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TERMINOLOGY AND NOTATION

Design speed - is a selected speed used to determine the various geometric features of the roadway.
Inferred design speed – the maximum speed for which all critical design-speed-related criteria are met at a particular location;
Posted speed – the maximum lawful vehicle speed for a particular location as displayed on a traffic sign.
Sight distance – the length along a roadway over which a driver has uninterrupted visibility. Different minimum sight distance design criteria exist for various operations and maneuvers, including stopping sight distance, overtaking (passing) sight distance and intersection sight distance;
Speed limit – the maximum lawful vehicle speed for a specific location;

ANALYSIS OF AVAILABLE SIGHT DISTANCE WITH A PROPOSAL FOR MEASURES TO ELIMINATE DEFECTS

1. INTRODUCTION

The subject of this Elaborate is the analysis of the available sight distance with a proposal for measures to eliminate deficiencies, on the part of the state road IB number 22, from node 2223 to node 2225. The basis for the realization of this Elaborate was the contract concluded between:

- Vojvodinaput a.d. from Novi Sad , as the Client on behalf of the Investor PE Roads od Serbia,
- design organization, Panpro Team doo from Belgrade, as Executor

No.	Number of section	Starting node label	End node label	Section length (km)	Chainage (km)	The name of the starting node	The name of the end node
26	**02224**	**2223**	**2224**	6,771	164,641	Kraljevo (Jarcujak)	Mataruska Banja
27	**02225**	**2224**	**2225**	39,053	203,694	Mataruska Banja	Usce
			Total [km]	**45,824**			

Table 1- Nodes and sections

The spatial position of the subject section is shown in the following picture.

Figure 1- Spatial position of subject State road IB22

The initial part of the subject route extends through the populated areas of Kraljevo, Konarevo and Progorelica, where speeds are mostly limited to 50-60 km/h.

For the purposes of speed analysis and sight distance, within the diagrams that are included in the graphic attachments of this elaborate, sections are marked which pass through populated areas. However, the sections marked in this way do not represent locations where the beginnings and ends of settlements are marked with traffic signs, but parts of the route that, due to their characteristics, the average driver could perceive as such. It was estimated that such, more or less homogeneous conditions last from the beginning of the route Km 157+870 to Km 167+420.

In the continuation, the route extends in conditions outside the populated areas and goes into the gorge of the river Ibar. The conditions of the stretch through the Ibar gorge are mostly uniform. The section in conditions of the cut on right side follows the river Ibar all the way to the populated area of Usce, where after crossing at the final node 2225, it crosses from the left to the right side of the river Ibar.

The horizontal geometry is characterized by a large number of mutually incompatible curves whose radius often limit speeds to 50(40) Km/h . The inferred design speed is very variable and ranges from 40-80 km/h.

The finish ground profile on the sections in question is mostly mild since it follows the course of the Ibar river and has no influence on the inferred design speed values.

2. FIELD WORKS

Field works were carried out on 10.05.2023. and included recording of point clouds with measuring equipment consisting of:

- a lidar (laser) device that records clouds of points with a density of 1.3 million points per second;
- INS (inertial) device connected to GNSS antennas and RTK modem, whose role is to georeference the points recorded by the lidar device.

The works in question were carried out in daytime conditions, and considering the period of the year in which the recording was made, it can be concluded that the vegetation along the road was 100% leafy.

In addition to recording point clouds along the section in question, recording was also done with a spherical video camera.

3. CABINET WORKS

After the completed field work, cabinet work was started, which consisted of the following activities:

- creation of georeferenced point clouds in the WGS84 system;
- projection of georeferenced point clouds in the UTM34N coordinate system;
- recognition of horizontal and vertical geometry based on data from the captured cloud of points;
- determining the locations of posted speed limits for both driving directions based on the established road alignment and information taken from point clouds and spherical video recordings;
- determination of locations where overtaking is allowed according to the same principle as the previous activity;
- determination of zones of passage through populated areas;

- creation a diagram of posted speed limits along the route for both driving directions;
- calculation and creation of the inferred design speed diagram based on the recognized horizontal and vertical alignment;
- calculation and creation of diagrams of the required sight distance for both driving directions calculated on the basis of the posted speed limits;
- calculation and creation of a diagram of the required sight distance for both driving directions calculated on the basis of inferred design speeds;
- determining the diagram of available sight distance for both driving directions based on the movement of the virtual driver through the cloud of points;
- visualization of the movement of the driver and moving obstacles through the cloud of points by creating appropriate animations for both driving directions;
- analysis of all materials obtained in the previous steps with identification of deficiencies and definition of proposals for measures to eliminate the observed deficiencies.

For the purposes of the subject analyses, a correlation was established between the road alignment obtained from the digital map of the valid reference system of state roads and the alignment obtained by geometry reconnaissance based on point clouds, and shown in the following table.

Reference system node	axis from the valid reference system	axle recognized based on point cloud
2223	Km 157+870	Km 157+870
2224	Km 164+639.71	Km 164+640.28
2225	Km 203+691.55	Km 203+709.38

The differences of stationing in relation to the tabular data presented in the valid reference system occur as a result of different axis paths from the starting node to the final node.

Since the difference in chainages is ~0.4 m / km', it can be stated that it is negligible and should be taken into account only when positioning the phenomena along the subject route in more detail.

All diagrams and graphic attachments within this elaborate are positoned in relation to the axis reconnoitred from the point cloud geometry.

3.1. Methodological approach to determining the diagram of available sight distance

Since the available sight distance plays a very important role in the safe flow of traffic on a certain section, as well as considering that this type of sight distance cannot be calculated but must be measured, its measurement was carried out within the framework of this Elaborate by placing a virtual driver in the cloud of points and creating its view-pyramid of sight distance.

For the purposes of measuring/determining the available sight distance, for both driving directions, the driver's eye movement paths and virtual obstacles were created, which were defined at a distance of 1.5m from the outer edge of the traffic lane. The height of the driver's eye is defined as 1.1 m above the road. The driver's eye paths for both driving directions are divided into steps of 5m. At each observed point of movement of the driver's eye, views into the virtual obstacle were created in the form of a rectangle (window) of certain dimensions. A virtual obstacle in the form of a window is placed at a minimum distance of 30m and then moved in steps of 5m along the path of movement of the obstacle until sight distance problems are identified.

When the available sight distance for one position is determined, the driver's eye moves to the next position on the path and the process repeats iteratively.

Bearing in mind the previous experience and knowledge in this field when determining/creating the diagram of available sightdistance, the entire procedure for any driving direction was repeated with two dimensions of the window, namely:

- 0.1x0.1m, which corresponds to the height of the obstacle as defined in the Serbian valid norms in the field of road design;
- 1.75x1.0m, which corresponds to the silhouette of the rear of the relevant passenger vehicle.

In connection with the previous one, we especially emphasize:

- German regulations for designing highways where the height of the obstacle is defined at 1m high;
  the EUsight project (https://www.cedr.eu/call-2013-safet y) within which, as a measure of harmonizing the different norms of the EU countries regarding the required sight distance, it was proposed that the height of the obstacle be 0.4-0.6m. The recommended height of the obstacle refers to the height of the rear light group on a passenger vehicle, although it should also be noted that modern cars are manufactured with the requirement that there be an additional STOP light on top of the rear windshield.
- the fact that defining the height of the obstacle at 0.1m is an extremely rigid requirement, in which case any steel fence can represent an obstacle to compliance with the required transparency conditions.

We note once again that meeting the required sight distance for an obstacle height of 0.1 m is an extremely rigid requirement that is impossible to comply with, especially if we take into account the height of steel or any other type of fence whose existence along the roads is mandatory as a safety measure. In other words, meeting that requirement would cause enormous construction interventions to correct the elements of the route and road profile, and the need for additional expropriation.

3.2. Adopted values and approximations

The following starting values and approximations were adopted for the purposes of making calculations and creating various diagrams:

- acceleration coefficient a=0.8 m/sec^2;
- deceleration coefficient d=0.8 m/sec^2;
- coefficient of tangential friction f_t – variable depending on the speed;
- rolling resistance coefficient w_k =0;
- reaction time t=2 sec;
- longitudinal slope of the road and I_N - the value is taken from the tangent polygon of vertical alignment (the influence of vertical curves is ignored)
- vehicle safety distance Δ L=5m;
- the diagram of permanent speed values for passenger vehicles is not taken into account, since it is very outdated, that is, it does not correspond to the current fleet. Research conducted in Switzerland at the end of the 20th century determined that grade of level line up to 8% have no effect on reducing the speed of passenger vehicles on climbs for speeds of up to 80 km/h (http://www.strc.ch/2005/Koy.pdf);
- driver's eye height = 1.1m;
- the position of the driver in relation to the outer edge of the traffic lane = 1.5m;
- obstacle height = 0.1m, alternatively = 1.0m;
- maximum design speed values V_{max} =V_d +20 km/h.

4. SPEED MANAGEMENT - CURRENT STATE

The distribution of posted speed limits along the route in question is given in the diagram in graphic attachment 1. From this diagram, numerous shortcomings can be seen, such as:

- non-compliance of posted speed limits by direction;
- non-compliance with inferred speed;

4.1. Inconsistency of speed limits by direction

By looking at the diagrams, it is easy to see that along the route there are numerous inconsistencies in the posted speed limits in the directions, which often amount to 20 km/h, on certain stretches and more, as is the case from Km 172+040 to Km 172+804, where for the direction of Kraljevo -Usce limit is 50 km/h, and for the opposite direction it is 80 km/h.

Bearing in mind that the geometry is identical for both driving directions, possible differences in speeds would be acceptable in the following cases:

- local differences in intersection zones – longer restrictions on the approach zones compared to the exit zones;
- differences in sight distance of the route by directions.

By looking at the layout of the interchages and sight distance problems in each direction, it can be concluded that the inconsistency of speed limits in each direction is not a consequence of these elements. When the differences in speeds are caused by different sight distance conditions in the directions, then those differences do not, as a rule, exceed 10 km/h.

Apart from the above, differences in speeds can also occur as a result of missing traffic signs, i.e. signs that have been destroyed over time and have not been restored. This is partly the case on the route in question since it was established that along the route there are cases such as the example in the following picture where at Km~167+040 there is a pillar with a missing traffic sign.

Figure 2 – Pillar on chainage Km~167+040 with a missing traffic sign

It is assumed that the 50 km/h speed limit termination sign is missing at the location in the previous figure.

