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RADAR – Risk Assessment on Danube Area Roads

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Abbreviation list

AADT	Average Annual Daily Traffic
BBARS	Bulgarian branch Association Road Safety
BCR	Benefit to Cost Ratio
CAD	Computer Aided Design
EU	European Union
EuroRAP	European Road Assessment Programme
FSI	Fatal and Serious Injuries
IMF	International Monetary Fund
PV	Present Value
RADAR	Risk Assessment on Danube Area Roads
RAP	Road Assessment Programme
iRAP	International Road Assessment Programme
RIA	Road Infrastructure Agency
RSEG	Road Safety Expert Group
SARS	State Agency Road Safety
SRIP	Safer Roads Investment Plan
TA	Thematic Area
ToR	Terms of reference
TEN-T	Trans-European Transport Network
WHO	World Health Organization
WP	Work package

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1. Executive Summary

Bulgarian Branch Association Road Safety - BBARS is Project Partner in the RADAR Project – Risk Assessment on Danube Area Roads. As part of the activities set out in Work Package 5 of the Project – Pilot actions, BBARS is responsible for performing Pilot Actions on Thematic Area 1 of the Project – Safer Road Investment Plans (SRIP). The main goal of SRIPs is to improve the overall road safety quality by implementing different types of specific measures, like for example installing roadside barriers and shoulder treatment for reducing run-off accidents

Different stakeholders were involved in the process. BBARS performed the Pilot Action with the supervision and participation of its Road Safety Experts. For best results, the well-established procedures and practices of the international Road Assessment Programme (iRAP) were followed and implemented according to Bulgarian national specifics and for the purposes of the road safety in Bulgaria.

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 of the RAP methodology 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.

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 provided by a road section 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-Star scale. This quantification aims at 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.

The Pilot project, implemented by BBARS, consists of three main parts:

1. Road Sections Selection for further road survey – road accidents statistics analysis of the Bulgarian National Road Network according to National protocols and procedures in order to select appropriate road sections for the survey;

2. Road survey of the preliminary selected road sections as per iRAP methodology, including coding using the iRAP online road safety software platform – VIDA, Star Rating and Safer Roads Investment Plan Analysis and Reporting;

3. Preparing of implementation ready road layout concept based on the SRIP measures and results.

In order to properly select road sections for the road assessment and SRIP preparation (part one of the above-mentioned project steps), a separate report is prepared. It is in Bulgarian language and its main purpose is to provide up-to-date information on road safety in Bulgaria and to additionally serve as a useful part of a methodological tool for creating and / or supplementing effective practices and policies for road safety in Bulgaria. There is an analysis of road safety statistics on the national road network in order to highlight road sections for

further road research and safety assessment. National protocols and procedures are observed - Road Traffic Act, Road Act and Regulation № 5 on the establishment and safety of areas with concentration of road accidents and categorization of road safety, 2011. Upon this, road sections with a total length of about 230 km for further assessment, categorization and preparation of investment plans for road safety are selected.

Next activities were performed by iRap accredited Automobile and Motorcycle Association of Serbia - AMSS-CMV. The selected road sections were inspected and the video survey data was coded according to the iRAP Survey and Coding specification. There are three road sections inspected. The surveyed network is 223.5 km long, but as some divided roads are surveyed in both directions, the survey length is 234,4 carriageway kilometres.

The report prepared by AMSS-CMV – Serbia describes the road assessment project in Bulgaria and includes details on data collection, methodology used and a summary of results in a form of Star Ratings, showing the level of risk on the road network. It also offers Safer Roads Investment Plans which have enormous potential to reduce road deaths and injuries on the inspected roads. iRAP results are available to the project stakeholders who can learn about precise locations where countermeasures should be considered for implementation.

The star rating showed that no road was rated as 5-star for vehicle occupants. Only 4% of the roads scored 4 stars for the car occupant safety. 13% of the network was awarded 3 stars, while 73% of the roads scored only 1 star or 2 stars.

Ratings for pedestrians and bicyclists were even worse. Only 10% of the network scored better than 1-star for pedestrians and only 8% for bicyclists.

Sources of deaths or serious injuries on the inspected network are likely to include:

- lack of run-off protection and hazardous objects close to the road
- inadequate intersection layout, control and marking
- lack of head-on protection
- lack of pedestrian facilities

The most efficient and cost-effective countermeasures include shoulder rumble strips, roadside barriers on both driver and passenger side, shoulder sealing etc.

The results showed that the current state of roads needs improvements in order to achieve the desired level of safety, and to climb higher in the international rating of safety level on roads.

The outputs of this work give support to the decision-makers as well as engineers in the process of identifying the areas of high risk and help them decide how to address these locations. The methodology of measuring the relative risk of various types of accidents based on coded attributes and collected data about the traffic flow proved to be effective in many countries of the world in the framework of the RAP programme.

Final step of the pilot project is the implementation-ready design plan. It consists of CAD files (dwg. drawings) and table, as well as explanatory note for a road section from road I-5 from km 51+560 to km 56+560 was prepared with a length of approx. 5 km. The beginning of the selected section coincides with the beginning of the section assessed. The section was chosen taking into account again the accidents statistic and the geometric characteristics of the road.

2. Introduction

Transport and transport infrastructure are the main engine and necessary prerequisite for development in every aspect of our modern society - economy, communication, social activities, education, healthcare, etc. An efficient transport system is a key factor for better distribution of population, industry, services and income. For years now, road transport has been the leading mode of transportation in Europe, both for passenger and freight transport (fig. 1). For that purpose, along with providing sufficient capacity, comfort, well developed network and road accessibility, it is essential to ensure safe operation for all users. Road Safety is a leading topic not only in European and worldwide national policies in the transport sector, but it is regarded as a socio-economic phenomenon, affecting also mobility, transport costs, environment, social affairs, healthcare and well-being as a whole. Therefore, road infrastructure needs to be designed, built and maintained with a high level of service and safety.

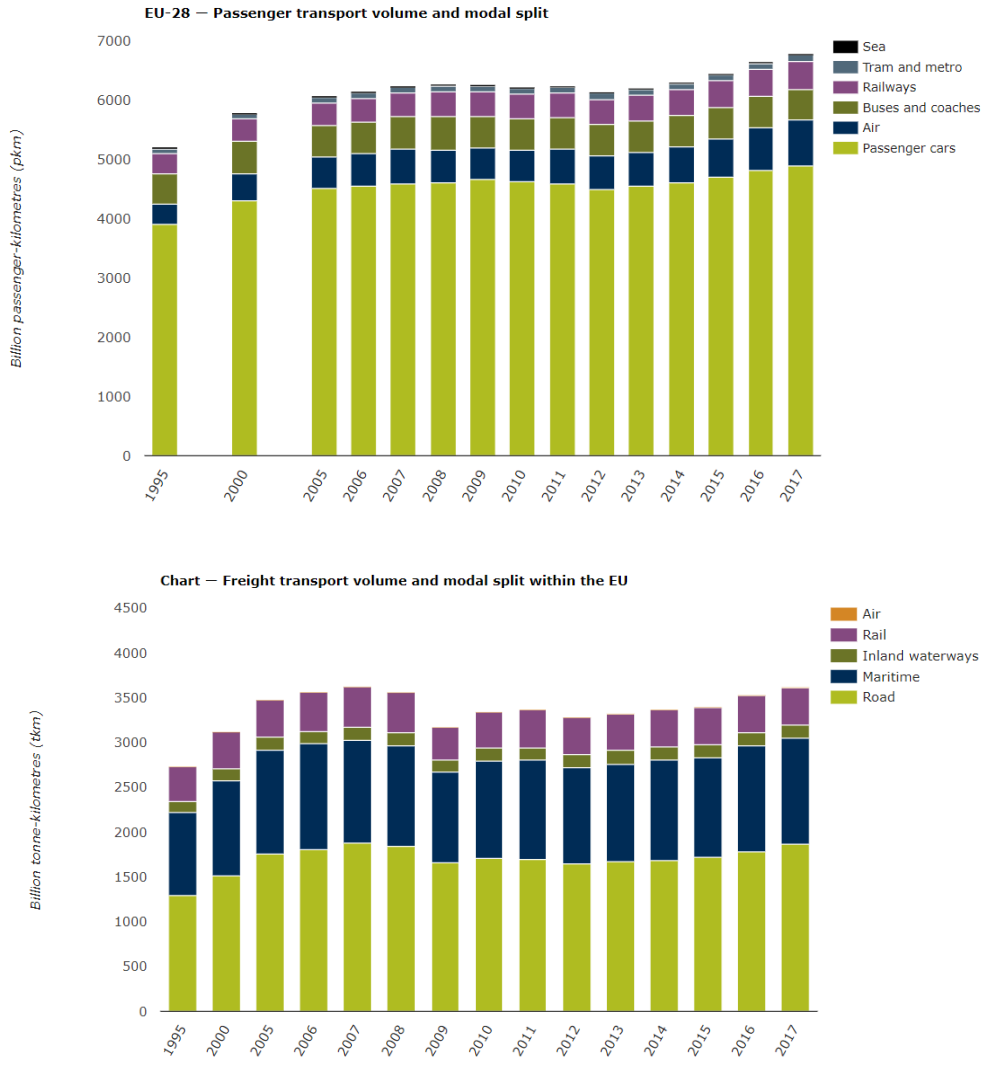


Figure 1 Passenger and freight transport volume and modal split (1)

The European Union is struggling to reduce fatalities and serious road injuries for decades. With various initiatives, public campaigns, research and innovation, the EU is working on the theme of Road Safety with all Member States, supporting them to share their experience and best practices.

Various studies show that in over 90% of road accidents, the main cause is found to be a driver's mistake. However, road infrastructure and road conditions are another main major factor, contributing to road accidents. (2) Therefore, the main priority is the road infrastructure to be designed, built and maintained with a high level of service and safety. Road design in accordance with the basic principles of road safety and subsequently properly maintained roads can reduce the likelihood of accidents, while "forgiving" roads (according to the principles of the "safe system" these are roads where mistakes made by the driver do not lead to serious consequences), may reduce the severity of accidents that occur.

This report is prepared in the framework of the RADAR project (Risk Assessment on Danube Area Roads), which main goal is to improve the safety of road infrastructure in the Danube region by increasing capacity and strengthening transnational cooperation for all road users, including vulnerable road users on the main, secondary and other road networks in the region. One of the main tasks of RADAR is to identify the "built-in" risk of road networks and to offer plans for systematic reduction of this risk by improving the infrastructure and road layout.

