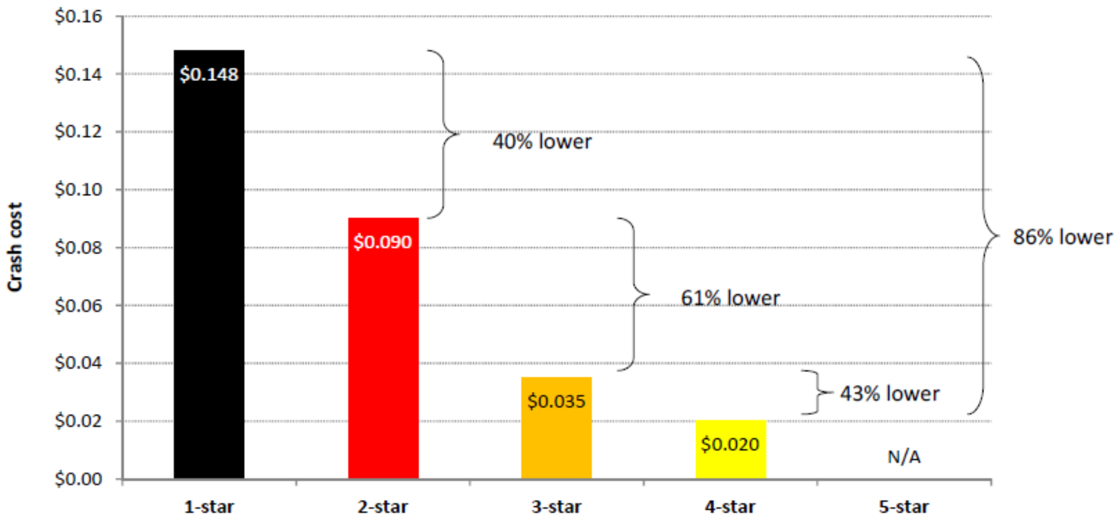


Figure 29 – Smoothed vehicle occupant Star Ratings and fatal and serious injury costs per vehicle kilometre travelled

The latest version of the EuroRAP/iRAP model, released in 2014, makes achieving the 3-star target more difficult than the earlier versions. This recalibration is common in other fields too – for example, in the European New Car Assessment Programme. Recalibration is a way of improving standards through time.