4.2. Non- compliance with inferred design speed

By comparing the diagram of the inferred design speeds with the diagram of the existing speed limits, numerous inconsistencies were determined. Deviations of posted speed limits from the inferred design speed, i.e. less posted speed than the inferred design, could be acceptable if they are the result of local restrictions such as: attraction zones (shops, restaurants), bus stops, pedestrian crossings, school zones, etc. Such a justified case occurs, for example. in the Bogutovac settlement, in the school zone (Km 174+925 – Km 175+145) where the speed limit is 30 km/h. Cases such as the stretch from Km~179+690 to Km~180+970 could be treated as justified, where due to the high variability of the inferred design speed, it is justified to make it uniform. However, when uniforming,

it should be taken into account that drivers generally do not respect artificially created restrictions that have no justification in geometry or some other limiting condition.

On the other hand, cases where the posted speed is higher than the inferred design speed should not occur anywhere along the route because it essentially means that the permitted speed is higher than the inferred speed allowed by the elements of the geometry. Such a situation occur at numerous stretches along the route, such as: Km 171+558 - Km 172+615, Km 176+647 - Km 178+528, but also in other places.

4.3. Disadvantages of existing geometric features

Looking independently at the inferred design speed diagram, unrelated to the shortcomings of the posted speed limits, a number of shortcomings can also be observed. They primarily refer to the non-compliance of geometric elements with the requirements arising from the norms.

Geometric elements that support speeds in the range of 40-80 km/h, and even more, alternate along the subject section. When creating the design inferred speed diagram, the authors of this elaborate adhered to the maximum speed limit of 80 km/h on road sections outside the settlement, as defined by the Law on Traffic Safety. Consequently, when creating the inferred design speed diagram, the value V_d=60 km/h was selected for the design speed, and the value V_{max} = V_d +20 km/h=80 km/h was defined for the maximum inferred design speed .

As an example on which numerous defects of geometry can be diagnosed, we will single out the stretch from Km 191+737.16 to Km 192+024.22, which is shown in the following Figure 3.

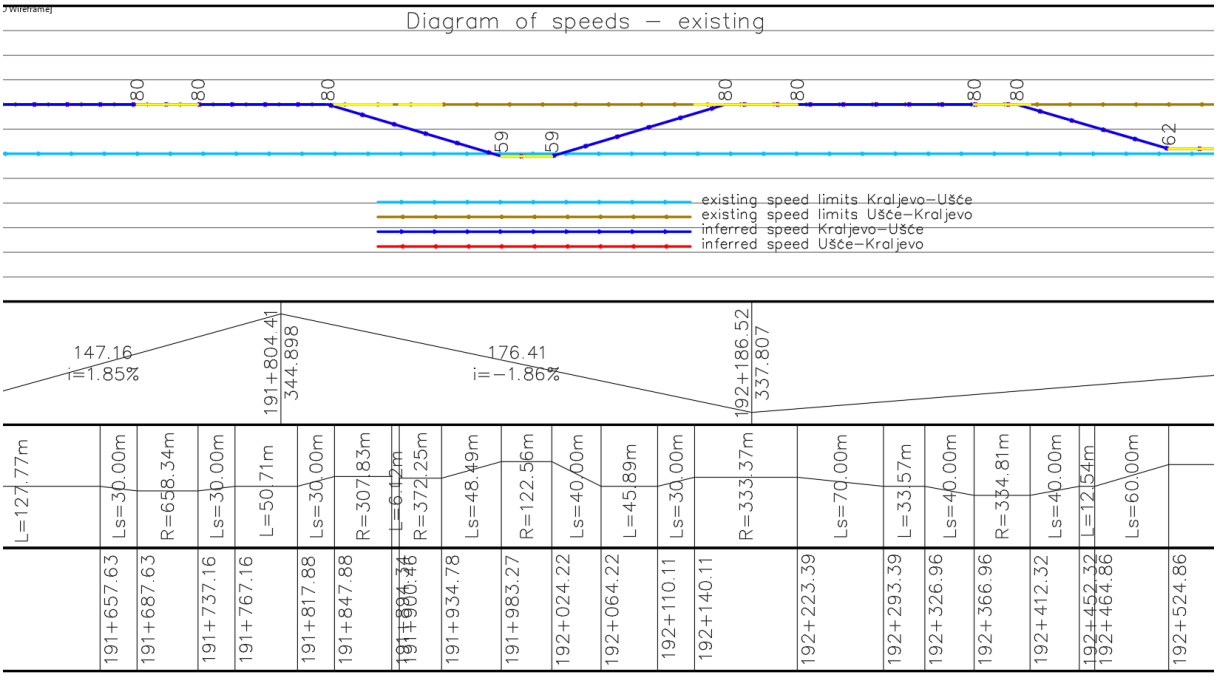


Figure 3 - Speed diagram with examples of "skipped" curves

Although it is not usual for the inferred design speed diagram, in it only the locations of purely circular curves are marked in yellow and the inferred design speed calculated for those curves is limited to a maximum of V_p =80 km/h, although the curve characteristics in some of them would allow movement and at higher speeds. If we take into account two successive curves R =307.83m and R=372.25m from Km 191+847.88 to Km 191+934.78, it can be seen from the inferred design speed diagram that they will be 'skipped'. That is, if the vehicle is moving from Kraljevo towards Usce, in order to slow down to a tolerable speed of the curve of radius R =122.56m (Km 191+983.27 – Km 19 2+024.22, V_p =59 km/h), it is necessary to start decelerating with the defined deceleration

coefficient (d=0.8 m/sec ^{2}) before the driver even reaches the curves R =307.83m and R=372.25m where he can safely drive 80 km/h and even more. This essentially means that the driver is not provided with a correct and timely understanding of the geometric characteristics of the road route. By looking at the current regulations, it is easy to state that the successive tracking of geometric elements with such characteristics is prohibited. That is, in addition to the radius R=122.56m, it is forbiden to exist the radius R=307.83m (R= 372.25). In this case, it is actually a very complex right curve consisting of several different radii, i.e. the so-called „basket“ curves, which are very unfavorable from the point of view of traffic safety because they confuse drivers, they are difficult to assess and adjust speeds.

The inferred design speed diagram abounds in other locations where curves are partially or completely 'skipped'.

The following can be stated as a general conclusion of the speed analysis:

- **the current state of posted speed limits is unacceptable and must be thoroughly reviewed/changed;**
- **along the route, there are numerous defects in geometry that do not correspond to valid norms and which cannot be corrected by short-term measures, but in some parts, their reconstruction must be planned for the long term.**
- In accordance with these conclusions, the definition of the proposed posted speed limit along the route in question was approached as a short-term measure. The proposed posted speed limits by direction is also shown in the corresponding diagram of graphic attachment 1. During the preparation of that proposal, interchanges, schools, pedestrian crossings, but especially the results of sight distance analyzes given in the next chapter, had a significant impact.

5. SIGHT DISTANCE ANALYSIS

Within the graphic attachments 1 shown are diagrams of sight distance containing:

- diagrams of required sight distance for existing posted speed limits in both directions;
- diagrams of available sight distance for obstacle heights of 0.1 m and 1.0 m;
- overtaking sight distance values for four different cases of speed ratio V1-V2-V3;
- segments of the subject route on which overtaking is allowed within the current state;
- proposal for correction of segments with permitted overtaking;
- required sight distance diagrams for the proposed posted speed limit by directions.

Diagrams of the available sight distance are shown without subsequent corrections, that is, in proportion to the results of the software algorithm and the methodology described in chapter 3.1. The discontinuities/jumps that appear in the diagrams of the available sight distance are the result of non-continuous disturbances and are most often caused by sporadic disturbances related to vegetation and even to sign that can represent disturbances for obstacles with a height of 0.1m. Since they mostly refer to pointly disturbances, sporadic jumps/discontinuities in the sight distance diagram can generally be ignored except in the case of their frequency.

5.1. Required sight distance for existing speed limits

By comparing the available sight distance diagrams with the required sight distance diagrams for the posted speed limits, numerous segments can be observed where the available sight distance falls below the required sight distance value. Those segments are certainly significantly more pronounced if the available sight distance for an obstacle height of 0.1 m is observed , compared to an obstacle height of 1.0 m.

If the diagrams of the required sight distance against the inferred design speed were taken into account, i.e. as required by Article 2 of the Law on Roads ***" Required sight distance is the distance required to safely stop a vehicle in front of an immovable obstacle on the road surface, which must be provided at every point of the road and which is determined based on the authoritative values of the inferred design speed in both driving directions "*** , sight distance problems would be even more drastic. Some of the examples of non-fulfillment of the required sight distance for the posted speed limits are shown in the Figure 4. The route where the required sight distance in different directions is not met are marked with different hatches, so that they overlap in certain parts.

Since it was already stated in the previous chapter that the current state of posted speed limits is unsustainable, that is, it must be thoroughly reviewed and corrected, it is unnecessary to list all the segments where the required sight distance is not met.

In general, it can be stated that on the section in question there are very pronounced problems with the fulfillment of the required sight distance for the posted speed limits, which can cause drivers to misjudge traffic situations and contribute to the occurrence of traffic accidents.