Looking at the countries of the Danube region, it appears that large parts of the Danube road network are characterized by poor safety scores, especially for vulnerable road users, and mortality in many countries in the region is higher than the EU average. Many countries do not have the professional capacity and approaches to the problem vary between countries. (3)

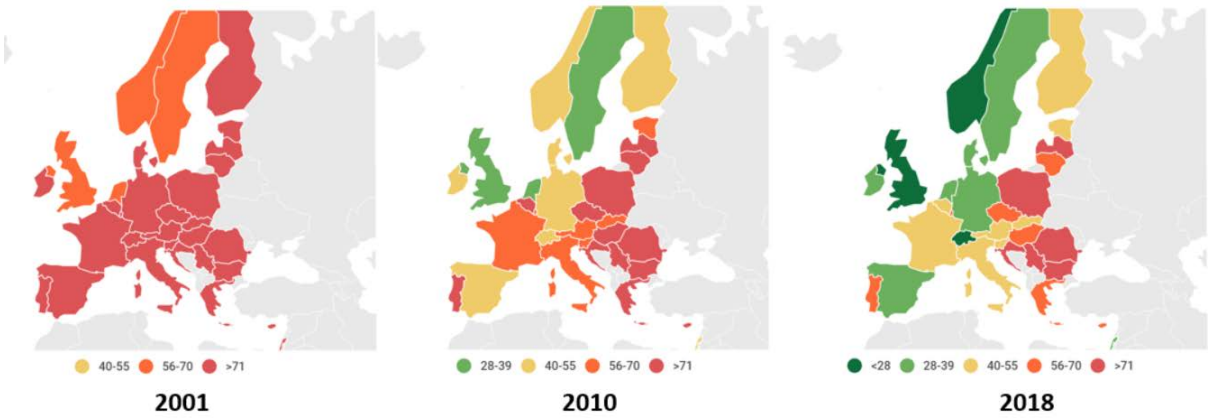


Figure 2 Road deaths per million inhabitants (4)

In the current reality and economic environment, it is particularly important to optimize the use of limited investment funds to improve the condition of roads and road safety, and this is done through the use of the most cost-effective engineering solutions on the most suitable road sections. The main thematic area considered in the framework of the RADAR project and the subject of its Work Package 5 are the Safer Roads Investment Plans (SRIP). (4)

3. Main objectives of the Pilot

As Project Partner, BBARS is responsible for performing Pilot Actions on Thematic Area 1 – Safer Roads Investment Plans. This enables a broad approach of targeting all road users, vehicle occupants, pedestrians, cyclists and motorcyclists simultaneously. The main aim of SRIPs is to improve overall road safety quality by implementing different types of specific measures, like installing roadside barriers and shoulder treatments for reducing run-off crashes. (3)

In order achieve best results, different stakeholders were involved in the process. BBARS performed the Pilot Action with the supervision of Road Safety Experts: national consultations

were made via national professional networks and national representatives of the Road Safety Expert Group RSEG.

BBARS prepared the Terms of Reference in which the three main services needed for accomplishing the pilot project were defined.

1. Service 1: Risk Analysis and Road Sections Selection for further Survey – Road Accident Statistics Survey/ Risk Mapping of the Bulgarian National Road Network according to National protocols and procedures – Road Traffic Act, Roads Act and Regulation No. 5 on the Establishment and Safety of sections with concentration of road accidents and road safety categorization, 2011 or else in order to select Road Section(s) for the further assessment and preparation of SRIP;

2. Service 2: Road survey of the preliminary selected road sections as per international road assessment programme (iRAP) methodology, including coding using the iRAP online road safety software platform – VIDA, Star Rating and Safer Roads Investment Plan Analysis and Reporting;

3. Service 3: Preparing of implementation ready road layout concept/ design plan based on Service 2. (SRIP measures and results).

All these services were performed by different suppliers and a detailed report was prepared for each of them. The Report on Service 1 was prepared by BBARS' road safety experts. It is summarized in chapter 5 of this report, service 2, summed up in chapters 6-8, was procured and then performed by AMSS Serbia and service 3 was accomplished by Bulgarian road designers and is summarized in chapter 9.

Main objective of this final overarching report is to summarize the conclusions and results from the individual services in order to provide a synthesis report for the implementation of the Pilot actions on SRIP in Bulgaria.

4. Risk analysis and selection of road sections for further survey

Report 1 on Service 1 consists of 36 pages and additional annexes with gathered databases. Its main goal is to deliver essential information about road safety in Bulgaria and to serve further as helpful part of a methodology for creating and/or completing efficient road safety practices and policies in Bulgaria. It contains an analysis of road safety statistics and risks on the National road network in order to define Road Sections for further road survey and safety level assessment, according to National protocols and procedures – Road Traffic Act, Roads Act and Regulation No. 5 on the Establishment and Safety of sections with concentration of road accidents and road safety categorization, 2011. These all resulted in a selection of road sections prior to further assessment and preparation of safety road investment plans.

4.1. National Road Network of Bulgaria – Key Features and Statistics

Quantitative and qualitive indicators for the road network, such as road length, AADT, road network distribution, traffic characteristics (speeds, flow density) and pavement condition have a direct impact on traffic flow and respectively road safety, both through engineering and behavioral effects.

Bulgaria is situated on the crossroads between Europe and Asia and in this means its good level of transport infrastructure is essential for international transportation of people and goods.

Two of the corridors of the Trans-European Transport Network (TEN-T) pass through the territory 6 of Bulgaria, namely - Orient-East Mediterranean and Rhine-Danube.

The Rhine-Danube is a water corridor passing through Bulgaria. The Orient-Eastern-Med route coincides mainly with some sections of Bulgarian motorways. It should be noted how important it is that road safety management procedures should cover not only the TEN-T roads on Bulgarian territory, but also the rest of the national and secondary road networks.

The total length of Bulgarian National road network as of 31.12.2019 is 19 853 km. Table 1 presents data on the distribution of National road network by road categories.

Table 1Bulgarian National Road Network

National Road Network lengths according by road category 31.12.2019 (km)		
Category	**Length (km)**	**Relative share (%)**
Motorways	734	3,70%
Expressways	*	
Category I	2954	14,88%
Category II	4025	20,27%
Category III	12140	61,15%
Total	19853	100,00%

*No exact length, because a lot of sections are under construction – new sections or rehabilitation works

Motorways as well as **expressways** provide transport services for large areas, conduct transit traffic over medium and long distances with high intensity and speed. Motorways have emergency lanes and the maximum allowed speed limit is 140 km/h. Expressways do not have any emergency lanes and the speed limit is 120 km/h. Both have intermediate barriers and grade separated intersections, usually 2 or more lanes per direction. As both are part of the Bulgarian national road network, tolls are collected.

Category I roads in Bulgaria are designed for transit traffic over long distances (mainly from border to border). They serve large areas and coincide with the directions of the main transport flows in the country. There are 9 Category I roads in the country, numbered from 1 to 9.

Category II roads in Bulgaria are designed for transit traffic over medium distances. They perform distribution functions in the transport system, consolidating the network of Category I roads and providing optimal routes of transit traffic to individual regions in the country. These roads are numbered with two-digit numbers (from 11 to 99), the first digit shows the number of the Category I road from which it deviates, and the second - the direction of deviation.

Category III roads in Bulgaria are all national roads that do not have the characteristics of motorways or first and second category roads. They serve to distribute traffic within the territories belonging to the roads of higher category, or provide connections between the individual municipalities.

The Road Infrastructure Agency (RIA) classifies the condition of the national road network (motorways, cat. I, II and III roads) on a three-point scale: good, medium and poor condition, according to the "Methodology for measuring and assessing deteriorations on road surfaces", taking into account the type and quantity of the existing damages, measured and assessed in relation to the total area of the assessed surface of the respective road:

- good condition - with damage to the pavements below 10% from the whole national road network;
- average condition - with damage to the pavements from 10% to 30%;
- poor condition - with damage to the pavements of more than 30%.

Following problems have been identified:

- poorly developed network of motorways and expressways;
- presence of insufficient capacity in some sections of the road network;
- poor condition of roads (on average for the country 35% are in good condition, 31% - average condition and 34% are in poor condition).
- Extremely poor condition of the road network in the districts of Vratsa (51%), Sofia (51%), Gabrovo (46%), Montana (45%) and Razgrad (43%).
- tendency to deterioration of the road surface

According to the Summary Report on Road safety in the Republic of Bulgaria (01.07.2019 - 31.12.2019) of State Agency Road Safety - SARS and the SARS analysis of the annual reports on the state of road infrastructure by districts, the following conclusions regarding the status of key other features directly related to road safety can be made:

- Safety Barriers – partly missing. Some of the barriers on national roads do not correspond to BDS EN 1317;
- Delineation - missing or bad quality;
- Traffic signs – there are a lot of places with discrepancies between vertical traffic signs and road markings;
- Road pavements and surfaces - part of the road network is in unsatisfactory condition with diverse deteriorations - open longitudinal joints, transverse, longitudinal and alligator cracking and potholes;

4.2. *European policies for road safety management. Road Safety Categorization and Risk Mapping*

Main European policies for road safety are reviewed in Report 1, including road safety categorization and risk mapping methodologies.

The European Union applies various policies, strategies and tools in the fight against road accidents. Two main approaches have been adopted - "Vision Zero" and "Safe System". Their main presumption is to rethink road safety policy, focusing on a proactive approach - preventing deaths and serious injuries before they happen.

In order to assess the risk of accidents on a given road, there is a vast field of factors and interactions that should be analyzed and evaluated, which is a complex and challenging task.

According to the WHO Regional Safety Report (6), only half of the countries in the European region have conducted standardized assessments for safer road infrastructure. Road safety assessments and star rating can help identify deficiencies in road infrastructure, where assessments can be performed for new and existing roads. More than 90% of the countries in the region require full or partial safety reviews for the design and planning of new road infrastructure. In Bulgaria such road safety audits are obligatory.

In order to successfully monitor road safety levels on a given network and to prioritize sections for taking measures, an effective road assessment program should be implemented.

There is a number of methodologies that exist or are being developed for assessing the safety performance of roads. Most of them are based on inspection of the physical characteristics of the road.

On European level, one of the most popular ones is the one, introduced by the European Road Assessment Programme - EuroRAP.

EuroRAP's Star Ratings are based on road inspection data and provide a simple and objective measure of the level of safety "built-in" to the roads for vehicle occupants, motorcyclists, pedestrians and bicyclists. (7) In order to show the varying level of risk across a road network, individual road sections are allocated into one of five colour coded risk bandings. 5-star roads (green) are the safest and 1-star (black) are the least safe.

Road infrastructure safety management in Bulgaria is based on Directive 2008/96/EC of the European Parliament and of the Council of 19 November 2008 on road infrastructure safety management and includes the following procedures: road safety impact assessment, road safety audit, road network safety management and periodic safety inspections procured or carried out by the Road Infrastructure Agency (RIA). The procedures related to the management of road infrastructure safety are applied to national roads (motorways and roads of first and second category), which are part of the trans-European road network on the territory of the Republic of Bulgaria, regardless of whether they are in the design stage, construction or operation. Road authorities may apply these requirements also for national roads which are not part of the trans-European road network and for municipal roads.

In Bulgaria, there is still no specific methodology for roads infrastructure risk assessment, risk mapping or categorization of the road network according to the established level of safety. Historical accident statistics and other parameters, such as traffic intensity are used in Bulgaria to identify, prioritize and treat high-risk areas. This is a basic approach. Although these sections should be priority sites for funding and implementation of measures, they include only a small part of the network, which is responsible for road accidents with casualties and serious injuries.

Road accidents are normally not evenly distributed along the entire length of the road, and some sections have a higher percentage of risk than others. The frequency of accidents in certain sections of the road depends largely on its shortcomings.

Based on a given accidents frequency, it is possible to determine which roads need significant improvements in order to increase the existing safety level of the road network. The countermeasures application process can then be carried out in accordance with certain priorities, based on the identified risk levels for the individual road sections of the road network surveyed. It is then possible to develop an optimal investment plan that guarantees the investment of available funds in critical sections or elements of the road network in order to achieve the most cost-effective results, namely an improved overall level of road safety and

reduced likelihood for the occurrence of serious and fatal road accidents, including a significant reduction in social and external costs in the overall road transport system. However, the values of the average daily annual traffic intensity for each section of the road must also be taken into account to ensure that appropriate routes are selected for the implementation of the relevant measures.

The information and analysis of road accident statistics as input data for decision-making consider the following indicators:

• number of fatal accidents and accidents with serious injuries;

• intensity of transport flows;

• main types of accidents distribution;

• the number of fatal and serious accidents on different categories roads;

• a certain average frequency of accidents by road category, etc.

From what has been described so far in the report, it is evident that in Bulgaria there is still no specific methodology for risk assessment, risk mapping or categorization of the road network according to its road safety level. Therefore, the selection of sections to be surveyed for the implementation of the project objectives will be based on the analysis of accident statistics and consultations with road authorities and stakeholders.

4.3. Accidents statistics on the Bulgarian national network - Overview 2015-2019

Accident data is usually collected by the police and entered into accident database systems for easy analysis and annual reporting. The collected database in most cases cannot provide enough information to give a complete picture of road injuries or to fully understand the mechanisms of injury. Bulgaria relies mainly on data collected by the traffic police. For the purposes of Report 1, all accidents statistics data is officially provided by Ministry of Interior through the traffic police.