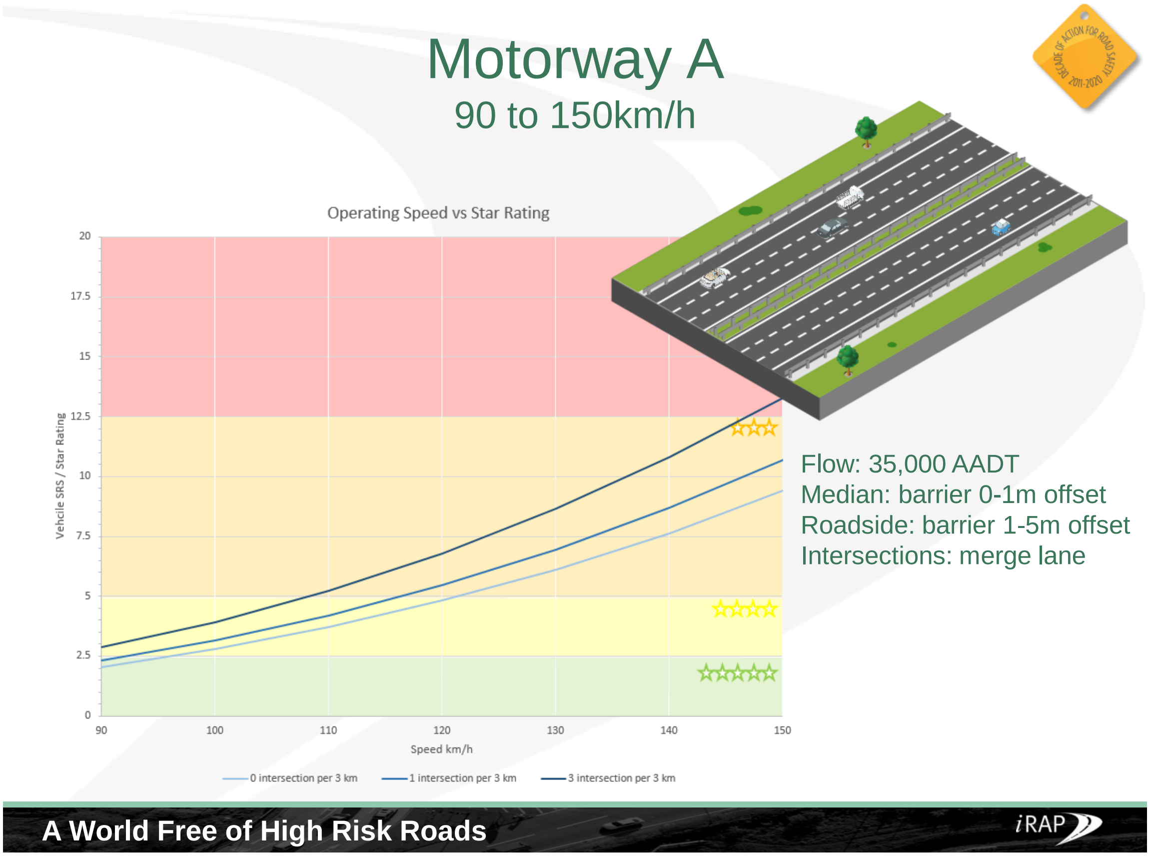
[5] In road improvement contracts, the percentage kilometrage with at least 3-star rating can form part of a results indicator, subject to the availability of economically viable infrastructure countermeasures. At locations where it is not economically viable to lift the Star Ratings to at least 3-stars using infrastructure countermeasures, lowering operating speeds is also be considered.

[6] See http://www.irap.org/en/about-irap-3/research-and-technical-papers?download=91:relationship-between-star-ratings-and-crash-costs-the-bruce-highway-australia and http://www.irap.org/en/about-irap-3/research-and-technical-papers?download=40:crash-rate-star-rating-comparison-paper for further details.

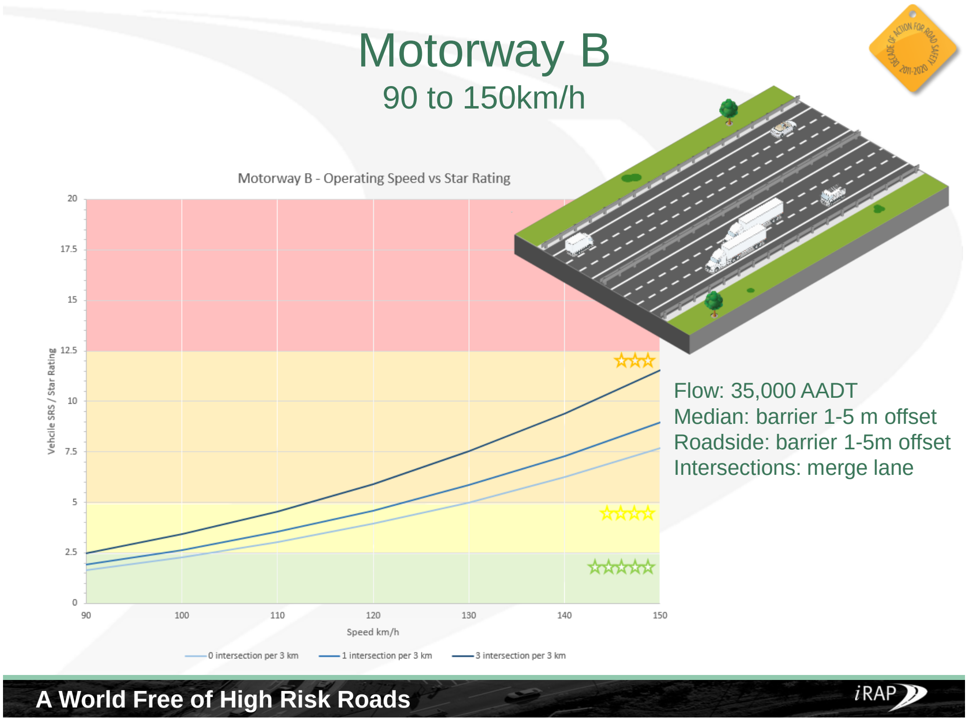
The operating speed of the road is a large factor in determining what the Star Rating will be. Roads are rated at the higher of the 85th percentile operating speed or the posted speed limit[7].