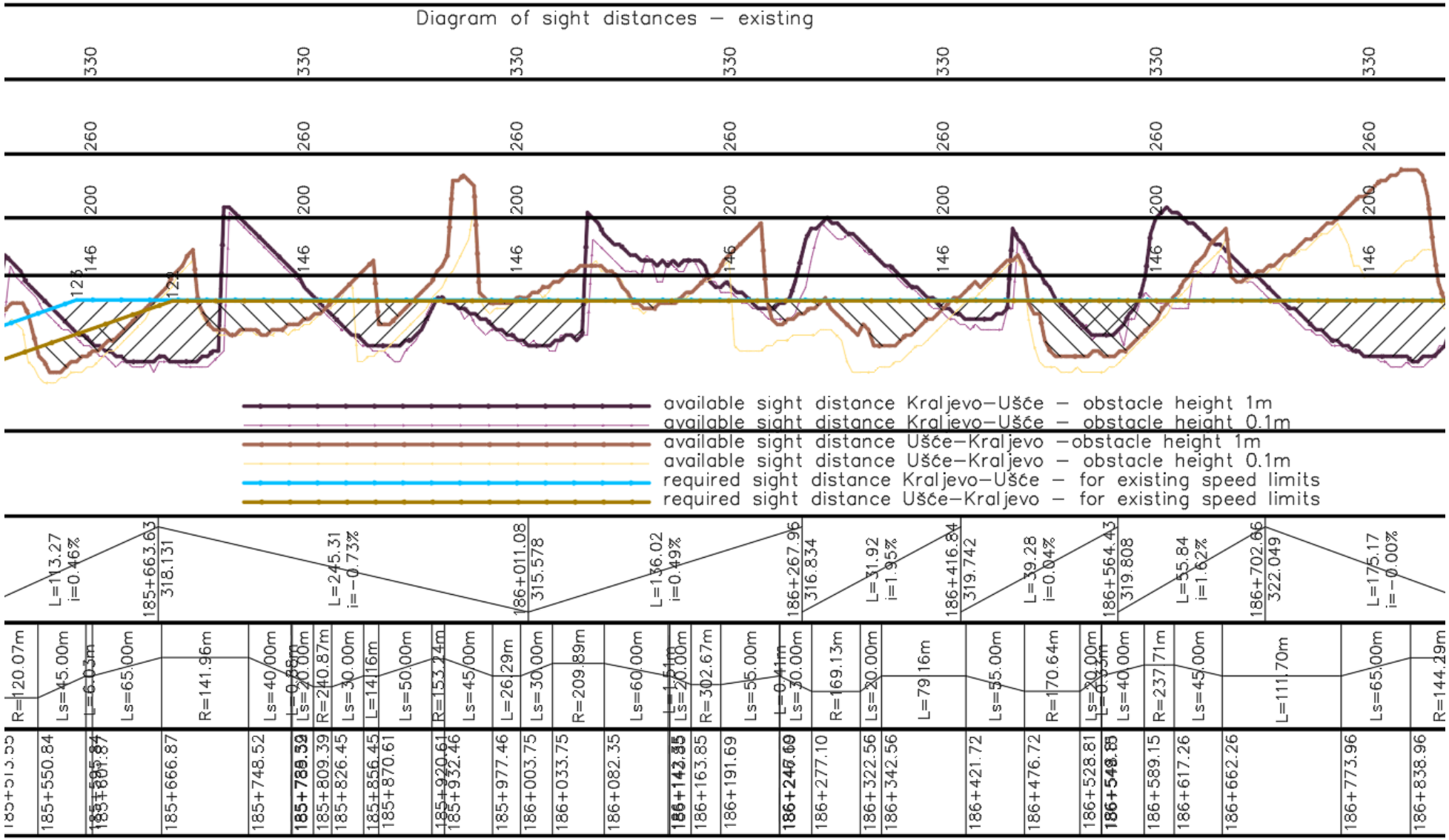


Figure 4– Diagram of sight distance with an example of zones where the required sight distance is not met

5.2. Overtaking sight distance

On the route in question, in the direction from Kraljevo to Ušće, the total length of the segments where overtaking is allowed within the current state is 8,096 km, while in the opposite direction it is 8,155 km. Looking in relation to the total length of the observed route, which is 45,983 km , the percentage of segments in the direction from Kraljevo to Ušće where overtaking is allowed is ~17.61%, and ~17.74% in the opposite direction.

However, if the segments on which overtaking is allowed but which by their characteristics do not allow it to be done in an exemplary and traffic-safe way were subtracted from the total lengths , i.e. which need to be abolished, such as:

Km 169+541 - Km 169+626, Km 173+834 - Km 173+984, Km 178+882 - Km 179+012, Km 187+300 - Km 187+450, Km 197+309 - Km 197+429, Km 197+784 – Km 197+914 for the direction Kraljevo - Ušće (total L = 765m)

Km 169+561 – Km 169+755, Km 174+004 – Km 174+134, Km 178+987 – Km 179+127, Km 187+445 – Km 187+541, Km 190+562 – Km 190+712, Km 197+429 – Km 197+559 , Km 197+914 – Km 198+004 for the direction Ušće – Kraljevo (total L=840m)

the total percentages would come down to:

- 15,94% for the direction Kraljevo-Ušće,
- 15,91% for the direction Usce-Kraljevo

In addition to the above, if the lengths of overtaking is allowed in the zones of passing through settlements were subtracted, primarily on the Kraljevo-Konarevo-Progorelica section and through Ušće, i.e. 2850 m for the direction Kraljevo-Ušće and 2885 m for the direction Ušće-Kraljevo, i.e. in zones where, due to low posted speeds, the need for overtaking is not particularly pronounced, the following total percentages are obtained:

- 12.47% for the direction Kraljevo-Ušće,
- 12,33% for the direction Ušće-Kraljevo

The percentages obtained in this way are significantly lower than the minimum value of 20%, which is defined by the norms. All of the above indicates that the issue of overtaking on the sections in question is extremely unfavorable, and its shortcomings are further emphasized by the fact that in the period from 2016-2022, 37 traffic accidents such as head-on collisions and overtaking accidents occurred along those sections. The data on the mentioned traffic accidents were taken from the database of the Agency for Traffic Safety and are shown in position within the sight distance diagram. A tabular overview of traffic accidents is attached to the text part of this report.

The segments on which overtaking is allowed within the current state are shown in the following tables, but it is unclear for which speed ratios are defined:

Kraljevo - Ušće		
The start [Km]	The end [Km]	Length [m]
Km 160+120	Km 160+970	850
Km 161+974	Km 162+199	225
Km 164+105	Km 164+496	390
Km 165+040	Km 165+145	105
Km 165+790	Km 166+915	1125
Km 168+165	Km 169+096	931

Ušće - Kraljevo		
The end [Km]	The start [Km]	Length [m]
Km 160+190	Km 161+110	920
Km 161+949	Km 162+309	360
Km 164+100	Km 164+481	380
Km 165+030	Km 165+160	130
Km 165+985	Km 166+920	935
Km 168+285	Km 169+301	1015

Km 169+541	Km 169+626	85
Km 170+542	Km 170+881	339
Km 173+129	Km 173+474	345
Km 173+834	Km 173+984	150
Km 175+325	Km 175+690	365
Km 178+376	Km 178+646	270
Km 178+882	Km 179+012	130
Km 181+329	Km 181+719	390
Km 182+860	Km 183+145	285
Km 183+675	Km 183+880	205
Km 184+340	Km 184+595	255
Km 187+300	Km 187+450	150
Km 188+350	Km 188+525	175
Km 188+695	Km 188+885	190
Km 190+157	Km 190+322	165
Km 191+517	Km 191+682	165
Km 194+454	Km 194+704	250
Km 197+309	Km 197+429	120
Km 197+784	Km 197+914	130
Km 202+317	Km 202+467	150
Km 203+333	Km 203+488	155
	sum=	**8096**

Km 169+651	Km 169+755	105
Km 170+662	Km 171+041	380
Km 173+294	Km 173+574	280
Km 174+004	Km 174+134	130
Km 175+455	Km 175+805	350
Km 178+546	Km 178+776	230
Km 178+987	Km 179+127	140
Km 181+509	Km 181+894	385
Km 183+056	Km 183+320	265
Km 183+815	Km 183+975	160
Km 184+460	Km 184+720	260
Km 187+445	Km 187+541	95
Km 188+480	Km 188+670	190
Km 188+850	Km 189+090	240
Km 190+287	Km 190+467	180
Km 190+562	Km 190+712	150
Km 191+642	Km 191+822	180
Km 194+629	Km 194+759	130
Km 197+429	Km 197+559	130
Km 197+914	Km 198+004	90
Km 202+467	Km 202+652	185
Km 203+418	Km 203+578	160
	sum=	**8155**

The shortcomings of existing locations where overtaking is allowed are primarily reflected in:

- ***<u>insufficient lengths</u>***
    - as a negative example, the segments Km 169+541 - Km 169+626, L=85m (Kraljevo-Ušće) and respectively Km 169+651- Km 169+755, L=105m (Ušće-Kraljevo) can be taken. In the wider zone of these segments, speeds are limited to 80 km/h within the current state, and the diagram of the calculated inferred design speed shows similar values in the directions. If it is taken into account that according to the Rulebook on Traffic Signals, a vehicle needs 165 m to perform an overtaking maneuver at a speed ratio of 80-60-80 km/h , it is obvious that it is not possible to achieve this on this segment. In addition, when defining the minimum length where overtaking should be allowed, the minimum time required for making a driver's decision must be taken into account, which is usually t=2sec. That is, for example for the desired speed ratio of 80-60-80 km/h, any road segment shorter than $165m+t*V_i=165m+45m=210m$ can be considered unacceptable.

- ***<u>inconsistency of the available sight distance with the requirements arising from the expected speeds of vehicle movement at those locations</u>***
    - by looking at the diagrams of posted speed limits and available sight distance, it is noticeable that there is a huge discrepancy between needs and possibilities in many locations where vehicle speeds close to the maximum acceptable value of 80 km/h can be expected. As an example, we cite the segments Km 187+300 - Km 187+450 , L=150m (for the direction Kraljevo-Ušće) and Km 187+445 - Km 187+541, L = 95 m (for the direction Ušće-Kraljevo). It is indicative that traffic accident with a fatality occurred in the immediate vicinity of this location. In addition, during the filming of

the sections in question for the purposes of this Elaborate, an extremely dangerous overtaking maneuver from the direction of Kraljevo towards Ušće was recorded by the video camera at this location, and the tragic consequences were avoided only thanks to the composure of the driver from the opposite direction who braked the vehicle practically to a stop. The video in question is an integral part of the digital version of this study.

A more detailed analysis of the case in question can lead to the following conclusions:

- the driver of the overtaking truck starts the maneuver at the traffic-legal location. Likewise, the maneuver ends practically at the end of the dotted line, which leads to the conclusion that he needed ~150m for that maneuver;
- telemetry recorded in the video shows that the overtaken vehicle was traveling at a speed of ~60 km/h. From this comes the assumption that the overtaking vehicle was moving at a speed of ~80 km/h ;
- available sight distance for the direction Kraljevo-Ušće very briefly reaches 275 m and for the direction Ušće-Kraljevo not even up to 230, which leads to the conclusion that in this zone eventualy is possible to ensure overtaking for a speed ratio of 70-50-70 km/h;
- the diagram of posted restrictions and inferred design speeds indicates that in front/behind and in the immediate zone of that segment there are no elements that would limit speeds lower than 80 km/h ;
- assumed oncoming vehicle speed is ~80 km/h, very likely and more than that.

Based on all of the above, it can be concluded that the location in question represents an extremely risky place for overtaking if it is not possible to ensure greater sight distance.