Analysis shows that in Bulgaria there is a tendency for reduction of the number of all accidents that have occurred on the national road network in the last five years. Unfortunately, the same does not apply to the number of injured people, on the contrary, for the last three years there has been an increase in the number of injured in road accidents.

It turns also out that the risk of accidents with severe or fatal consequences is highest on roads of first and second category. In this sense, the selection of sections for the purposes of the pilot project is limited to these road categories. There are nine category I and 44 category II roads in Bulgaria.

The number of killed and injured people on black spots on all category I roads in Bulgaria in the specified period is as follows:

Table 2 Accidents statistics on black spots on category I roads for the period 2015 - 2019

	Total accidents	Killed	Injured
I-1	319	7	63
I-2	20	0	12

I-3	81	1	16
I-4	152	10	63
I-5	374	7	108
I-6	73	6	24
I-7	24	1	7
I-8	4	0	0
I-9	51	0	7

The highest number of accidents with the most injured and a significant number of killed is on road I-5.

In the statistics for black spot locations for years 2016, 2017, 2018, a significant number of accidents is also observed on category II roads II-55, II-54, II-81, II-86, II-26, II-62 etc. and for 2018 on II-21 too.

Road II-55 is worth noting, because besides the fact that there is the highest number of black spot locations over the years, there is also the highest number of accidents, the number of killed and injured and a high relative accident rate.

4.4. Road Sections to be surveyed

Bulgaria's associated partner in the Radar project is the Road Infrastructure Agency. Directly related to road safety is the activity of the State Agency for Road Safety, which main goal is to pursue an active policy to improve road safety in the Republic of Bulgaria by ensuring coordination among institutions, as well as between institutions and society, in order to take adequate measures, based on prevention, objective and systematic analysis, in order to significantly reduce the adverse effects of road traffic accidents. For the implementation of the conditions and objectives of RADAR's WP 5, preliminary consultations were held with both agencies. A formal inquiry has been sent and a joint meeting has also been held. As a result, the following priority road sections for further survey and analysis were defined:

- Road I-5 Ruse – Byala from km 6+700 to km 56+200, total length = 49,5 km
- Road II-55 from km 0+000 to km 57+800, total length = 57,8 km
- Road I-1 Vidin – Vratsa, total length = 145 km
- Road I-4 Sofia – Varna, undefined length
- Road II-21 Ruse – Silistra, total length = 124 km

These sections are selected on the basis of high average annual daily traffic - AADT, including heavy vehicles, the presence of a significant number of black spots, including those with recurrence, respectively high relative accident rates, which is evident from the accident statistics described in the previous point. The above-cited sections also stand out from the analysis of the statistics of road traffic injuries.

Because of the limited budget, available for the Pilot and some other considerations about soon expected maintenance activities on some of the sections, the final choice was:

- Road I-5 Ruse – Byala from km 6+700 to km 56+200, total length = 49,5 km
- Road II-55 "Pass of the Republic" from km 0+000 to km 57+800, total length = 57,8 km
- Road II-21 Ruse – Silistra, total length = 124 km

total Length of the road sections object to the survey was **231, 3 km**.

In Report 1 and its Annex 2, there is information about the current condition of the sections, geometric characteristics, AADT and possible reasons for the high number of traffic accidents.

4.5. General description of the selected road sections

According to the Summary Report Road Traffic Safety and transport situation in the Republic of Bulgaria (01.07.2019 - 31.12.2019) of SARS (8) the annual average daily traffic (AADT) on Road I-5 in the sections between Ruse and Byala and between Veliko Tarnovo and the connection with Road I-4 - is over 9,800 vehicles per day, about 2,200 of which are heavy vehicles. Probable causes of the increased number of accidents are improper overtaking and speeding, poor condition of the roadside area, poor visibility (uncleaned grass and bushes). Increased freight traffic causes a higher risk of accidents involving trucks, which often have very serious consequences.

Road II-55 in the section between Veliko Tarnovo and Gurkovo (Pass of the Republic) - the pass is preferred by a large number of vehicle drivers due to the recent rehabilitation of the road and the better road conditions. On average, about 5,100 vehicles pass daily. More than 2,000 of them are heavy ones. Possible reasons for the increased number of accidents are loss of control over the vehicle due to improper driving with the high incline of the road when descending, entering the oncoming lane, as well as driver fatigue. Increased heavy traffic leads to a higher risk of accidents involving trucks, which often have very serious consequences.

Road II-21 in the section between Ruse and Silistra - the road is the connection between two regional towns with an AADT of 6,000 vehicles, 20% of which are heavy vehicles over 12 tons. It is characterized by increased road accidents, where most of the accidents occurred in the area of the intersection with the main road I-7. As the secondary road is congested, some drivers are mistaken and do not follow the established organization of traffic with road signs.

More detailed data about the traffic intensity and road widths can be found in the annexes form the databases of the project.

5. Road survey

The selected road sections were assessed according to the iRAP methodology, a Star Rating was made and an investment plan (SRIP) with specific countermeasures was prepared. All these activities were performed by AMSS - Centar za motorna vozila d.o.o. - Serbia, and there is a separate report in the framework of WP 5.

Due to the Covid-19 global pandemic, there was a little delay compared to the initial schedule. The survey was carried out on 04-05.-8.2020. 23 km less than originally planned were assessed, as in the section of the road I-5 Ruse - Byala at that time repair works (Figure 3) were carried out.

Figure 3 Road works on Road I-5

5.1. Methodology

As already mentioned earlier, the main objective of the project is to select appropriate road sections and further assess their safety level and build capacity for a sustainable road safety inspection and maintenance and network safety management.

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 the 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. Projects receive support from the World Bank Global Road Safety Facility, mobility clubs, regional development banks and donors.

National governments, automobile clubs and associations, charities, automotive 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 of the RAP methodology 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 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 provided by a road section 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-Star scale. This quantification aims at 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. (5)

5.2. Measuring the road infrastructure safety

The assessment of the road safety requires 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 recording 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: drive-through and video-based inspection. During the first one, recording of the infrastructure's elements is performed manually, with the help of the specialized software, while during the second type of inspection, a specially equipped vehicle is used, so that the recorded video could be used for a virtual drive-through of the network and an automated identification of the infrastructure's elements.

Following the survey, 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 road segments of 100 meters each. Road user types include the following vulnerable road users: car occupants, motorcyclists, bicyclists and pedestrians, who may be involved in road accidents. The respective RPS is calculated for each road user type and each of the 100m road segmentation, in the following way:

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

where "n" is the number of 100 m 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: Likelihood that the "i" crash may be initiated, S: Severity of the "i" crash, OS: Degree to which risk changes with the Operating Speed for the specific "i" crash type, EFL: 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: Potential that an errant vehicle will cross a median (Median Traversability).

5.2.1. The Star Rating process

The aim of the Star Rating process is awarding the "n" 100m road segments with Stars, depicting the safety offered to each of the "u" road user 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-star 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 the 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) of 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).

5.2.2. Developing the Safer Roads 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 100 m road segment, on an annual basis, if 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 100 m 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 in 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 on 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 in a 100 m road segment is the function of the $F_{n,u,c}$ 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 the appropriate data are missing, 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 and Dahdah (2008).

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 in order to reduce the rate of fatalities and serious injuries. Each countermeasure is characterized by its trigger sets and its effectiveness for each of the 100 m 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, with the aim of calculating 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.

5.3. Data collection

The survey was carried out using the CAMSS digital imaging system with three high resolution cameras (1280 x 960 pixels), manufactured by the AMSS-CMV. Together, the three cameras recorded a panoramic view of the road and roadside verges in front of the vehicle. The image was sufficiently wide to identify intersections, roadside usage and also roadside hazards. These images were collected every 10 meters of travel. The cameras were also calibrated to allow the measurement of particular features of the road, such as lane and shoulder widths and distance to roadside hazards which are important components in the safety assessment of the road. (5)

After the completion of the road inspection phase, the process of coding of video material took place. The coding of the roads was undertaken by the AMSS-CMV.

The coding of the recorded video material was carried out on the basis of the iRAP Star Rating Coding Manual. The coding staff used the coding software to rate road infrastructure features at 100-meter intervals along the road.

Traffic volumes, pedestrian and bicycle volume, operating speed and crash data are also used for the purposes of this RAP method.

5.4. Countermeasure cost

The iRAP model requires inputs concerning local construction and maintenance costs for the 70 potential countermeasures that are considered when developing the Safer Roads Investment Plans. The costs are categorized by area type (urban, semi-urban and rural) and upper and lower costs (low, medium and high).

The countermeasure cost estimates used in this study are attached in Appendix 1 of the SRIP Report.

5.5. Economic data

RAP uses a standard approach globally to estimate the economic cost of deaths and serious injuries. The economic data were collected from the International Monetary Fund - IMF and other websites in the prescribed manner.

Table 3 Economic data

Category	Units / Description	Data
Current year		2020
Assessment Year	Year in which the analysis was carried out.	2020
Side of the road driven on	Left or right	right
Analysis period	Years - default 20 years	20
GDP per capita	In local currency (current prices)	16,416
Discount rate (%)	%	4
Minimum attractive Rate of Return	Discount Rate / 100 or user defined	0.04
Internal Rate of Return	%	0.12
Value of Life Multiplier	Default 70	70
Value of Life	In local currency – Official National Figure or (GDP per capita * Value of Life Multiplier)	1,149,120
Value of Serious Injury Multiplier	Default 0.25	0.25
Value of Serious Injury	In local currency – Official National Figure or (Value of Life x Value of Serious Injury Multiplier)	287,280
Serious injuries to fatalities ratio		10

5.6. Results from the survey

A detailed condition report is a constituent part of any road assessment survey and report and is therefore important for all the stakeholders. The attributes obtained on the basis of survey data are listed in the original SRIP Report.

AMSS' coding team assessed the condition of more than 30 road infrastructure elements, at 100 metre intervals throughout the network. This assessment shows that the network mainly consists of single carriageway roads (90%) and another 10% with divided lanes, traversing mainly rural/open areas (98%).

Throughout the network, lanes are wider than 3.25 metres (99%). Shoulders are paved (53%) and sealed and are 0 to 1 m wide (narrow), on the passenger's side (52%).

Many of the roads traverse rural terrain, which is reflected by the fact that (77%) of the roads have straight or gentle curves. The majority of the road network length has unprotected fixed objects close to the travelling lanes.

The most common type of intersections is 3 and 4-leg (unsignalised) with no protected turn lane.

The maximum posted speed limits are mostly 90 km/h (63%), whereas the speed of the remaining roads is generally posted at 60km/h.

As for the pedestrian facilities, they do not exist in 99% of the inspected roads, i.e. there is a very small number of unsignalized pedestrian crossings, with or without refuges and grade separated facilities. The same goes for bicyclist facilities.

When it comes to hazardous objects, such objects are recorded in about 80% of the surveyed road network. These objects include poles of a diameter greater than 10cm, unprotected barrier ends, steep slopes and trees.

6. Road safety assessment results

Based on the analysis of the coded survey data and safety indicators, i.e., background data, the roads are Star Rated for safety using the iRAP methodology. Star ratings are given for the following road user categories: vehicle occupants, motorcyclists, pedestrians and bicyclists.

6.1. Overall Star Ratings Results

The overall Star Ratings for the road sections assessed are shown below in *Table 4*.

1-star roads are those with the highest risk and 5-star roads have the least risk.