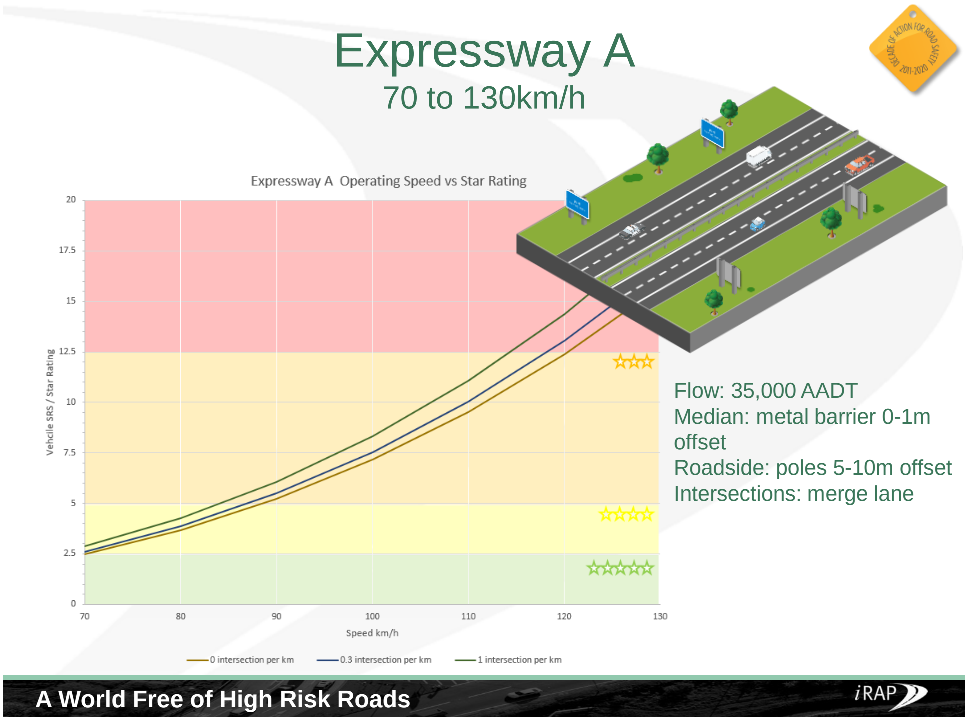
The figures below show the relationship of speed with Star Rating for different scenarios and illustrate the speeds at which a road may achieve 3-star or 4-star rating. Intersection frequency is also a factor.

Figure 30 – Common scenarios of the relationship between speed and Star Rating



[7] An explanation of this is provided at: http://www.irap.org/en/about-irap-3/methodology?download=135:irap-methodology-fact-sheet-7-star-rating-bands and http://www.irap.org/en/about-irap-3/methodology?download=143:irap-road-attribute-risk-factors-operating-speed.





In some situations it is not difficult to see how to increase the safety and the Star Rating of road sections in order to achieve 3-star. Some of the more obvious countermeasures which benefit various road users and have been used in other EuroRAP and iRAP studies to increase the Star Rating include:

- Safety barriers
- Increasing the paved shoulder width on the driver-side between the lane and the barrier
- Turn lanes at intersections
- Roundabouts
- Good delineation, including at curves
- Paved shoulders (especially if they incorporate space for bicycles)
- Footpaths
- Traffic calming