In the text that follows, the locations of zones where overtaking is allowed in the current state but where the same should be prohibited are listed and explained.

overtaking existing	direction	Comments:
Km 169+541 - Km 169+626	Kraljevo-Ušće	The posted speed limits on these segments are 80 km/h, and the inferred speed is in the range of 70-80 km/h . The proposed speed limit in the immediate zone of this segment is in the range of 60-80 km/h for the direction Kraljevo - Usce, and 70-80 km/h for the opposite direction. The values of the available sight distance are such that for the direction Kraljevo - Ušće they would enable overtaking sight distance for a speed ratio of 60-40-60 km/h, and for the opposite direction 70-50-70. Since vehicles with speeds of 80 km/h and more can appear in the immediate area, viewed in both directions, it is estimated that there is a high risk of an overtaking traffic accident. The posted overtaking lengths are extremely short and do not correspond to the diagram of available sight distance. Two traffic accidents occurred in the immediate area during the observed period (2016-2022).
Km 169+561 - Km 169+755	Ušće-Kraljevo	
Km 173+834 - Km 173+984	Kraljevo-Ušće	Diagrams of posted, inferred design and proposed posted speed limits are similar in the immediate zone of this segment. The speeds in the directions are variable and conditioned by the limiting radius of the horizontal curve, which is R=69m (V~48 km/h). The available sight distance meets the needs of overtaking
Km 174+004 - Km 174+134	Ušće-Kraljevo	

		sight distance for a speed ratio of 70-50-70 km/h. The driving dynamics of the route and overtaking for the direction Kraljevo - Ušće are opposed to each other. In overtaking, it is calculated with maintaining a constant speed until the maneuver is completed, while the geometry of the route conditions the vehicle's deceleration due to encountering the limiting radius R=69m (V~48 km/h) . In the opposite direction, the situation is somewhat more favorable, considering that vehicles leave the limiting radius and accelerate. However, the acceleration of the overtaking vehicle would have to be significantly greater than the overtaking vehicle in order to perform the maneuver in the intended length.
Km 178+882 - Km 179+012	Kraljevo-Ušće	Diagrams of posted speed limits and inferred design speed are identical in the immediate zone of this segment. The diagrams of the proposed posted speed limits in each direction are lower by 20 km/h (10 km/h) due to the limitation imposed by ensuring the required sight distance. However, considering that, apart from the available sight distance, the geometry of the route is not a limiting factor in the immediate zone of this segment, vehicle speeds of 80 km/h and more can be expected. The existing lengths of overtaking is allowed in the directions are short and do not meet the requirements for overtaking speeds of 80 km/h. Available sight distance ensures overtaking for speed ratios of 60-40-60 km/h but not over that.
Km 178+987 - Km 179+127	Ušće-Kraljevo	
Km 187+300 - Km 187+450	Kraljevo-Ušće	The location in question is taken as an example of deficiencies related to the inconsistency of the available sight distance with the requirements arising from the expected speeds of vehicle movement and has already been described in the previous part.
Km 187+445 - Km 187+541	Ušće-Kraljevo	
Km 190+562 - Km 190+712	Ušće-Kraljevo	The posted speed limits in the directions are inconsistent, 60 km/h for the direction Kraljevo - Ušće, 80 km/h for the direction Ušće - Kraljevo. Diagrams of the inferred design and proposed posted speed limits are variable and range from 60-80 km/h and are conditioned by the limiting radius R = 136m of the horizontal curve. The available sight distance provides conditions for overtaking at a speed ratio of 70-50-70, but a vehicle moving at 80 km/h and more can be expected from the opposite direction. In addition, the unfavorable circumstance is that both vehicles (overtaking and overtaken) will accelerate when leaving the limiting radius.
Km 197+309 – Km 197+429	Kraljevo-Ušće	The posted speed limits in the directions are inconsistent, 60 km/h for the direction Kraljevo - Ušće, 80 km/h for the direction Ušće - Kraljevo. Diagrams of the inferred design and proposed posted speed limits are variable and range from 60-80 km/h and are conditioned by the limiting radius R = 137m of the horizontal curve. The existing permitted overtaking lengths are short, they almost do not provide the length of the overtaking maneuver for the speed ratio of 70-50-70 km/h . The available sight distance provides conditions for overtaking at a speed ratio of 70-50-70, but a vehicle moving at 80 km/h and more can be expected from the opposite direction.
Km 197+429 – Km 197+559	Ušće-Kraljevo	
Km 197+784 – Km 197+914	Kraljevo-Ušće	The existing speed limits in the directions are inconsistent, 60 km/h for the direction Kraljevo - Ušće, 80 km/h for the direction Ušće - Kraljevo. Diagrams of the inferred design and proposed
Km 197+914 –	Ušće-Kraljevo	

Km 198+004		posted speed limits are variable and range from 60-80 km/h and are conditioned by the limiting radius R = 137m of the horizontal curve. The existing lengths of allowed overtaking are short, they almost do not provide the length of the overtaking maneuver for the speed ratio of 70-50-70 km/h . The available sight distance provides conditions for overtaking at a speed ratio of 70-50-70 for the direction Kraljevo-Ušće but not for the opposite direction. When overtaking from the opposite direction, a vehicle may appear moving at a speed higher than expected for overtaking conditions at a speed ratio of 70-50-70 km/h.

Since it has already been stated in chapter 4that the distribution of posted speed limits is inadequate and unsustainable, it is pointless to enumerate in detail all the segments where there is a discrepancy between the available and overtaking sight distance, which is easy to see by looking at the diagrams given in graphic attachment 1.

At this place, it is important to point out the mutual inconsistency of the applicable regulations regarding overtaking sight distance (OSD), which is shown in the following table.

Rulebook on conditions that must be met by road facilities and other elements of the public road from the aspect of traffic safety (Official Gazette of RS, No. 50/2011)							
Speed (km/h)	40	50	60	70	80	90	100
OSD (m)	260	320	370	430	480	540	600
Rulebook on traffic signals (Official Gazette of RS, no. 85/2017 and 14/2021)							
V1:V2:V3 (km/h)		50:30:50	60:40:60	70:50:70	80:60:80	90:70:90	100:80:100
OSD (m)		146	200	260	330	406	492

Table 2- Non-conformity of the current norms related to lengths of overtaking sight distance

For the purposes of the analysis of sight distance, the authors of this study adhered to the overtaking sight distance values defined by the Rulebook on Traffic Signals.

In general, it can be stated that on the section in question there are very pronounced problems with the fulfillment of overtaking sight distance for the posted speed limits, which can cause drivers to misjudge traffic situations and contribute to the occurrence of traffic accidents with very serious consequences.

6. PROPOSAL FOR SHORT-TERM MEASURES

After the analyzes carried out in the previous chapters, the proposal for short-term and long-term measures was defined in order to:

- short-term measures - primarily refer to low-budget measures that can be implemented in the short term, such as: correction of traffic signals and removal of vegetation;
- long-term measures - primarily refer to measures that cannot be applied without the use of construction machinery and prior development of project documentation, such as: widening of cut berms, changes in geometry, etc.

6.1 Proposal for short-term measures

6.1.1. Correction of speed limits by direction

According to the analyzes carried out in chapters 4 and 5 , the definition of proposals for speed limit corrections by directions has been conducted. In addition to the usual restrictions such as geometry,

intersection zones, schools, pedestrian crossings, bus stops, etc., a special influence on the proposal of speed limit corrections was the diagram of available sight distance by directions.

The diagram of proposed posted speed limit corrections by direction is also shown in graphic attachment 1.

As can be seen in the diagrams, the differences in the proposed speed limits by directions are primarily due to the differences in available sight distance. For example, in the section from Km~172+275 to Km~172+514, the posted speed for the direction from Kraljevo to Ušće is proposed to be 50 km/h, while in the opposite direction it is 60 km/h. This is a consequence of the fact that the available sight distance for an obstacle height of 1.0 m in the direction from Kraljevo towards Ušće drops to a value of 50 m, while in the opposite direction it is a minimum of 70 m. Since the route at this location is located in an side cut with a very steep rock mass on the right, it is not possible at this location to expand the sight distance berm on that side by short-term measures, but it is necessary to limit the speed for the direction in question. The layout of the side cut at the location in question is shown in the following picture.

Figure 5 – Layout of the side cut at the location in question

It is important to point out here that minor deviations of 5-10 m, required in relation to the available sight distance, are tolerated only on short stretches with the explanation that the driver (vehicle) is free to move within his traffic lane. Namely, if it is taken into account that the width of the traffic lane is 3.25 m, and that the driver's position is not in the middle of the vehicle but shifted to the left by ~30-40 cm, it can be determined by simple calculations that the driver's position can be safely moved in the range of 1.5 -2.5m in relation to the outer edge of the traffic lane. That is, the driver tends to positionally move towards the opposite lane in sharp unobservable curves in order to improve his sight distance.

It is also important to note that the proposed posted speed limit correction was made on the basis of satisfying the available sight distance for an obstacle height of 1 m , although the norms define that value as 0.1 m . Namely, strict adherence to archaic norms, which in this element differ from most developed countries in the world, would be not only irrational but also fundamentally wrong from

the point of view of traffic safety. That is, mere adherence to such a strictly defined element would condition:

- more drastic speed limits;
- potential creation of even bigger crowds and lines;
- extension of travel time and reduction of service level;
- creation of mistrust in traffic signals;
- non-compliance with traffic regulations.

How big the influence of the steel fence is on the differences in the available sight distance for the obstacle height of 0.1 m and 1.0 m, can best be recognized in the diagrams of sight distance. Stretches with a continuously large difference in available sight distance, for different heights of obstacles in the same direction, are almost as a rule the consequence of interference with sight distance caused by the steel fence. In accordance with all the above, 0

By looking at the diagrams of sight distance and the notes given in them, other segments of the road can be seen along which the available sight distance also falls below the required one, but no additional speed limit was applied on those segments , for the reason that sight distance can be improved on them by removing vegetation.

6.1.2. Correction of zones where overtaking is allowed

According to the diagram of the proposed posted speed limits and the available sight distance, the zones where overtaking is allowed were also corrected. The proposed corrections are shown in graphic attachment 1.

Figure 8shows the model by which the corrections of the allowed overtaking zone are defined. The description of the displayed model is given below, and it refers to the case where the variable is the proposed posted speed limit, but on the safety side adopted is the speed ratio V1:V2:V3= 80:60:80 km/h in overtaking, i.e. overtaking sight distance of 330 m.

Observed for the direction Kraljevo - Ušće, as already mentioned earlier, the possibilities for increasing the sight distance in the right curves are limited due to the fact that the road profile is in cut conditions with very steep rock slopes on the right side. For this reason, the proposed segment of overtaking is allowed for that direction begins at the point where the diagram of available sight distance intersects the sight distance line of 330 m (Km 184+295.71). In the continuation, the driver has sight distance of 330 m and more until the point at Km 184+436.24. It is the last point where the driver can start overtaking, which he must complete in the next 165 m, that is, to the chainage 184+601.24.

For the needs of the opposite direction, the sight distance of 330 m opens at the chainage Km 184+769.18 and within the existing condition continues to the chainge Km 184+681.74. However, for this direction, the expansion of the sight distance berm is significantly more favorable because it is obstructed only by the vegetation on the left side of the road, viewed in the direction of the chainage's growth. This disturbance can be eliminated by cutting the vegetation through short-term measures. At this point, the question arises to what width it is meaningful to remove the vegetation and open the berm for sight distance. The answer to this question is not simple and is usually directly dependent on property-legal relations, i.e. the border of the road belt. However, along the section in question, the road plot is mostly bordered by water land, that is, in both cases, the state is the owner and there are no restrictions on clearing vegetation as in the case of private owners. Figure 6shows the cadastral plots (KO Maglič, Kraljevo) in the subject zone taken from the Geosrbija web portal.