Table 4 Star Rating results of the inspected network

	Vehicle Occupant		Motorcycle		Pedestrian		Bicycle	
Star Ratings	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent
5 Stars	0.0	0%	0.0	0%	0.0	0%	0.0	0.%
4 Stars	10.2	4.35%	9.1	3.88%	0.5	0.21%	2.1	0.9%
3 Stars	29.3	12.50%	17.8	7.59%	4.8	2.05%	2.5	1.07%
2 Stars	54.1	23.08%	36.7	15.66%	18.20	7.76%	15.4	6.57%
1 Star	117.2	50%	147.2	62.8%	12.7	5.42%	13.9	5.93%
Not applicable*	23.6	10.07%	23.6	10.07%	198.2	84.56%	200.5	85.54%
Totals	234.4	100%	234.4	100%	234.4	100%	234.4	100%

The results show that no section on the 234.4 km long surveyed network was awarded 5 stars for vehicle occupants. Only 4% of the sections scored 4 stars for the car occupant safety. 12.5% of the network was awarded 3 stars, while 60% of the roads scored only 1 star or 2 stars.

10% of the network was rated as not applicable due to major roadworks on it, so Star Ratings were not generated for these segments of road.

It is evident that the rated road sections for the vulnerable road users were awarded poor rating, especially in terms of pedestrian safety which turned out to be very low.

The Star Rating results (vehicle occupants) from the table above are also shown on the Star Rating maps in the following chapters.

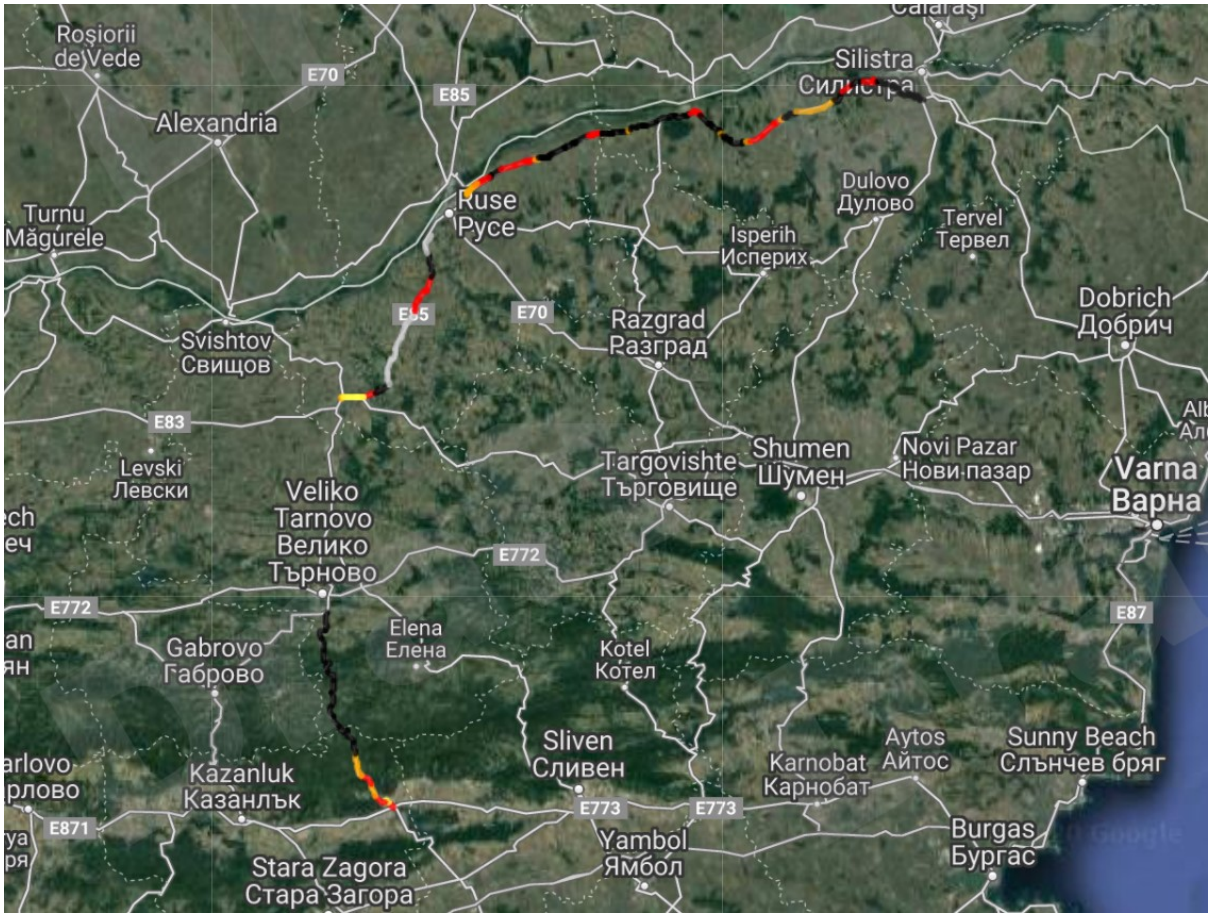
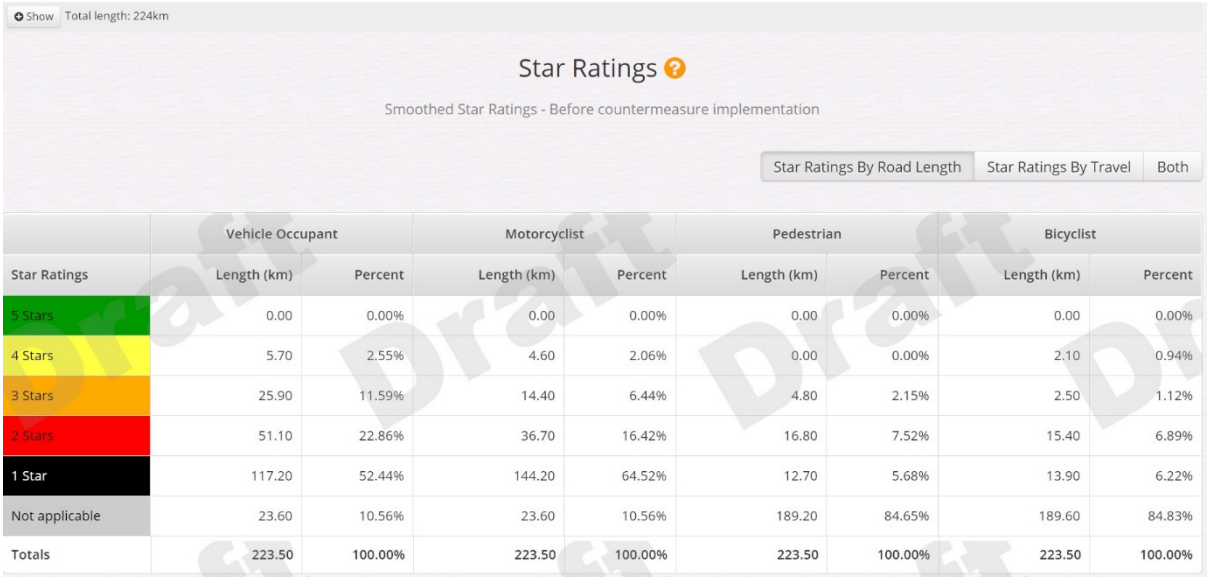


Figure 4 Star Rating Map for vehicle occupants

Detailed explanations of the Star Rating results for all surveyed sections can be found in the original SRIP report.


Show Total length: 224km

Star Ratings

Smoothed Star Ratings - Before countermeasure implementation

Star Ratings By Road Length | Star Ratings By Travel | Both

	Vehicle Occupant		Motorcyclist		Pedestrian		Bicyclist	
Star Ratings	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent
5 Stars	0.00	0.00%	0.00	0.00%	0.00	0.00%	0.00	0.00%
4 Stars	5.70	2.55%	4.60	2.06%	0.00	0.00%	2.10	0.94%
3 Stars	25.90	11.59%	14.40	6.44%	4.80	2.15%	2.50	1.12%
2 Stars	51.10	22.86%	36.70	16.42%	16.80	7.52%	15.40	6.89%
1 Star	117.20	52.44%	144.20	64.52%	12.70	5.68%	13.90	6.22%
Not applicable	23.60	10.56%	23.60	10.56%	189.20	84.65%	189.60	84.83%
Totals	223.50	100.00%	223.50	100.00%	223.50	100.00%	223.50	100.00%

Figure 5 Star Ratings before countermeasure implementation

After processing the data and preparing the investment plan for all surveyed sections, a total of 25,628 countermeasures have been prescribed to improve road safety. More detailed information can be found in the SRIP report, which is delivered in English language.

7. Safer Roads Investment Plan

7.1. Overview of the method

To enable economic evaluation of various countermeasure options, an estimate of the number of deaths and serious injuries under existing conditions on each 100 m section of road was made. As discussed earlier, it is estimated that 29 deaths occur each year on the surveyed roads in Bulgaria. Since the number of deaths was available only in aggregate form the deaths and serious injuries needed to be distributed among the 100 m sections of road, the number distributed to each section was a function of the product of each section's Star Rating Score and exposure (in the case of vehicle occupants, exposure is measured as the annual average daily traffic). Hence, it is feasible that a road with a 1-star rating (indicating high risk) can still experience very few deaths if its traffic volume is low, and vice versa.

For each 100 m section of road, a series of countermeasures that could be feasibly implemented were identified. This was achieved by considering each countermeasure's ability to reduce risk (using a series of 'triggers') and 'hierarchy' rules.

Each countermeasure option identified was then subject to a BCR (Benefit-Cost Ratio) analysis. Countermeasures that failed to achieve a BCR that met a prescribed threshold for a given 100 m segment were excluded from the analysis. The benefit of a countermeasure was determined by calculating the net present value of deaths and serious injuries that would be avoided over twenty years if the countermeasure was installed (a discount rate of 4% was used). The cost of a countermeasure was determined by calculating the net present cost of constructing and replacing it (based on its service life) over 20 years.

7.2. Investment plan

The basic output of the RAP method is the Safer Roads Investment Plan. The SRIP presents all the countermeasures that proved to be able to provide improved safety and maximize the benefit over spent cost of the planned investments. The cost of each countermeasure is compared to the

value of lives and serious injuries that could be saved. The Benefit to Cost Ratio (BCR) is calculated for each countermeasure proposed. It has to be mentioned that the countermeasures listed are indicative and will need to be assessed and sense-checked with local engineers.

Table 5 The Safer Roads Investment Plan

Currency: BGN

Total FSIs Saved	Total PV of Safety Benefits	Estimated Cost	Cost per FSI saved	Program BCR
4 059	288 158 264	136 292 283	33 575	2

Countermeasure	Length/ Sites	FSIs saved	PV of safety benefit	Estimated Cost	Cost per FSI saved	BCR
Additional lane (2+1 road with barrier)	89.70 km	1.124	79.802.084	27.766.000	24.699	3
Roadside barriers – passenger side	90.10 km	541	38.387.448	36.040.000	66.645	1
Roadside barriers – driver side	60.90 km	350	24.823.811	24.360.000	69.660	1
Shoulder sealing passenger side (>1m)	147.50 km	192	13.623.534	5.533.600	28.833	2
Shoulder rumble strips	96.9 km	188	13.378.938	3.367.080	17.865	4
Delineation and signing (intersection)	55 sites	176	12.483.911	2.912.329	16.560	4
Shoulder sealing driver side (>1m)	127.40 km	155	10.978.569	4.628.000	29.924	2
Improve delineation	76.70km	138	9.829.490	5.459.793	39.429	2
Impove curve delineation	36.90 km	135	9.590.089	2.057.899	15.233	5
Clear roadside hazards - driver side	54.50 km	130	9.252.817	744.400	5.711	12
Footpath provision driver side (adjacent to road)	20.60 km	129	9.134.016	3.336.000	25.926	3

