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Original research paper

APPROACH FOR DEFINING THE LIMIT VALUE OF THE STOPPING SIGHT DISTANCE ON THE ROADS IN THE REPUBLIC OF NORTH MACEDONIA

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Abstract. *The most of the existing road network in the Republic of North Macedonia consists of sections that in the past were designed to provide the most durable and permanent engineering solutions of the carriageway, with minimal commitment to the road geometry. The visibility on the road is a key condition that would significantly contribute to better driving dynamics as well as to road safety. An analysis of Stopping Sight Distance (SSD) on all main roads was conducted within the paper. The visibility is checked simultaneously, through video recordings and CAD drawings, and is recorded tabularly by sections. In the analysis, checks are treated in two projections with additional subtypes: Horizontal solution (open route and intersections) and vertical solution (for convex and concave curves). The obtained values are quantified according to the length of each section, thus determining the individual sizes for each type. According to the resulting diagram of all the sections and the range from minimum to maximum, an economically acceptable visibility limit is defined through which all existing and future roads are weighted and it is defined whether they have a satisfactory visibility or not.*

Key words: *visibility, roads, driving dynamics, safety, sections*

1. INTRODUCTION

Traffic safety and traffic flow quality can be increased by applying already proven approaches and methodologies. SSD is crucial for road safety for several reasons such as: Preventing collisions or run-off-road incidents, quick observation of road surroundings (fog, rain, snow), ensuring a continuous flow of traffic without sudden braking, etc. [1][2][3][4][5].

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The current practice for the design, construction and maintenance of roads in the Republic of North Macedonia was focused mainly on the basic useful properties of the road without going into the reasons that cause serious reduction of safety.

The safety problem has come to the fore significantly with the increase of Annual Average Daily Traffic (AADT) and with the more powerful features of the vehicles. The continuous increase in traffic accidents has imposed the need to ask numerous questions about the ways of management and methodologies to improve road safety. Currently, we do not have specific statistics and an appropriate agency that will accurately and systematically record the problematic sections of the road. All unsafe locations are only recognized in principle and locally resolved, and future monitoring and planned management are not foreseen for them. The defined deficiencies in management bring out the need to prepare strategic approaches to increase security in several of its sub-areas.

One of the key phases of safety is visibility on the road. It is currently the least treated in our country, and there is still no adequate database for it that will record all unexamined locations.

The previous researches in the field of visibility are mainly focused on the qualitative approach and the methodology for checking visibility. The analysis covered in this paper is based on the quantitative approach.

Below is presented a draft approach for the classification of visibility for stopping, which will show the non-inspectable sections in a quantitative manner and define a limit level of visibility through which, in the future, it can be revised whether a section is at a critical or a satisfactory level.

2. Scope of the Research

The large AADT and the large number of traffic accidents initiates the research to focus on the highest category of Class A roads - national roads. The sections are divided according to the current traffic unit and according to the current counting places.

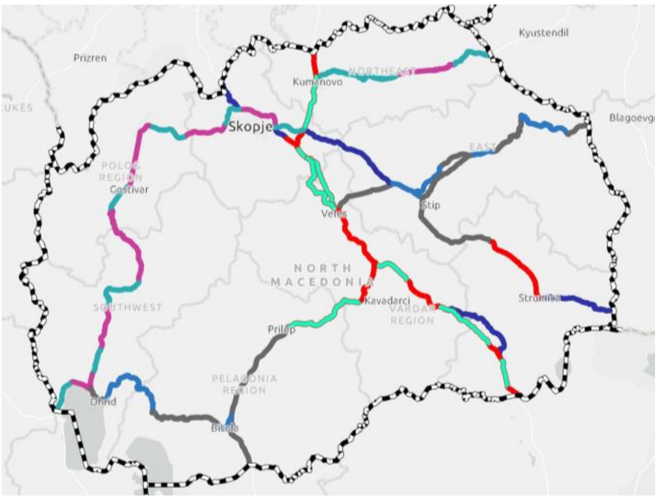

Fig. 1 Class A roads in the Republic of North Macedonia

The entire analysis includes 45 sections with different geometric cross-sections (motorways L=311 km, expressways L=100 km and two-lane road L=565 km). In Figure 1 there are four main corridors which are marked with two different colors to show the subsections. The average width of the belt is at least 100 m, i.e., 50 m on both sides of the road.

3. Method of Defining the Stopping Sight Distance

The determination of the SSD is made according to the Rulebook on Road Design of the Republic of North Macedonia, according to which, the visibility for stopping (Pz) represents the minimum length at which the driver notices the obstacle in order to be able to stop the vehicle completely in conditions of allowed values of the coefficient of friction and it is determined according to the following equation:

$$Pz = Lz + \Delta L \quad (1)$$

In the equation, the first summation Lz contains the driver's reaction time (2s) and the length of forced braking Lfk (as a function of speed, friction coefficient and longitudinal slope), and the second summation represents the safety distance of a stopped vehicle to the obstacle (7m).

The type of friction coefficients and the specific longitudinal slope make a significant difference to the forced braking length Lfk, which is why the determination of the length Lz (Figure 2) is made through the already calculated diagrams [6][7].