After consultation with the representatives of PE Roads of Serbia, Road Maintenance Sector, the position was taken that the width of 6-7 m from the edge of the roadway can actually be considered as a rational width in which it is justified to expand the sight distance berm in such conditions , and it

refers to the effective working width of modern machines for cutting vegetation along the roadside. The Figure 7shows one such machine.

Accordingly, as an auxiliary tool to the diagram of sight distance, the creation of lines of sight and their envelopes for a specific location such as this one is used. An example of the lines of sight and their envelopes for the subject zone and the direction from Ušće towards Kraljevo is shown in Figure 9. The line of sight bordering the selected bandwidth in which it is rational to open the sight distance berm is taken as authoritative. In this particular case, that line of sight is located at chainage Km 184+620.

Figure 6 – Layout of cadastral plots in the Km~184+400 zone (K.O. Maglič, Kraljevo)

Figure 7- Example of a machine for cutting vegetation in the service of road maintenance

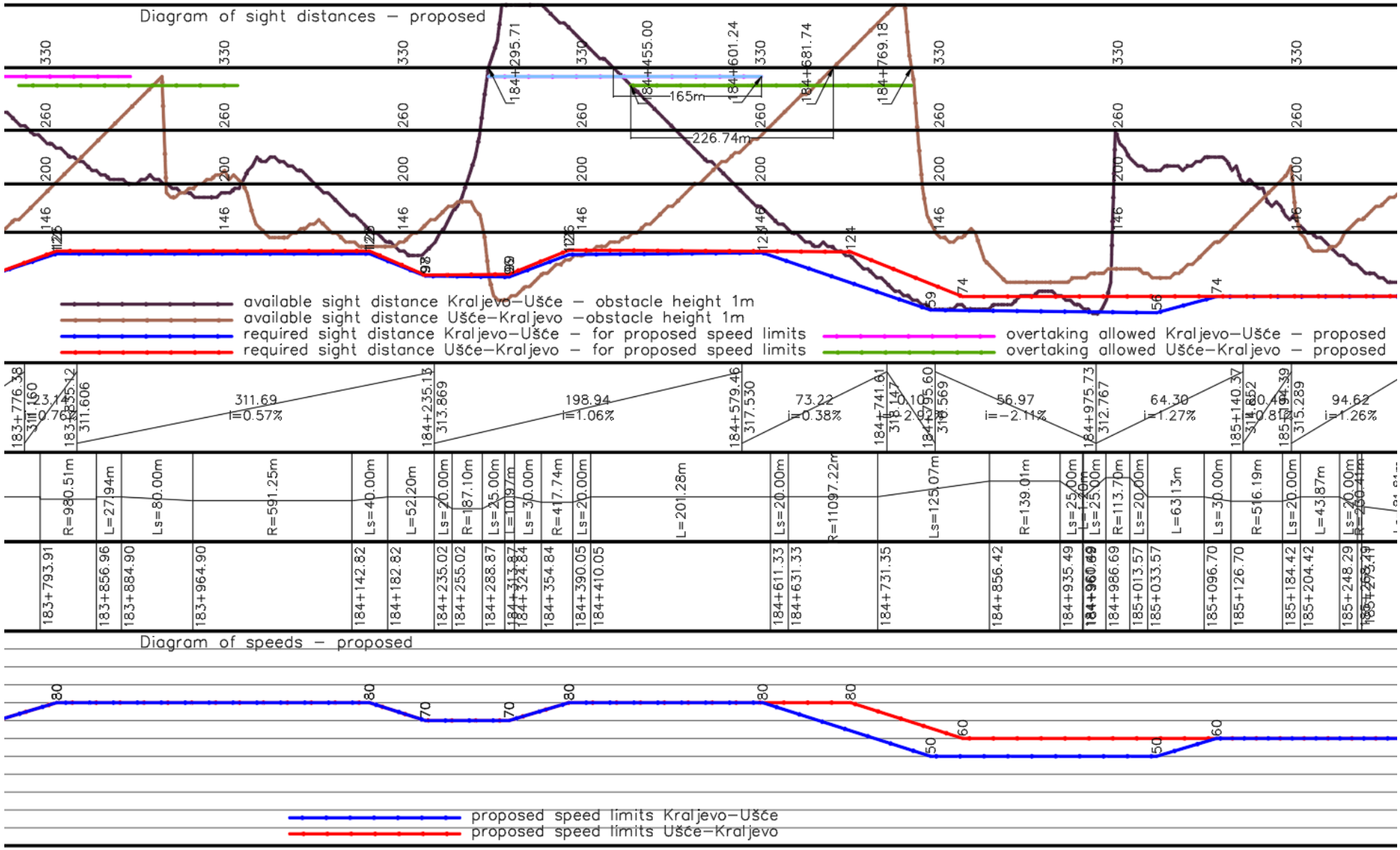


Figure 8 – Model for defining overtaking zones in the diagram of sight distance

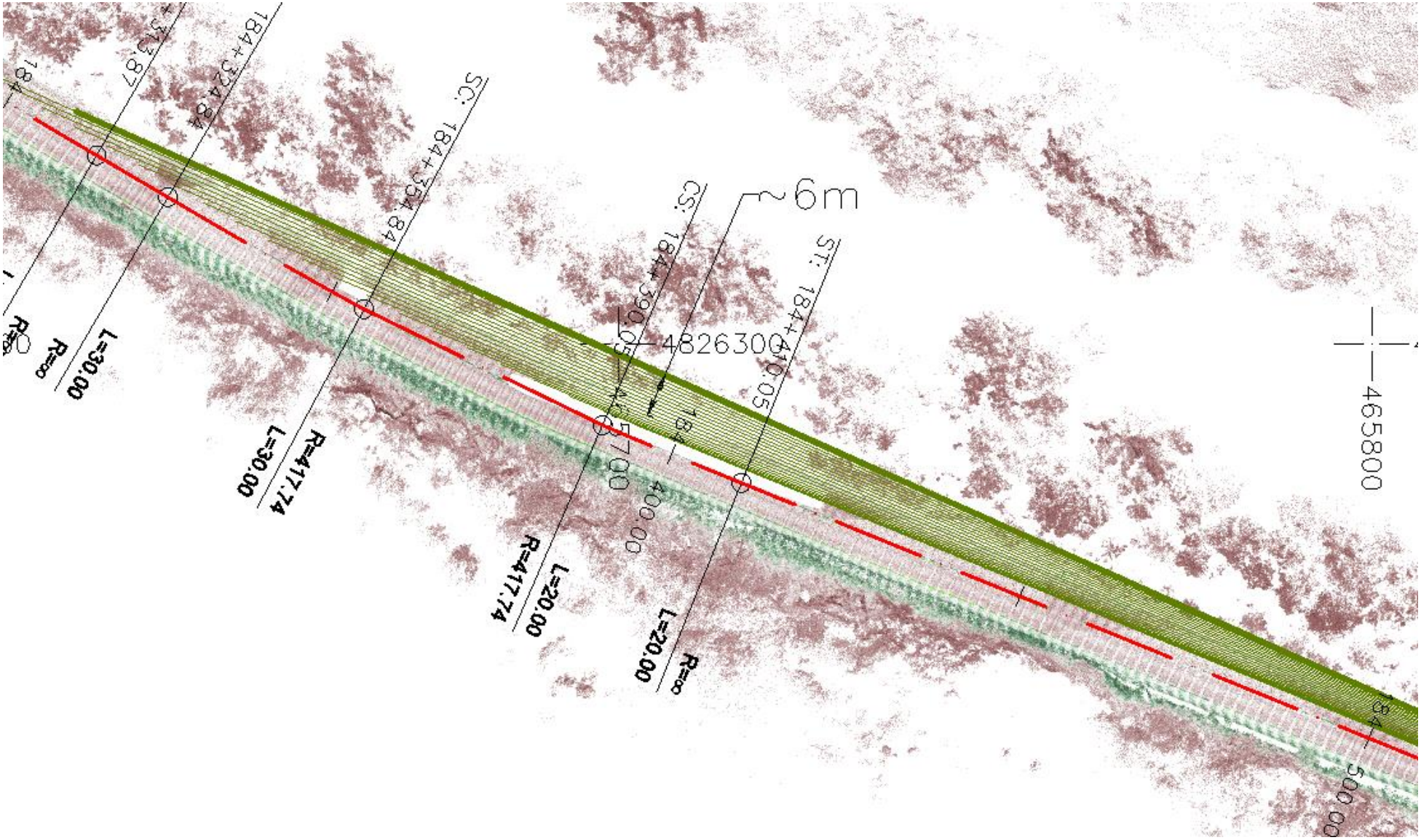


Figure 9 – Model for defining overtaking zones in the layout plan

In general , it can be stated that the arrangement of overtaking zones has undergone major corrections. For some that existed within the current state, it was proposed to be completely removed, as already stated in chapter Error! Reference source not found.**. However, with the given proposal, a few new overtaking zones appeared that did not exist before, while most of them underwent significant changes in terms of their start and end.**

A tabular overview of the proposed overtaking zones is given in the following table, and they are shown graphically in the graphic attachments 1

Kraljevo - Ušće			
Start [Km]	End [Km]	Length [m]	Speed ratio [Km/h]
158+050	158+482	432	50-30-50
158+482	158+630	148	60-40-60
159+629	161+481	1852	60-40-60
161+563	162+645	1082	60-40-60
162+834	163+306	472	60-40-60
163+680	164+410	729	50-30-50
164+891	165+182	291	50-30-50
165+267	165+462	195	60-40-60
165+730	167+131	1402	80-60-80
168+137	168+838	701	80-60-80
170+473	170+920	447	80-60-80
173+082	173+478	396	80-60-80
173+804	174+043	239	70-50-70
174+284	174+461	176	70-50-70
175+251	175+664	413	80-60-80
177+615	177+840	225	70-50-70
178+349	178+626	277	80-60-80
181+035	181+712	677	80-60-80
182+814	182+170	356	80-60-80
183+626	183+895	269	80-60-80
184+296	184+601	306	80-60-80
188+330	188+546	216	80-60-80
188+690	188+935	245	80-60-80
190+148	190+589	441	80-60-80
191+399	191+645	245	80-60-80
192+196	192+416	220	70-50-70
194+457	194+669	212	80-60-80
196+481	196+675	194	80-60-80
197+276	197+448	171	70-50-70
197+735	197+921	186	70-50-70
201+082	201+250	168	70-50-70
202+159	202+475	317	80-60-80
203+333	203+467	134	60-40-60
	sum=	**13834**	