Footpath provision passenger side (adjacent to road)	20.00 km	126	8.928.165	3.178.600	25.272	3
Clear roadside hazards - passenger side	50.70 km	125	8.896.174	672.400	5.365	13
Refuge Island	107 sites	69	4.874.442	3.585.707	52.218	1
Protected turn lane (unsignalised 3 leg)	11 sites	62	4.423.058	2.211.745	35.497	2
Side road unsignalised pedestrian crossing	5 sites	54	3.849.702	26.809	494	144
Street lighting (mid-block)	1.10 km	53	3.778.870	2.490.400	46.782	2
Centreline rumble strip / flexi post	22.60 km	49	3.472.732	1.390.718	28.428	2
Pedestrian fencing	0.80 km	44	3.143.442	616.000	13.911	5
Central hatching	53.00 km	39	2.767.767	1,235.896	31.698	2
Roundabout	4 sites	33	2.368.943	1.440.000	43.150	2
Sideslope improvement – driver side	12.70km	31	2.185.045	428.000	13.905	5
Street lighting (intersection)	2 sites	29	2.037.525	1.128.000	39.299	2
Sideslope improvement – passenger side	10.40 km	24	1.700.134	379.600	15.850	4
Unsignalised crossing	51 km	18	1.287.558	288.197	15.889	4
Upgrade pedestrian facility quality	6 sites	18	1.252.324	201.068	11.397	6
Bicycle lane (on road)	24.10km	13	932.621	671.000	51.073	1
Parking improvements	1.90 km	12	837.984	120.400	10.199	7
Traffic calming	0.1 km	2	116.155	5.362	3.277	22
School zone warning – flashing beacon	1 sites	0	20.915	17.280	58.649	1
		4.059	288.158.264	136.292.283	33.575	2

Deaths and serious injuries	Deaths (per year)	Deaths and serious injuries (per year)	Deats and serious injuries (20 years)
Before Countermeasures	29	318.9	6.150
After Countermeasures	10	108.2	2.091
Prevented	19	210.7	4.059
FSI reduction	66 %		
Program BCR	2,0		
Cost per death and serious injuries prevented	33 575 BGN		

According to the investment plan, the total cost of the engineering measures is 136 292 283 BGN, while the present value of safety benefits amounts to 288 158 264 BGN. If the SRIP is implemented, the estimated number of FSI saved will be 4 059 in the next 20 years, i.e. 33,575 BGN per FSI saved.

The top five most efficient and cost-effective measures that could help save the greatest number of lives include the following identified solutions: Shoulder rumble strips, Roadside barriers – driver side, Roadside barriers – passenger side, Shoulder sealing passenger side (>1m), Additional lane (2+1 road with barrier).

The Star Rating results after adopting all the proposed countermeasures are presented in the next figures.

Table 6 Star Rating after implementation the SRIP

	Vehicle Occupant		Motorcycle		Pedestrian		Bicycle	
Star Ratings	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent	Length (km)	Percent
5 Stars	40.6	17.32%	0.0	0.00%	0.0	0.00%	0.0	0.00%
4 Stars	98.7	42.11%	39.3	16.77%	28.8	12.29%	2.9	1.24%
3 Stars	71.5	30.50%	165.5	70.61%	6.6	2.82%	18.7	7.98%
2 Stars	0.0	0.00%	6.0	2.56%	0.7	0.30%	10.5	4.48%
1 Star	0.0	0.00%	0.0	0.00%	0.1	0.04%	1.8	0.77%
Not applicable *	23.6	10.07%	23.6	10.07%	198.2	84.56%	200.5	85.54%
Totals	234.4	100.00 %	234.4	100.00 %	234.4	100.00 %	234.4	100.00 %

It is clear that the SRIP would improve the road network safety significantly. For vehicle occupants, the number of 1 and 2-Star high-risk roads would decrease to a great extent, whereas the 5-Star roads would be present in 17% of the network. Practically all road network will be minimum 3-star. There are improvements in bicyclists' and pedestrians' safety as well. However, the effect of the SRIP on these user groups is relatively lower than on vehicle occupants.

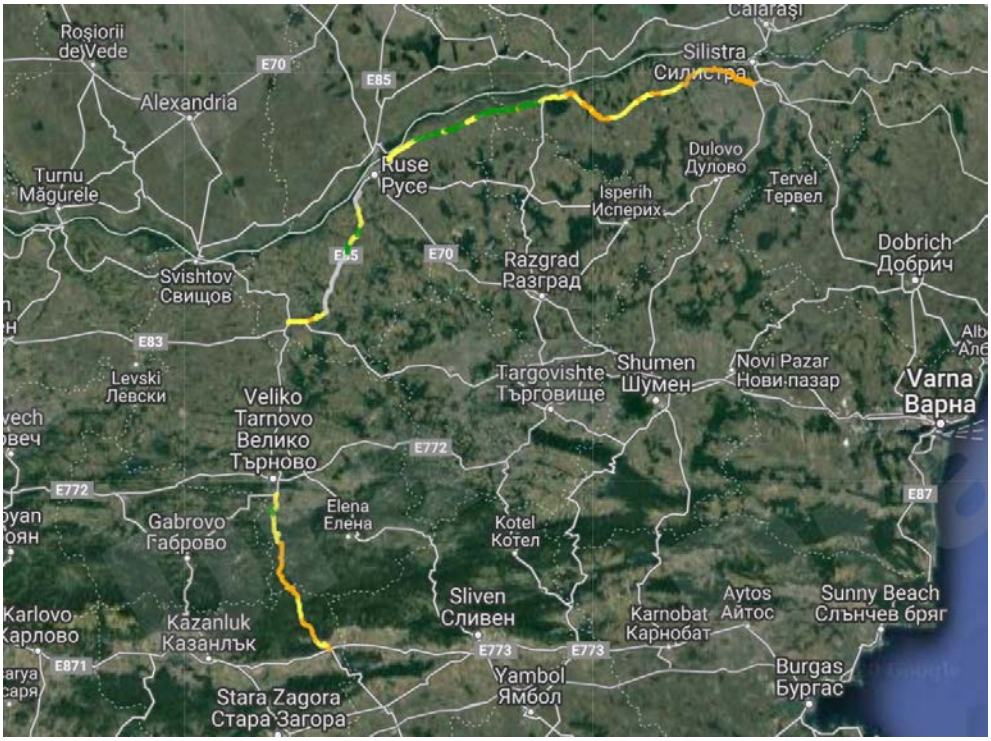


Figure 6 Star Rating map for vehicle occupants after implementing the SRIP

8. Implementation ready design plan

As final result from the Pilot an implementation ready design plan, consisting of CAD files (dwg drawings) and tables, as well as explanatory note for a selected road section had to be prepared.

The road section was selected by the road safety experts from BBARS. For that purpose, the accidents statistic was reviewed once again.

As seen in 3.4. road 1-5 is the one with the highest number of accidents. Besides there is high intensity of the traffic and several number of black spots sections with repetition over the years. The whole statistic can be found in the database for the project.

Table 7 Black Spots statistics in the Municipality of Ruse 2016-2018

year	Road Category	Black spot beginning point	Black spot end point	Black spot length	AADT	Number accidents	Killed	Injured	Ur
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
16 r.	I-2	27+800	28+100	300	7 468	7	0	7	8,54
17 r.	I-5	9+000	9+600	600	10 513	9	0	0	3,91
18 r.	I-5	9+850	10+150	300	10 265	6	0	2	5,34
17 r.	I-5	10+800	11+400	600	8 759	11	1	9	5,73
18 r.	I-5	10+850	11+150	300	9 098	6	0	4	6,02
16 r.	I-5	12+000	12+500	500	8 746	10	0	4	6,25
17 r.	I-5	12+000	12+600	600	8 759	8	0	6	4,17
16 r.	I-5	13+000	13+500	500	8 746	7	0	1	4,37
18 r.	I-5	17+000	17+300	300	9 098	8	0	5	8,03
16 r.	I-5	22+000	22+200	200	8 540	7	0	0	11,20
16 r.	I-5	46+000	47+000	1 000	7 221	11	3	4	4,16
16 r.	I-5	48+000	49+000	1 000	7 221	14	1	7	5,30
17 r.	I-5	51+600	51+900	300	7 800	9	0	1	10,54
16 r.	I-5	51+800	52+000	200	7 221	42	0	7	79,46
18 r.	I-5	51+800	52+100	300	9 818	11	0	1	10,23
17 r.	I-5	51+900	52+200	300	7 800	29	0	3	33,95
18 r.	I-5	56+000	56+300	300	9 818	6	0	0	5,58
18 r.	II-21	0+900	1+200	300	6 736	5	0	1	6,78
18 r.	II-21	1+800	2+100	300	6 736	5	0	2	6,78
18 r.	II-21	5+900	6+200	300	6 736	5	0	6	6,78

It is obvious in Table 7, that the section between km 51+000 to 58+000 is the one with highest number of accidents and black spots over the observed years.

The conducted road survey of road I-5 starts at km 51+860. The selected road section for the preparation of an implementation ready design plan begins therefore at km 51+860 and ends at 56+560 with an approximate length of 5 km. It includes more than one black spot.

8.1. I-5 (Byala – Ruse) – Overall information from the Road survey results

This section starts at Byala and ends in Ruse. The main terrain of this section is rural-undeveloped. It is a single carriageway road, of a total length of about 50 km and a short part (5 km) of dual carriageway. The traffic flow on this section is 5,000 - 10,000 vehicles per day. Median type on 90% of the section is central line only, the number of lanes is one, or two and one, and the lane width is mainly over 3.25 m.

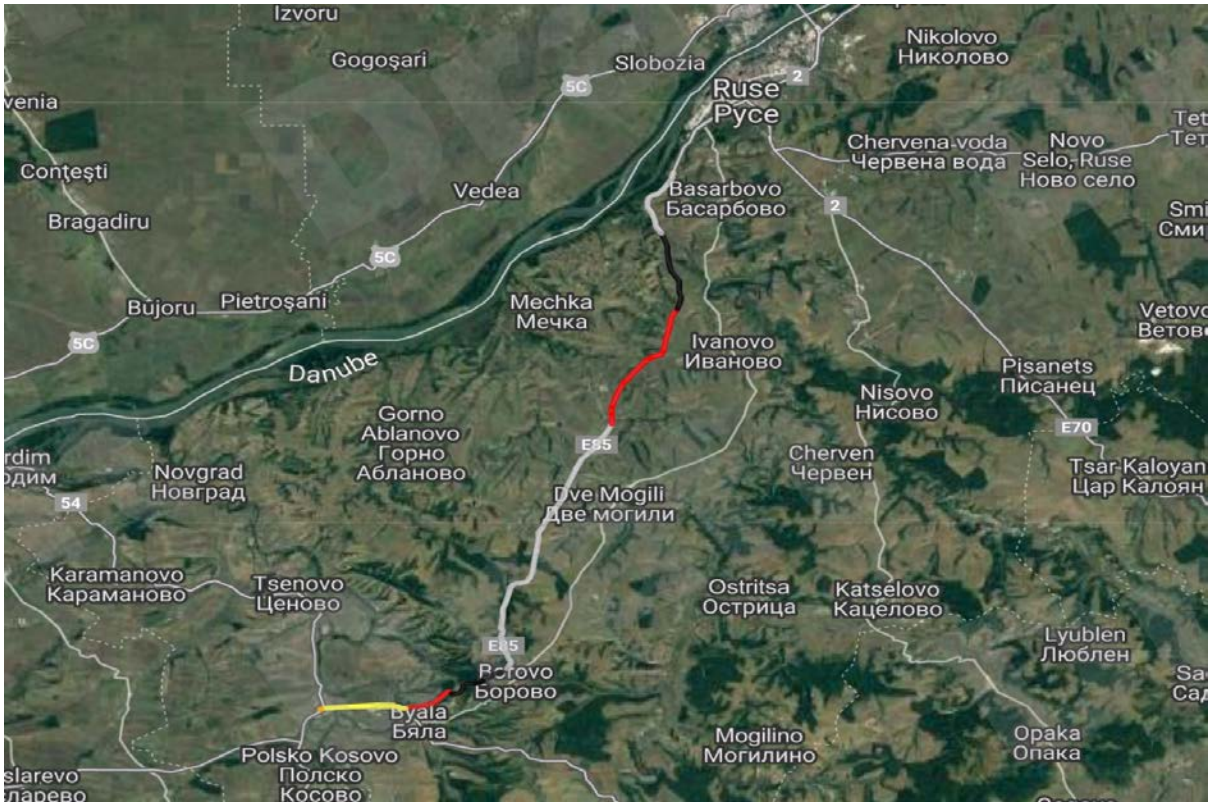


Figure 7 Vehicle Occupant Star Rating map – before countermeasures are implemented