Ušće - Kraljevo			
End [Km]	Start [Km]	Length [m]	Speed ratio [Km/h]
158+482	158+630	148	60-40-60
158+690	158+930	240	60-40-60
159+270	159+650	380	60-40-60
159+765	161+546	1782	60-40-60
161+712	162+422	710	60-40-60
162+552	162+837	284	60-40-60
162+951	163+511	559	60-40-60
163+750	164+410	660	50-30-50
165+410	165+719	309	60-40-60
165+941	167+274	1333	80-60-80
168+160	168+946	786	80-60-80
169+115	169+386	271	80-60-80
170+612	171+107	495	80-60-80
173+070	173+668	598	80-60-80
173+936	174+183	247	70-50-70
174+295	174+475	180	70-50-70
175+205	175+875	670	80-60-80
177+760	177+999	239	70-50-70
178+510	178+813	303	80-60-80
181+430	181+945	515	80-60-80
182+995	183+367	372	80-60-80
183+770	184+015	245	80-60-80
184+455	184+769	314	80-60-80
188+490	188+735	245	80-60-80
188+845	189+071	226	80-60-80
190+282	190+488	206	80-60-80
191+595	191+890	295	80-60-80
192+288	192+552	264	70-50-70
194+554	194+808	254	80-60-80
196+611	196+850	239	80-60-80
197+375	197+562	187	70-50-70
197+870	198+040	170	70-50-70
202+430	202+666	236	80-60-80
203+323	203+587	265	60-40-60
	sum=	**14230**	

Table 3- Table of proposed overtaking is allowed zones by direction

Observing the total lengths of overtaking zones by directions, it can be noted their significant increase within the framework of the newly proposed solution compared to the existing situation. Actually, in relation to the total length of the route, the percentage of allowed overtaking in the directions for the newly proposed solution would amount to:

- 30.08 % for the direction Kraljevo - Ušće;
- 30.95 % for the direction Usce - Kraljevo.

If, as in the case of the existing situation, the zones of allowed overtaking in populated areas were excluded from those percentages, we would get the following values:

- 19.81 % for the direction Kraljevo - Ušće;
- 21.10 % for the direction Usce - Kraljevo.

However, the following overtaking zones, which were the subject of analysis, the authors of this study do not recommend that they be elaborated further in the Traffic signal correction project. Those zones and the reasons for elimination from the final solution are given below.

overtaking proposed	direction	Comments:
Km 173+804 – Km 174+043	Kraljevo-Ušće	At these locations, there are existing overtaking zones Km 173+834 - Km 173+984 (for the direction Kraljevo-Ušće) and Km 174+004 - Km 174+134 (for the direction Ušće-Kraljevo). The reasons for their elimination from the proposed solution are identical to the reasons for the proposed elimination within the current state. Diagrams of posted limits, inferred design and proposed posted speed limits are similar in the immediate zone of this segment. The speeds in the directions are variable and conditioned by the limiting radius of the horizontal curve, which is R=69m (V~48 km/h). The available sight distance meets the needs of overtaking sight distance for a speed ratio of 70-50-70 km/h. The driving dynamics of the route and overtaking for the direction Kraljevo - Ušće are opposed to each other. In overtaking, it is calculated with maintaining a constant speed until the maneuver is completed, while the geometry of the route conditions the vehicle's deceleration due to encountering the limiting radius R=69m (V~48 km/h) . In the opposite direction, the situation is somewhat more favorable, considering that vehicles leave the limiting radius and accelerate. However, the acceleration of the overtaking vehicle would have to be significantly greater than the overtaking vehicle in order to perform the maneuver in the intended length.
Km 173+936 – Km 174+183	Ušće-Kraljevo	
Km 177+615 – Km 177+840	Kraljevo-Ušće	In these zones, vegetation can be removed within the envelope of sight distance and achieve tolerable sight distance for an overtaking speed of 70 km/h. However, looking at the inferred design speed diagram, the appearance of vehicles with speeds of 80 km/h and over can be expected, especially in dry road conditions. Namely, bearing in mind that the values of the inferred design speed diagram are theoretically related to a lone vehicle on the road in wet road conditions, it is easy to conclude, as evidenced by practice, that higher vehicle speeds
Km 177+760 – Km 177+999	Ušće-Kraljevo	

		can be expected in dry road conditions. That is, there is a high probability of vehicles moving in opposite directions at speeds higher than those for which the overtaking conditions are defined, and for these reasons, its further elaboration is not recommended.
Km 192+196 – Km 192+416	Kraljevo-Ušće	In these zones, vegetation can be removed within the sight distance envelope achieve tolerable sight distance for an overtaking speed of 70 km/h. The width of the belt along the edge of the road where the vegetation should be removed in that case would be ~10.5 m. However, looking at the inferred design speed diagram, the appearance of vehicles with speeds of 80 km/h and over can be expected, especially in dry road conditions. Namely, bearing in mind that the values of the inferred design speed diagram are theoretically related to a lone vehicle on the road in wet road conditions, it is easy to conclude, as evidenced by practice, that higher vehicle speeds can be expected in dry road conditions. That is, there is a high probability of vehicles moving in opposite directions at speeds higher than those for which the overtaking conditions are defined, and for these reasons, its further elaboration is not recommended.
Km 192+288 – Km 192+552	Ušće-Kraljevo	
Km 197+276 – Km 197+448	Kraljevo-Ušće	Locations of existing overtaking zones, which elimination is proposed in chapter **Error! Reference source not found.**. Additional analyzes determined that certain shortcomings such as the length of those zones and overtaking sight distance for the direction from Ušće to Kraljevo can be improved. However, there is still a risk that a vehicle from the opposite direction may appear in these zones whose speed is higher than expected for overtaking conditions at a speed ratio of 70-50-70 km/h.
Km 197+375 – Km 197+562	Ušće-Kraljevo	
Km 197+735 – Km 197+921	Kraljevo-Ušće	
Km 197+870 – Km 198+040	Ušće-Kraljevo	

When we eliminate these five zones from the total lengths, we arrive at the following percentage values of overtaking is allowed:

- 16.90% for the direction Kraljevo - Ušće;
- 18.01% for the direction Usce - Kraljevo.

Although the percentages finally obtained in this way do not meet the requirements of the regulations (>20%), they still represent a significant improvement compared to the current situation.

6.1.3. Removal of vegetation that obstructs sight distance

During the analysis of sight distance and the definition of proposals for the correction of speed limits by directions, phenomena that affect reduced sight distance were analyzed in detail and classified. This is of particular importance because the removal of vegetation that obstructs sight distance is one of the short-term measures that are easy to implement and can have a very significant impact on increasing operational characteristics and traffic safety.

In this regard, within the diagram of sight distance given in graphic attachment 1, special notes are marked in the zones where vegetation should be removed in order to ensure the planned required and overtaking sight distance. In addition, on the basis of the proposed required and overtaking sight distance, a special graphic attachment 2 was prepared, in which **line of sight** and their **envelopes** for both directions were entered on the layout plan. For the purposes of a clearer graphic representation, only envelopes of required and overtaking sight distance per direction are given in

the printed view of graphic attachment 2, while the digital version also contains their lines of sight sorted by layers that can be turned on/off.

The layout plan with envelopes of lines of sight is of particular importance for adequate road maintenance. Based on it and with the help of modern mobile devices, supported by satellite positioning, it is possible for the road manager and maintenance companies to automatically find the boundaries of the road strip within which it is necessary to maintain vegetation and remove other obstacles that may affect sight distance.

An example of a layout plan with entered envelopes of lines of sight is shown in Figure 10-

Although it was stated in the previous chapter 6.1.2that the removal of vegetation only in a width of 6-7m from the edge of the roadway can be considered as a rational measure, along the sections in question we encounter exceptions. The locations and reasons for deviations are given in the following table.

Section	Exception description
Km 159+945 – Km 160+092	This section belongs to the proposed overtaking zone for the direction from Ušće to Kraljevo. The exception was made in order to remove obstacles to the available sight distance on a longer stretch and achieve the continuity of the overtaking zone. The maximum width of vegetation removal on this stretch is 10m from the edge of the carriageway.
Km 170+634 – Km 170+918	This section belongs to the stretch of existing/proposed overtaking zone for direction from Ušće towards Kraljevo. The exception was made in order to remove obstacles to the available sight distance on a longer stretch and achieve the continuity of the overtaking zone. The maximum width of vegetation removal on this section is 12.5m from the edge of the carriageway. It is located in the zone of overtaking of the existing state, where in certain parts the available sight distance decreases significantly and does not correspond to the required overtaking sight distance for the speed ratio of 80-60-80 Km/h. In the event that it is not acceptable to remove vegetation in the given width, it is necessary to predefine zones of overtaking with interruption of the existing continuity.
Km 174+265 – Km 174+396	This section belongs to the proposed overtaking zone for the direction from Ušće to Kraljevo. An exception has been made to overtaking in this direction as well after passing through an intersection. Although the proposed posted speed limit in this zone is 50 km/h, overtaking sight distance and its envelope are defined for the speed ratio 70-50-70 km/h. The maximum width of vegetation removal on this stretch is 10.5m from the edge of the carriageway.
Km 196+405 – Km 196+689	This section belongs to the proposed overtaking zone for the direction from Ušće to Kraljevo. Overtaking sight distance and its envelope are defined for the speed ratio 80-60-80 km/h The maximum width of vegetation removal on this section is 8.6m from the edge of the carriageway.
Km 201+791 – Km 201+926	The maximum width of vegetation removal on this section is 8.0m from the edge of the carriageway and it is necessary to satisfy the required sight distance for the direction Ušće-Kraljevo.