Table 8 Star Rating table – before countermeasures are implemented

	Vehicle Occupant	
Star Ratings	Length (km)	Percent
5 Stars	0.0	0.00%
4 Stars	4.6	9.24%
3 Stars	0.3	0.60%
2 Stars	12.0	24.10%
1 Star	9.3	18.67%
Not applicable*	23.6	47.39%
Totals	49.8	100.00%

As seen on the above table, the Star Rating results of this particular road are quite poor. More than a 40% of the section scored 1-2 stars for vehicle occupants' safety. The results for the pedestrians and bicyclists are almost the same as for vehicle occupants, i.e. almost 80% of the section scored 1-star. To illustrate the risk distribution along the road, a specific ViDA tool can be used – the Risk Worm - *Figure 8*

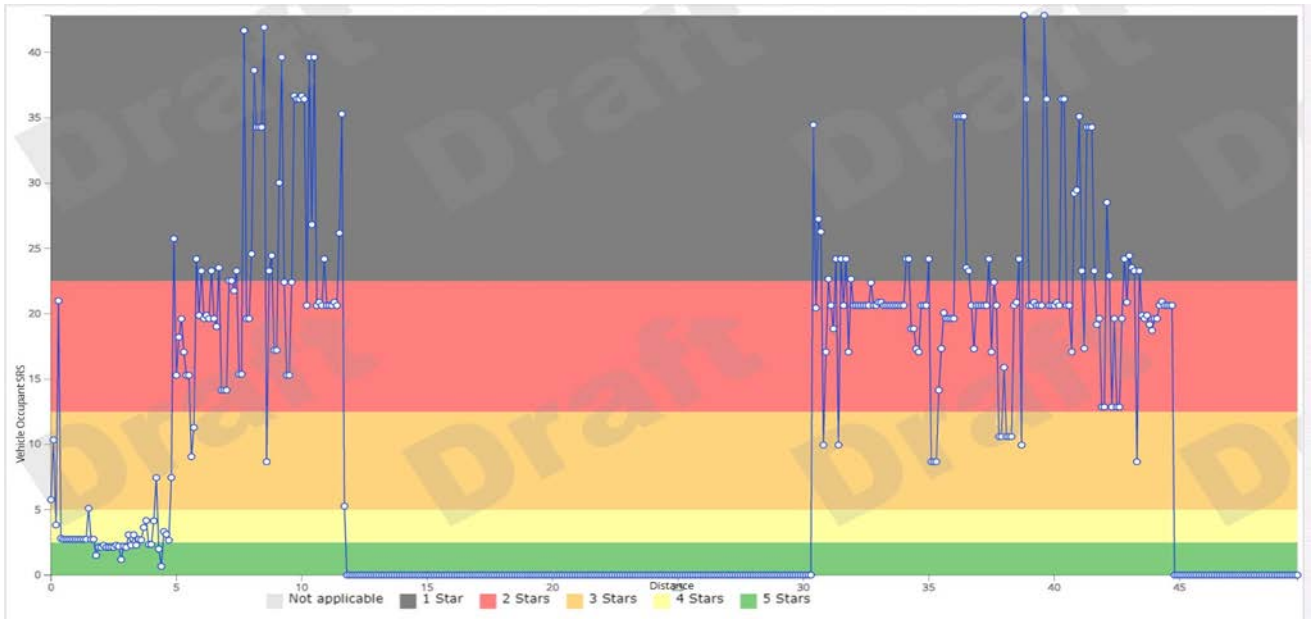


Figure 8 Risk Worm for the section I-5 (raw data)

Examples of the locations with high-risk distribution are shown on pictures below.

Figure 9 "Informal" intersection on the section I-5

The example above shows an 'informal' crossing intersection through the median, together with dangerous objects on the driver side (poles).

Figure 10 Dangerous objects (trees) on the section I-5

8.2. Black spots Road I-5, from km 51+860 to km 56+560

8.2.1. Black spot from km 51+800 to km 52+100 (51+900 – 52+200; 51+600 – 51+900)[1]

The black spot is mainly situated in an intersection. The intersection is before km 51+860. The annual average daily traffic is 9 000 vehicles/day. This road section is registered as black spot for first time in year 2015 with 89 accidents in total and 7 injured people. It is registered as black spot after a roundabout was built.

From the on-site inspection it could be noted, that:

- Mainly in a roundabout;
- Road sign A40 is missing; there are too many road signs, leading to confusion;
- The signs for the roundabout intersection begin at 2 km before it;
- The pavement is in good condition
- Shoulders in bad condition
- Many accidents due to driver's error;
- Deficiencies in the geometric design of the roundabout, because many of the accidents occurred after the vehicle has left the lane and entered the island of the roundabout.

[1] https://www.google.at/maps/@43.46805,25.7261749,3a,75y,120.08h,65.96t/data=!3m6!1e1!3m4!1sJTcC7wg9iwN9vaO71z2uTQ!2e0!7i13312!8i6656

Figure 11 On-site inspection 51+800 to km 52+100

8.2.2. Black spot from km 56+000 to km 56+300[2]

The black spot is situated in a straight section of the road. The AADT is 10 500 vehicles/day.

Figure 12 Black spot section km 56+000 till 56+300

The section is registered as a black spot for first time in year 2018 with 6 accidents.

Following deficiencies could be noted:

- The road marking is satisfactory;
- Road signs are not visible from vegetation;
- Asphalt pavement in good condition;
- Shoulders in good condition;
- The section is at a crossroad. Heavy trucks stop at the auxiliary lanes.

2 https://www.google.at/maps/@43.4692505,25.7152767,3a,75y,99.62h,70.37t/data=!3m6!1e1!3m4!1sxeIdbvp3mnO-uXCyacRkXw!2e0!7i13312!8i6656

Figure 13 Black spot section km 56+000 till 56+300

8.3. Implementation ready design plan for the selected section from 51+860 to km 56+560

The project of the implementation ready design plan aims to illustrate and present graphically the data from the survey of the road section and the prepared investment plan SRIP and the measures it proposes. Maximum number of countermeasures from the ones envisaged in the investment plan and which are which do not contradict each other are selected for application.

The countermeasures envisaged for the improvement of the road safety, as initial information, are presented in tabular form in world coordinates and specific mileage of the measurement, which does not coincide with the mileage of Road I-5.

The coordinate system has been brought to BGS2005, as well as the mileage of the road is linked to that of the previous surveys and the investment plan SRIP.

The specific location of the relevant measures envisaged, according to the methodology used by SRIP, is at 100-meter intervals. This accuracy is sufficient as a guide for the possible application of the countermeasures that are prescribed. The countermeasures are typified according to their type and the corresponding positive effect they could have. Each of them is applicable separately, but in some sections different treatments can be combined for greater effect.

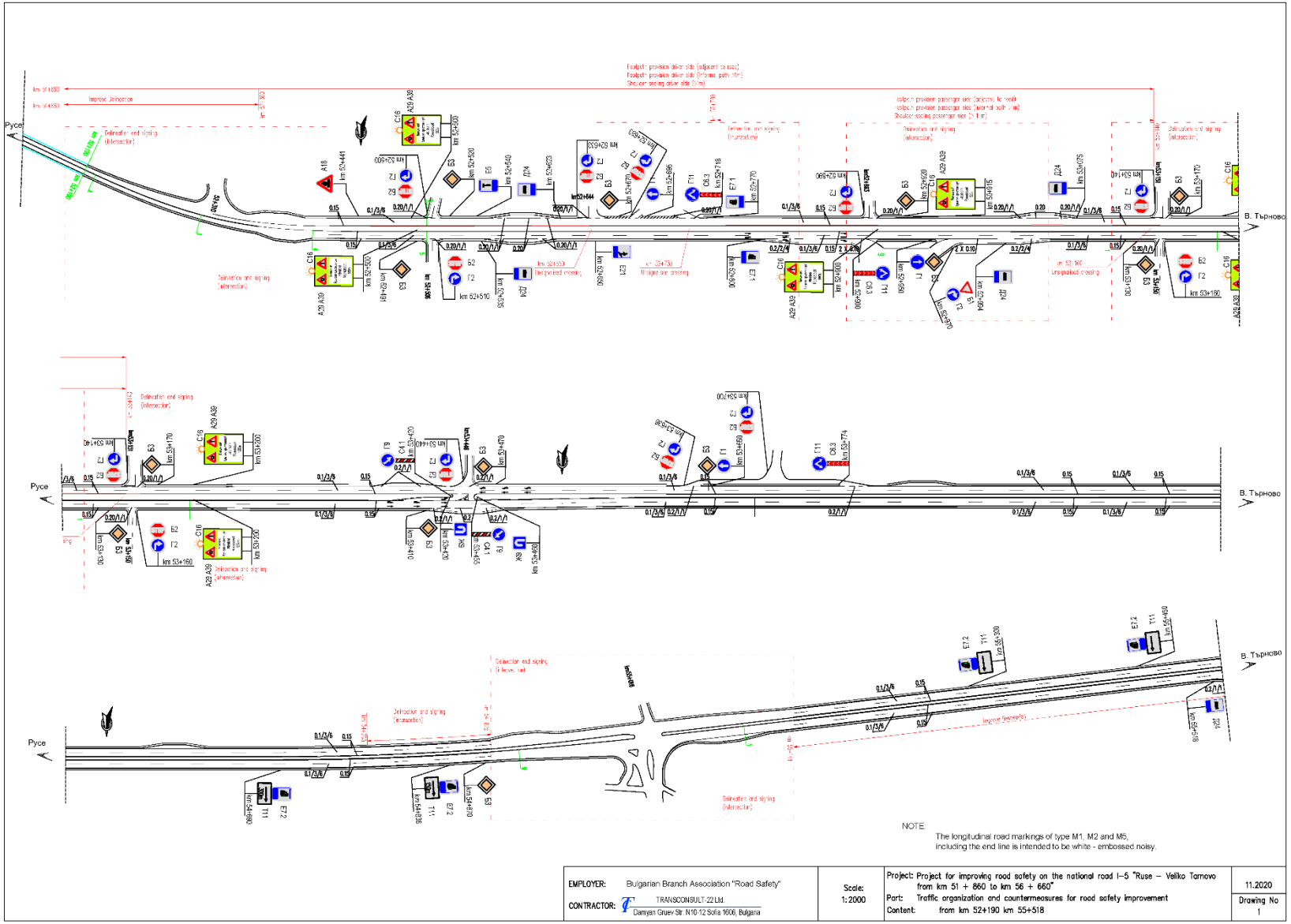
For the specified section from km 51+860 to km 56+560 are prescribed more than 30 different countermeasures, including improving delineation, installing road safety barriers, pedestrian safety improvements etc.

The design plan presents graphically the interventions prescribed in the SRIP countermeasures, as each of them is located and defined with the respective mileage, according to the leading mileage of Road I-5 Ruse - Veliko Tarnovo. A 5 km section was selected, starting from km 51 + 560 to km 56 + 560, the beginning of which coincides with the beginning of the measurement. The section was chosen taking into account the inclusion in it of a black spot with repetition and the diverse characteristics of the road geometry in this section - straight sections, curves, intersections, rural road and passages through settlements.