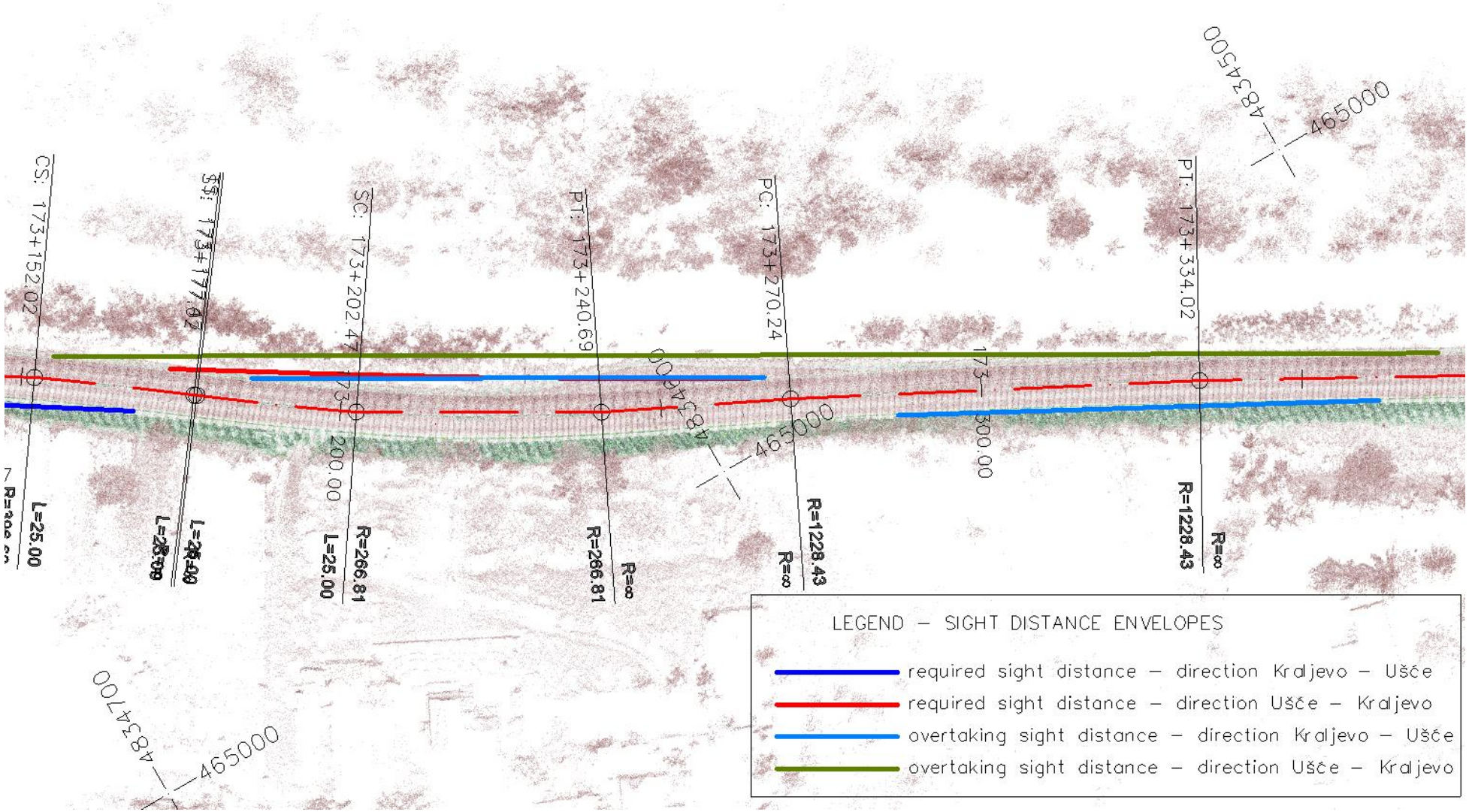


Figure 10- Example of a situational plan with envelopes of required and overtaking sight distance entered

6.1.4. Zones where it is necessary to prohibit parking and keeping of vehicles

A frequent phenomenon along state roads in the Republic of Serbia is the positioning of parking lots/rest areas on the inner sides of curves, precisely in places where such facilities obstruct sight distance. The problem of parking/stopping is particularly pronounced in urban areas, where it also happens on areas that are unorganized or not even planned for that purpose. One such example is shown in the pictures Figure 11i Figure 12.

Figure 11- Parking on the inside of the curve on unplanned and unorganized surfaces

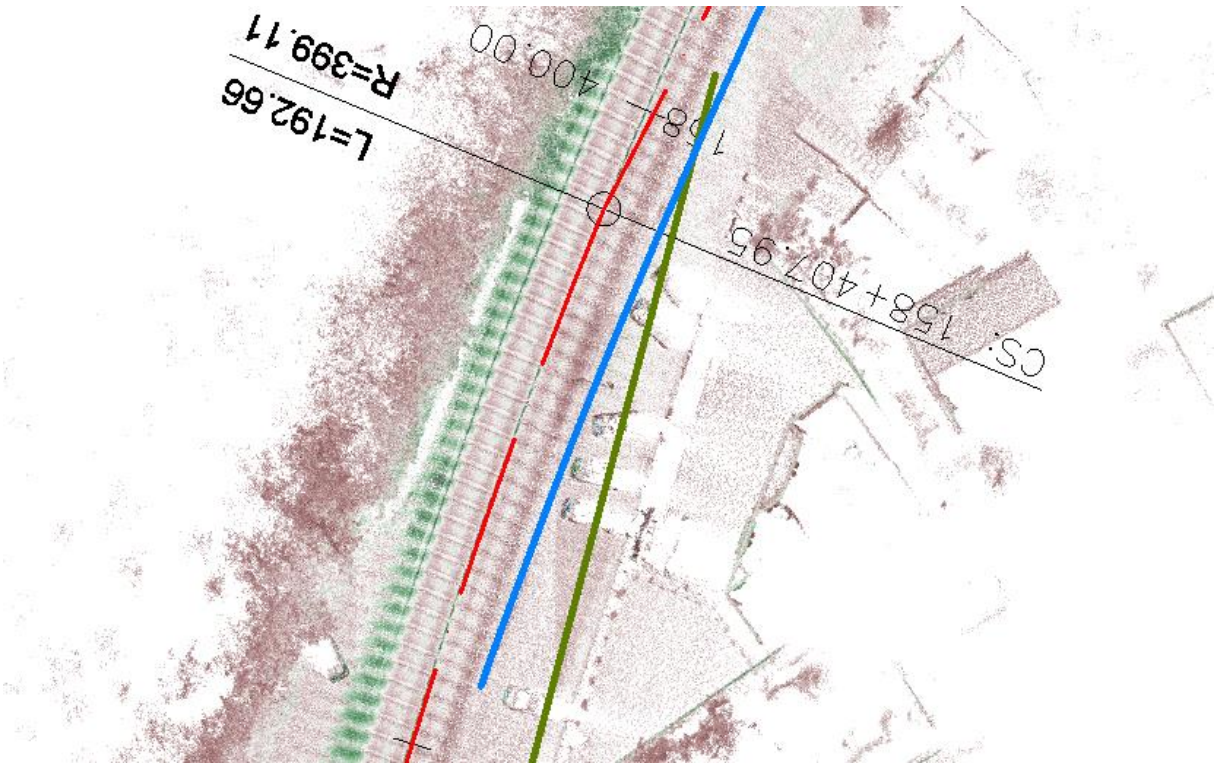


Figure 12- Presentation of the layoutl plan with envelopes of lines of sight which cross over parked vehicles

In such locations, it is necessary to either prohibit temporary/permanent stopping/parking of vehicles or limit overtaking.

Some bus stops positioned on the inner sides of curves can also be included in this type of disturbance. However, when considering their impact on sight distance, the following facts should also be taken into account:

- pedestrian crossings where overtaking is prohibited are most often found in the zones of bus stops, and for this reason sight distance requirements are reduced;
- the duration of occupation of their surfaces is small;
- the locations are directly dependent on the distances and accessibility of their users, and it is very difficult to dislocate them to positions where sight distance will not be compromised.

Locations where similar problems have been identified along the route in question are as follows:

Km 158+407 – Km 158+475	left
Km 159+660 – Km 159+775	right
Km 168+680 – Km 168+800	left
Km 175+250 – Km 175+320	left
Km 178+035 – Km 178+085	left
Km 181+160 – Km 181+220	left
Km 182+535 – Km 182+565	left
Km 183+850 – Km 183+925	left
Km 183+995 – Km 184+050	left
Km 185+270 – Km 185+325	left
Km 190+615 – Km 190+700	left
Km 190+735 – Km 190+775	left
Km 194+765 – Km 194+840	left
Km 198+600 – Km 198+670	left
Km 199+795 – Km 199+850	left
Km 201+915 – Km 201+990	left
Km 203+490 – Km 203+560	right

Table 4- Locations with sight distance problems due to stopping/parking of vehicles

6.1.5. Correction of horizontal and vertical traffic signals

According to the results of the analyzes carried out in this study, it is necessary to proceed with the development of the traffic signalization correction project, which will primarily refer to:

- speed limit corrections by directions;
- corrections of horizontal and vertical signaling related to overtaking is allowed zones.

6.2. Proposal for long-term measures

6.2.1. Correction of speed limit by directions

The proposal for long-term measures related to the correction of speed limits by direction refers primarily to their harmonization-equalization in those locations where it was not possible to predict this through short-term measures.

As a rule, such cases occur in location where it is rationally and feasible to extend the berm of sight distance by means of construction interventions in cuts. Along the route in question they are located in the following sections:

side cut right	Km 175+908	Km 175+969
side cut right	Km 177+854	Km 177+927
side cut right	Km 178+066	Km 178+112
side cut right	Km 178+183	Km 178+242
side cut right	Km 192+417	Km 192+678
side cut right	Km 193+952	Km 194+118
side cut right	Km 194+169	Km 194+312
side cut right	Km 196+255	Km 196+477
side cut right	Km 196+725	Km 196+831
side cut right	Km 197+177	Km 197+273
side cut right	Km 200+615	Km 201+055

Table 5- Sections where berms need to be widened

6.2.2. Geometry correction

In order to comply with the valid legal and by-law norms, as a long-term measure, the correction of geometric elements is proposed at all locations where it deviates from the prescribed ones, and especially at locations where the so-called 'skipped' curves in the speed diagram as described in chapter 4.3.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

Based on all the above, as a general conclusion, the following can be stated.

The analyzes implemented in this Elaborate revealed very significant shortcomings of the subject route of the state road, which primarily relate to:

- non-compliance of speed limits by direction, but also their non-compliance with the geometric characteristics of the route;
- poorly maintained and inadequately placed traffic signals;
- non-fulfillment of the required and overtaking sight distance;
- poor maintenance, removal and mowing of vegetation, probably as a consequence of the absence of clear boundaries within which to do so;

The application of short-term measures defined in chapter 6.1would significantly improve traffic safety, and the application of long-term measures defined in chapter 6.2would further improve traffic safety and improve the operational characteristics and level of service on the subject section of the state road IB 22.

7.2. Recommendations

Taking into account the problems highlighted in this Elaborate, which refer to the obsolescence and mutual inconsistencies of the norms in the field of sight distance on road, the authors of this Elaborate make the following recommendations.

7.2.1. The relevant height of the obstacle

According to the facts that the height of the obstacle:

- of 0.1 m as defined by domestic norms represents an extremely rigid value that is impossible to respect in the case of steel and any other type of fence along the roadway;
- defined by domestic norms is inconsistent with the recommendation given by the EU in the Eusight project ;
- has a direct impact on defining the boundary radii of the convex vertical curve;

the authors of this study make the following alternative recommendations:

1. change the norms in such a way that the value of 1.0 m is adopted for the height of the obstacle which would eliminate sight distance disturbances related to the steel fence to the greatest extent;
2. change the norms in such a way that the value (0.4-0.6 m) recommended by the Eusight project is adopted for the height of the obstacle;
3. keep the height of the obstacle at 0.1 m , excluding the influence of the steel fence on sight distance;

The opinion of the author of this Elaborate is that the proposed alternative 3, with the following explanations, is preferable.

The boundary elements of the convex vertical curve for decades in the Republic of Serbia were tied to the height of the obstacle of 0.1 m. Changing that value would automatically create the need to change other elements defined by the norms, and their application would create inconsistency with the existing road network. In addition, the steel fence, which mostly obstructs sight distance in the case of an obstacle height of 0.1 m , is most often found along the roads in side cuts and embankments, where in the side cuts it is located along a strip that is farther from the slope from which a piece of rock threatens to break off and slide. Even if it fall, it will most likely stay in the traffic lane close to cut slope. On embankments, there is no danger of the rock breaking off and falling onto the road.

As an additional argument, the fact that drivers rarely find themselves in the situation of a lone vehicle on the road, but most often move behind another vehicle, and coordinate their reactions with the reactions of the vehicle in front of them. In the rare cases when they find themselves in these situations and in the event of encountering a sudden obstacle that they could not see, drivers actually most often perform a maneuver around that obstacle without stopping.

7.2.2. Definition of required sight distance in the Law of roads

The request defined in Article 2, paragraph 45, which reads:

"Required sight distance is the distance required to safely stop a vehicle in front of an immovable obstacle on the road surface, which must be ensured at every point of the road and which is determined based on the authoritative values of the inferred design speed in both directions of travel "

at least when it comes to the inherited-existing network of state roads, it is most often not satisfied, nor is it rational to be satisfied, since the definition of the inferred design speed is directly related only to elements of horizontal and vertical geometry, i.e. it is not related to other types of restrictions such as: passage through a populated place, intersections, school zones, special facilities (tunnels/bridges), bus stops, pedestrian crossings, etc.

The proposal of the author of this study is to change the relevant article so that it reads:

"Required sight distance is the distance required to safely stop a vehicle in front of an immovable obstacle on the road, which must be provided at each point of the road and which is determined based on the speed limited at that point, and must be met in both directions of travel " '

The existing definition has an extremely negative effect on road managers, not only for the reason that it is impossible to satisfy it, but also for reasons arising from the penal provisions of the same law.

7.2.3. Mutual inconsistency of bylaws

Mutual inconsistencies of book of rules:

- Rulebook on conditions that must be met by road facilities and other elements of the public road from the aspect of traffic safety (Official Gazette of RS, No. 50/2011), and
- Rulebook on traffic signals (Official Gazette of RS, no. 85/2017 and 14/2021)

has already been commented on in chapter **Error! Reference source not found.**, so there is no need to repeat it here.

Regarding the inconsistencies in question, the authors of this report recommend that both regulations be reviewed and harmonized in the part defining overtaking sight distance with the following arguments :

- on the basis of numerous worldwide researches on the real-practical behavior of drivers in overtaking maneuvers, it can be concluded that the distances necessary for the execution of those maneuvers are far lower than those included in the value of overtaking sight distance defined by the "Regulation on the conditions that must be met by road users from the aspect of traffic safety objects and other elements of the public road (Official Gazette of RS, No. 50/2011)''. The values defined by this rulebook correspond to the theoretical model of overtaking on the basis of which the values were calculated, but it is obvious that the model in question does not correspond to the driver's behavior in practice.
- the values of overtaking sight distance defined by the "Rulebook on Traffic Signals (Official Gazette of the RS, No. 85/2017 and 14/2021)" are much closer to the real behavior of drivers in practice, but do not correspond to the theoretical model of overtaking referred to in the regulation. The values of overtaking sight distance defined by this regulation are more consistent with the theoretical model of reduced lengths, i.e. for cases when the vehicle is already in overtaking with its front end aligned with the rear end of the overtaking vehicle, and not with the theoretical model of constant speeds, where the initial phases are also included in the calculation while the overtaking vehicle is still behind the overtaken one.

The Republic of Serbia is no exception to this inconsistencies. According to the research of the authors of this study, many countries in the world have the same problem. Among them was the USA, which noticed the problem, investigated it in detail and made the appropriate decision through a document entitled NCHRP Report 605 Passing Sight Distance Criteria (2008).

8. COMMENT REGARDING GRAPHIC ATTACHMENTS

The graphic appendices of the report consist of the following units:

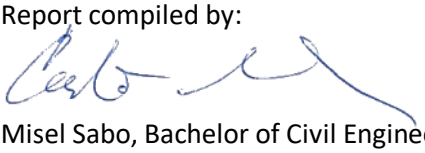
A. Graphic attachments suitable for printing, which are formatted in such a way as to be an integral part of the printed and digital version of the report:
  - speeds and sight distance diagrams - graphic attachment 1;
  - situational plans with envelopes of sight distance - graphic attachment 2 ;

B. Graphic attachments, animations and video materials that are not suitable for printing and are an integral part of the digital version of the report:
  - georeferenced point cloud in UTM34N coordinate system, in Autodesk Recap *.rcs, *.rcp format;
  - video animations (simulations) of the driver's movements and virtual obstacles at the distance of the required visor of sight distance from the driver, in a cloud of points. The subject animations were created for different cases of speed and obstacle height of 1.0m. Animations for an obstacle height of 0.1m can be created, but due to the

small height of the virtual obstacle in question, it is very difficult to recognize them and follow them through the animation;

- video recording of the section in question made with a spherical (360°) camera during field work;

Report compiled by:



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APPENDICES - TABLE OF TRAFFIC ACCIDENTS OF THE TYPE OF HEAD-ON CRASH AND OVERTAKING IN THE PERIOD 2016-2022

Num	Accident code	Y	X	Chainage	Type of location	Settlement	Lon	Lat	Date of accident	Consequence
1	1202640	471792	4841860	158+282.49	Intersection	Yes	20.6498	43.7292	26.12.2017	TA MD
2	1277989	470532	4840852	160+100.50	The road	Not	20.6342	43.7201	10.01.2020	TA MD
3	1396439	470389	4840786	160+258.16	The road	Not	20.6324	43.7195	18.10.2022	TA MD
4	1199400	470340	4840761	160+313.46	The road	Not	20.6318	43.7193	01.11.2017	TA SBI
5	1305002	470087	4840646	160+590.62	The road	Not	20.6287	43.7182	19.11.2020	TA MBI
6	1154850	469701	4840479	161+011.37	The road	Yes	20.6239	43.7167	31.10.2016	TA MBI
7	1175078	469331	4840205	161+474.06	The road	Yes	20.6193	43.7142	16.04.2017	TA MD
8	1133298	468214	4838264	163+820.56	The road	Yes	20.6055	43.6967	19.05.2016	TA MD
9	1285572	468080	4838235	163+957.30	The road	Not	20.6039	43.6964	15.04.2020	TA MD
10	1354351	467337	4838194	164+703.61	The road	Yes	20.5947	43,696	28.01.2022	TA MD
11	1187836	466434	4837995	165+635.12	The road	Yes	20.5835	43.6942	01.08.2017	TA SBI
12	1378537	466069	4837479	166+283.55	The road	Not	20,579	43.6896	06.07.2022	TA MD
13	1358881	465865	4837108	166+707.05	The road	Not	20.5765	43.6862	28.02.2022	TA MBI
14	1138225	465781	4836956	166+880.13	The road	Yes	20.5754	43.6848	26.06.2016	TA MBI

15	1137217	466210	4835233	168+956.13	The road	Yes	20.5809	43.6693	18.06.2016	TA MD
16	1344011	466435	4835133	169+203.35	The road	Not	20.5837	43.6684	01.12.2021	TA MD
17	1366937	466684	4835052	169+466.63	The road	Not	20.5868	43.6677	17.04.2022	TA MBI
18	1372617	466915	4834901	169+743.22	The road	Not	20.5896	43.6664	01.06.2022	TA MD
19	1302960	464246	4827997	181+677.55	The road	Not	20,557	43.6041	28.10.2020	TA MD
20	1245452	464278	4827346	182+417.83	The road	Not	20.5574	43.5982	23.02.2019	TA SBI
21	1185935	467126	4824318	187+185.03	The road	Not	20.5929	43.5711	23.07.2017	TA FAT
22	1388809	468072	4823469	188+529.27	The road	Not	20.6046	43.5635	31.08.2022	TA MD
23	1229473	468800	4822700	190+483.20	The road	Not	20.6137	43.5566	15.09.2018	TA FAT
24	1262042	468382	4822096	191+291.53	The road	Not	20.6086	43.5511	01.08.2019	TA MBI
25	1117979	468488	4821984	191+448.97	The road	Not	20.6099	43.5501	21.01.2016	TA SBI
26	1331783	468514	4821978	191+475.51	The road	Not	20.6102	43.5501	17.08.2021	TA MD
27	1289025	468539	4821972	191+500.91	The road	Not	20.6105	43.55	05.06.2020	TA MD
28	1221363	468758	4821909	191+728.64	The road	Not	20.6132	43.5495	29.06.2018	TA MBI
29	1116316	468290	4821058	193+528.19	The road	Not	20.6075	43.5418	04.01.2016	TA MBI
30	1290276	468555	4820363	194+317.98	The road	Not	20.6108	43.5356	14.06.2020	TA FAT P

31	1266102	468363	4820063	194+677.91	The road	Not	20.6085	43.5328	18.09.2019	TA MD
32	1191856	468726	4817651	197+422.40	The road	Not	20.6131	43.5111	17.09.2017	TA MD
33	1236714	468703	4817585	197+491.44	The road	Not	20.6128	43.5105	24.11.2018	TA FAT P
34	1241976	468886	4816042	199+309.41	The road	Not	20.6152	43.4967	14.01.2019	TA MBI
35	1276481	468394	4814408	201+866.98	The road	Not	20.6092	43.4819	27.12.2019	TA MBI
36	1234557	468443	4814368	201+930.55	The road	Not	20.6098	43.4816	02.11.2018	TA MBI
37	1122239	469102	4813070	203+674.08	The road	Yes	20,618	43.4699	17.02.2016	TA MD

Abbreviations:

- TA MD - traffic accident with material damage
- TA MBI - traffic accident with minor bodily injuries
- TA SBI - traffic accident with serious bodily injuries
- TA FAT - traffic accident with fatalities