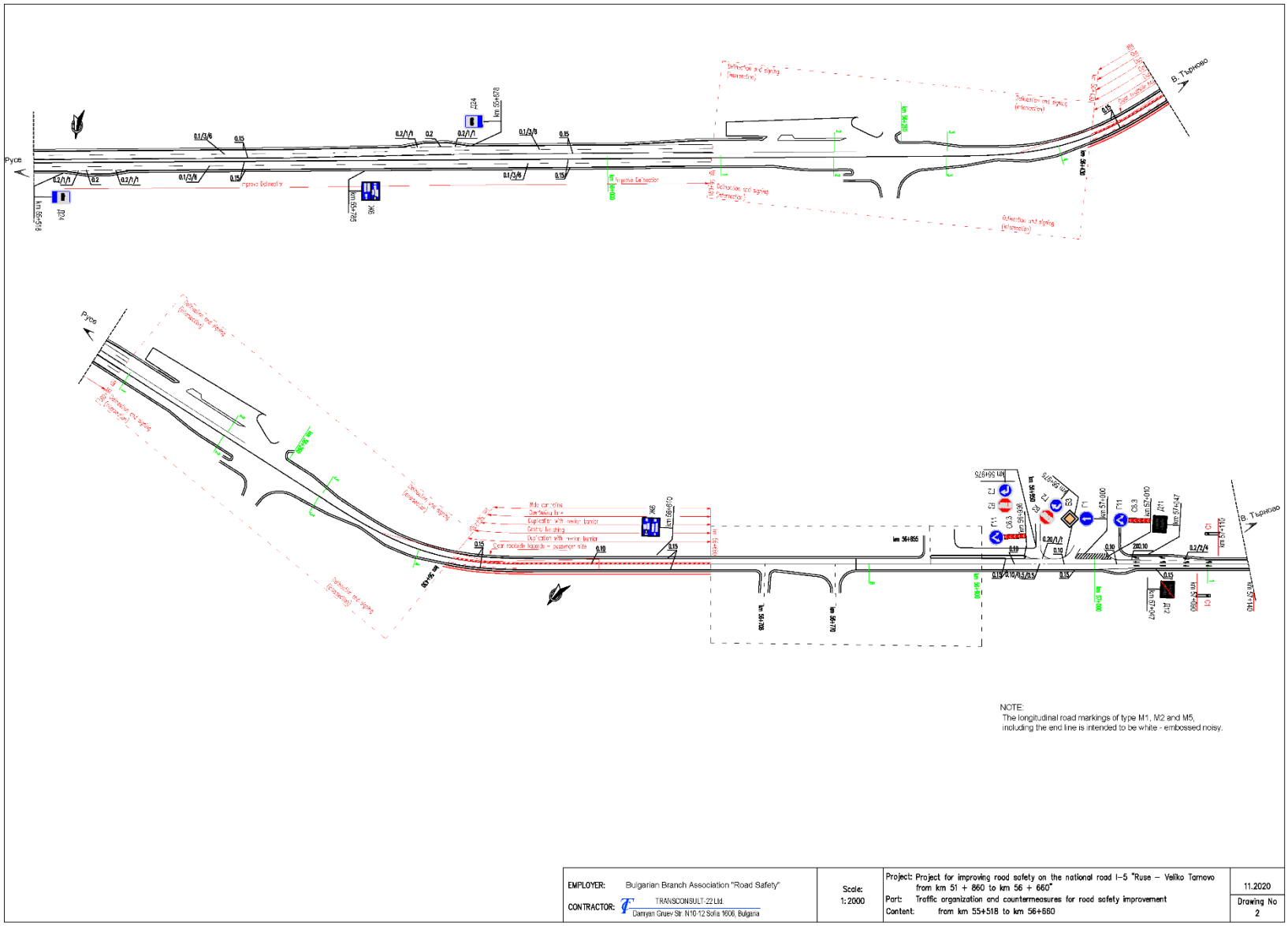
Drawings are presented, which contain a permanent organization of the traffic on the above-mentioned road section and the adjacent intersections with the roads crossing it, as well as the countermeasures for improving road safety, which are registered and prescribed on the basis

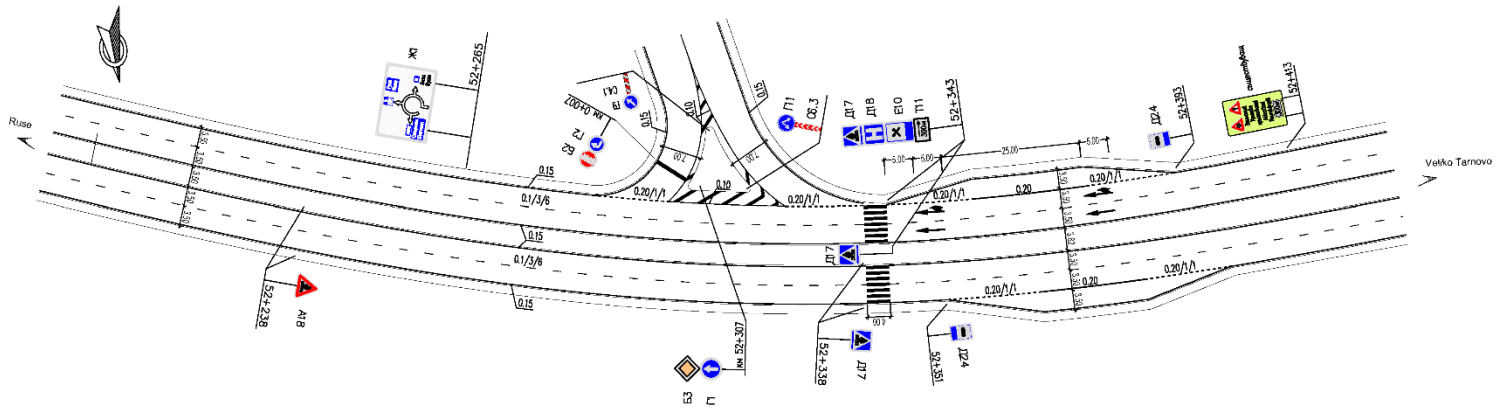
of the investment plan. In addition, a table is included, where all selected measures from the SRIP with their location according to the respective hectometry and mileage are given.

The implementation ready design plan is fully compliant with the relevant guidelines in Bulgaria, namely: Guidelines for road design (Regulation No. 02-20-2 from August 2018. for road design), Regulation No.18 from 23.07.2001 for the signalization of roads with traffic signs, Regulation No. 2 from 17.01.2001 for signalization of roads with pavement markings.

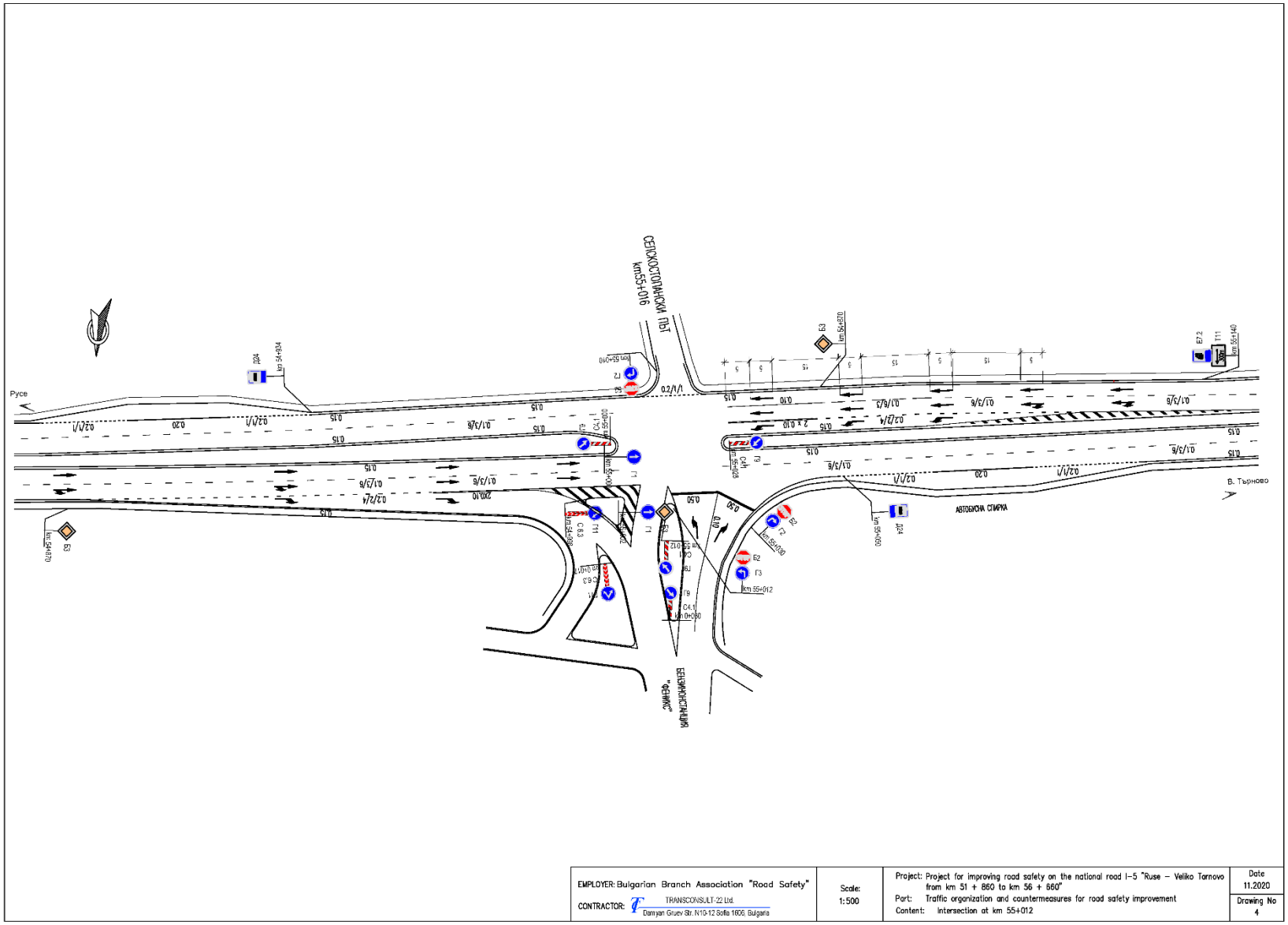


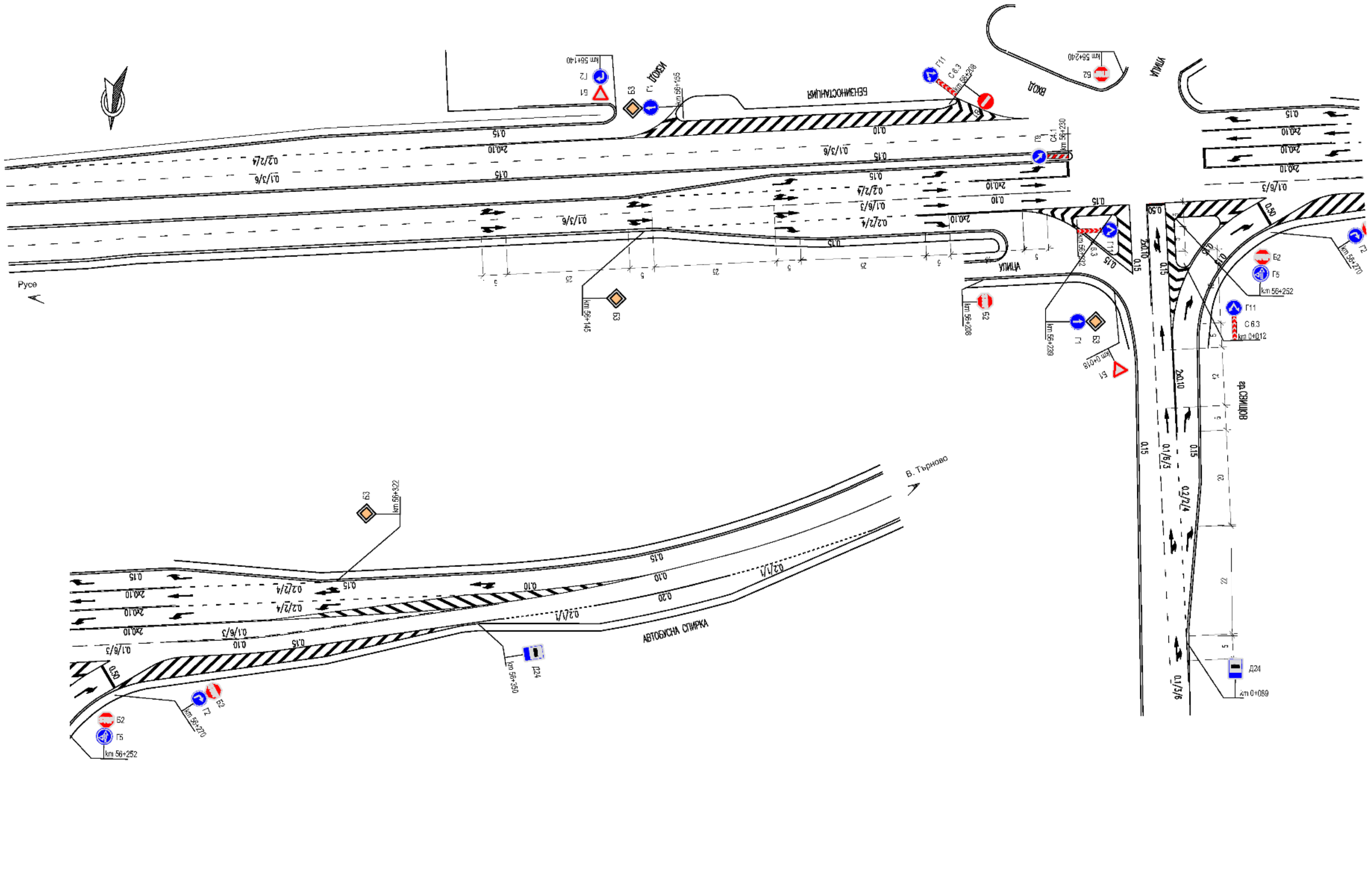
EMPLOYER: Bulgarian Branch Association "Road Safety" CONTRACTOR: TRANSCONSULT-22 Ltd. Damyan Gruev Str. N10-12 Sofia 1606, Bulgaria	Scale: 1:2000	Project: Project for improving road safety on the national road I–5 "Ruse – Veliko Tarnovo from km 51 + 860 to km 56 + 660" Part: Traffic organization and countermeasures for road safety improvement Content: from km 52+190 km 55+518	11.2020 Drawing No 1


Pyce
B. Търново
Pyce
B. Търново
NOTE:
The longitudinal road markings of type M1, M2 and M5,
including the end line is intended to be white - embossed noisy.
EMPLOYER: Bulgarian Branch Association "Road Safety"
CONTRACTOR: TRANSCONSULT-22 Ltd.
Damyan Gruev Str. N10-12 Sofia 1606, Bulgaria
Scale: 1:2000
Project: Project for improving road safety on the national road I–5 "Ruse – Veliko Tarnovo from km 51 + 860 to km 56 + 660"
Part: Traffic organization and countermeasures for road safety improvement
Content: from km 55+518 to km 56+660
11.2020
Drawing No 2



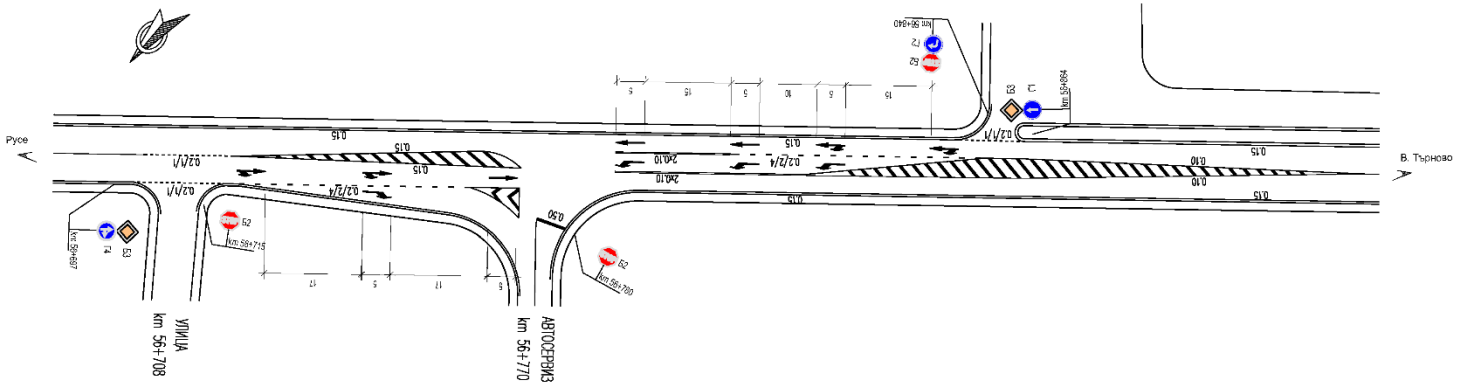
EMPLOYER: Bulgarian Branch Association "Road Safety" CONTRACTOR: TRANSCONSULT-22 Ltd. Damyan Gruev Str. N10-12 Sofia 1606, Bulgaria	Scale: 1:500	Project: Project for improving road safety on the national road I-5 "Ruse – Veliko Tarnovo from km 51 + 860 to km 56 + 660" Part: Traffic organization and countermeasures for road safety improvement Content: Intersection at km 52+307
		Date: 11.2020 Drawing No 3


СЕПТЕМВРИЙЧАНИ
"ФЕНИКС"
АВТОБУСНА СПИРКА
Руse
В. Търново
EMPLOYER: Bulgarian Branch Association "Road Safety"
CONTRACTOR: TRANSCONSULT-22 Ltd.
Damyan Gruev Str. N10-12 Sofia 1606, Bulgaria
Scale: 1:500
Project: Project for improving road safety on the national road I–5 "Ruse – Veliko Tarnovo from km 51 + 860 to km 56 + 860"
Part: Traffic organization and countermeasures for road safety improvement
Content: Intersection at km 55+012
Date 11.2020
Drawing No 4



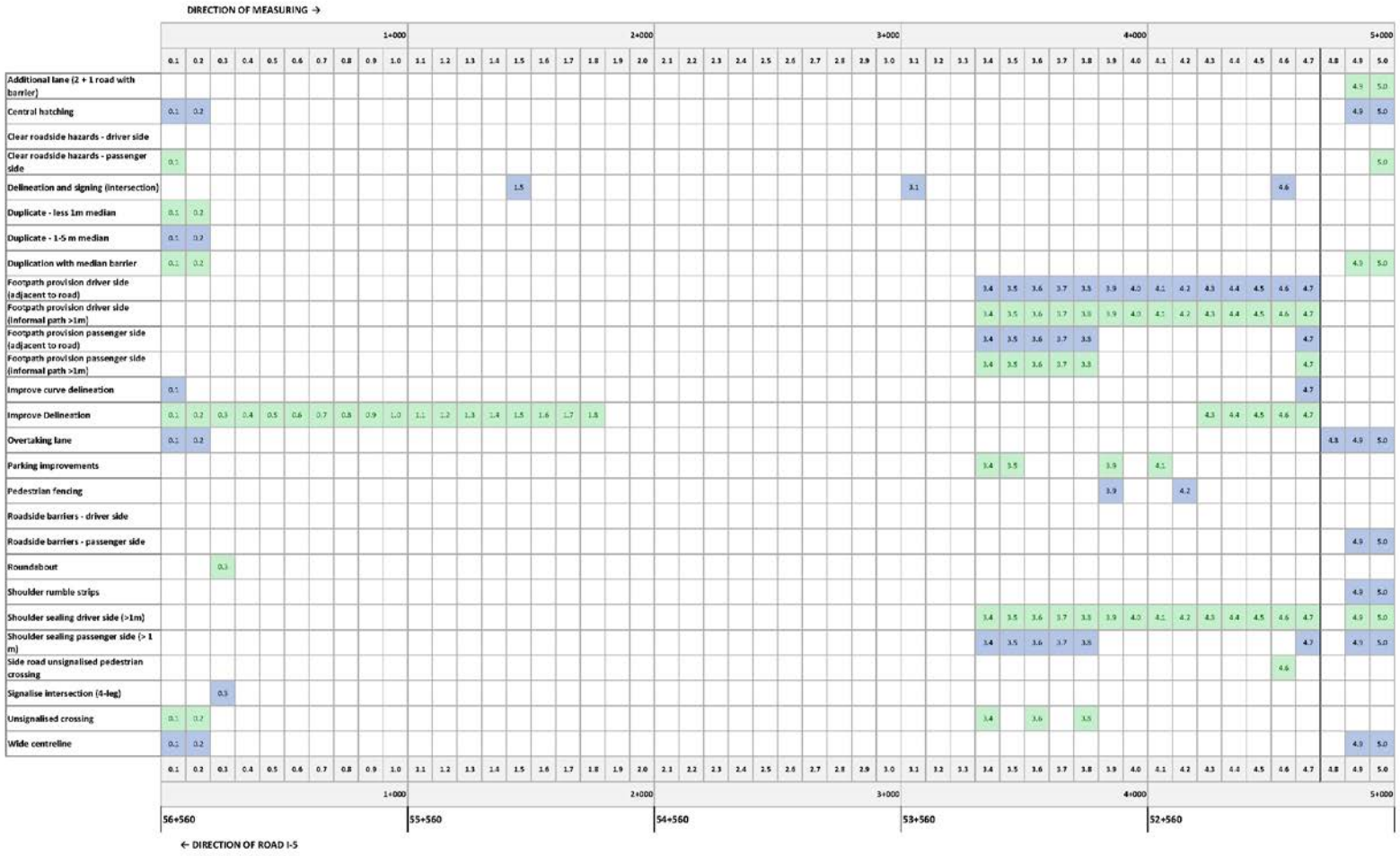
EMPLOYER: Bulgarian Branch Association "Road Safety" CONTRACTOR: TRANSCONSULT-22 Ltd. Damyan Gruev Str. N10-12 Sofia 1606, Bulgaria	Scale: 1:500	Project: Project for improving road safety on the national road I–5 "Ruse – Veliko Tarnovo from km 51 + 860 to km 56 + 660" Part: Traffic organization and countermeasures for road safety improvement Content: Intersection at 56+252	Date 11.2020 Drawing No 5

4



EMPLOYER: Bulgarian Branch Association "Road Safety" CONTRACTOR: TRANSCONSULT 22 Ltd. Damyan Gruev Str. N10-12 Sofia 1606, Bulgaria	Scale: 1:500	Project: Project for improving road safety on the national road I-5 "Ruse – Velko Tarnovo from km 51 + 860 to km 56 + 660" Part: Traffic organization and countermeasures for road safety improvement Content: Intersection at km 56+775

Date 11.2020
Drawing No 6


DIRECTION OF MEASURING →
1+000
2+000
3+000
4+000
5+000
Additional lane (2 + 1 road with barrier)
Central hatching
Clear roadside hazards - driver side
Clear roadside hazards - passenger side
Delineation and signing (intersection)
Duplicate - less 1m median
Duplicate - 1-5 m median
Duplication with median barrier
Footpath provision driver side (adjacent to road)
Footpath provision driver side (informal path >1m)
Footpath provision passenger side (adjacent to road)
Footpath provision passenger side (informal path >1m)
Improve curve delineation
Improve Delineation
Overtaking lane
Parking improvements
Pedestrian fencing
Roadside barriers - driver side
Roadside barriers - passenger side
Roundabout
Shoulder rumble strips
Shoulder sealing driver side (>1m)
Shoulder sealing passenger side (> 1 m)
Side road unsignalised pedestrian crossing
Signalise intersection (4-leg)
Unsignalised crossing
Wide centreline
56+560
55+560
54+560
53+560
52+560
← DIRECTION OF ROAD I-5

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