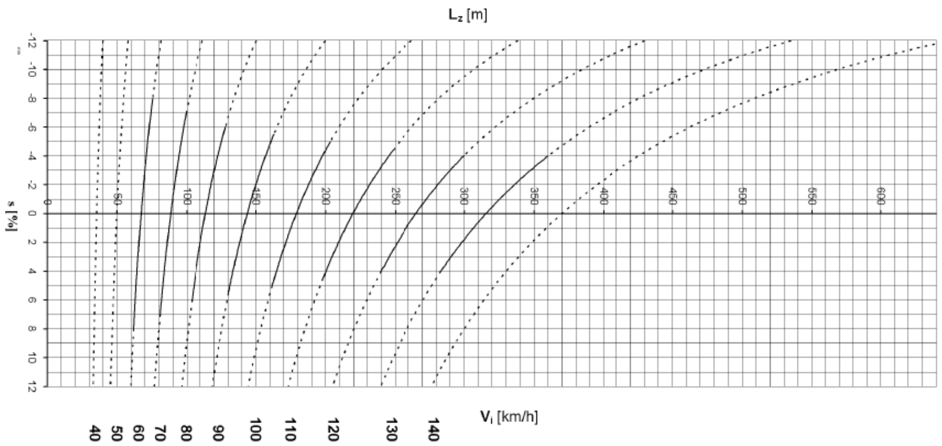

Fig. 2 Stop length for roads of technical group A

The sum of the stop length and the safety distance is used as the sight beam in determining the horizontal and vertical stopping sight distances (Figure 3) in all four characteristic cases [8]. In a longitudinal profile the stop length Pz will be equal to SSD.

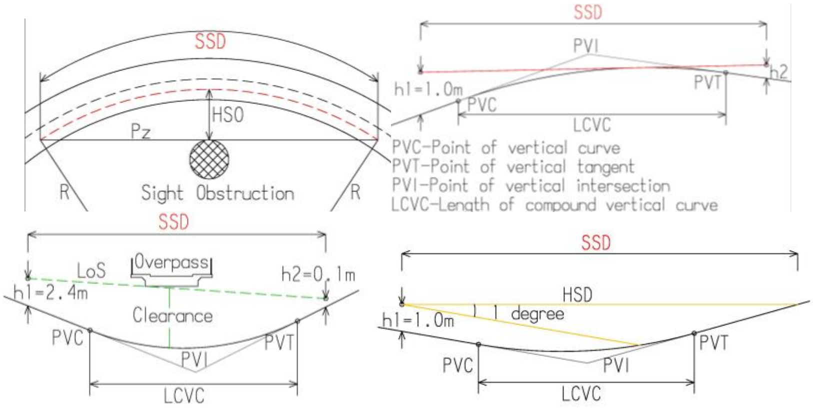

Fig. 3 Typical SSD check cases

4. VIEWABILITY ANALYSIS DATA

The collection of data on the characteristics of each section is done through video recording with a GPS camera (DOD LS460W, IS420W) where a 3D viewer displays the specific route in coordinates (Open Street Map) and current driving speed (min, max and average) (Figure 4 & 5).

Fig. 4 Horizontal SSD at speed of V=70km/h and a visible beam of Pz=90m, section: A3 Prevalec – Kamenica

Fig. 5 Vertical SSD at speed of V=70km/h and a visible beam of Pz=90m, section: A3 Prevalec – Kamenica

The observation period of the analyzed sections is from August to November 2023. The clear length of the stop is determined according to the defined limited speed and the current slope of the road section, which is used to check the SSD in the horizontal and vertical view.

Table 1 shows only a part of the observed sections and contains the number of unsightly horizontal and vertical locations, their total and corresponding coefficients of SSD calculated as the ratio of the number to the length of the section.

Table 1 Extract from SSD Coefficient display table

Road code	Road Section	Sum of critical locations		P_z (m)	Section length L (km)	Coefficient of SSD - Horizontal h/L (n/km)	Coefficient of SSD - Vertical v/L (n/km)	Coefficient of SSD - Sum (h+v)/L (n/km)
		Hor. h(n)	Ver. v(n)					
A4	Miladinovci Kadrifakovo	0	1	265	39,40	0,00	0,38	2,54
	Kadrifakovo Miladinovci	2	0	265	39,40	5,08	0,00	5,08
A4	Shtip Radovish	2	1	180	39,10	5,12	0,56	7,67
	Radovish Stip	2	0	180	39,10	5,12	0,00	5,12
A4	Radovish Strumica	1	0	115	26,60	3,76	0,00	3,76
	Strumica Radovish	1	0	115	26,60	3,76	0,00	3,76

5 Discussion

The comparison in this quantitative approach mainly refers to the results obtained from horizontal, vertical and resultant coefficients.

The defined coefficients for each section are shown through diagrams of horizontal, vertical and aggregate SSD (Figure 6 & 7).

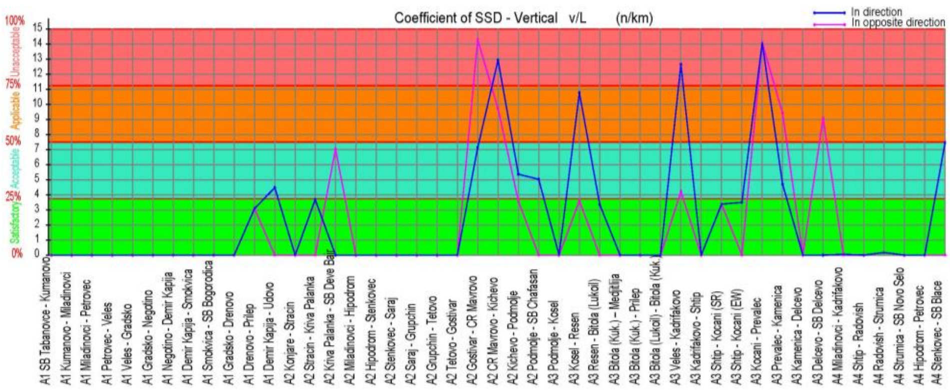

Fig. 6 Coefficient of Vertical SSD

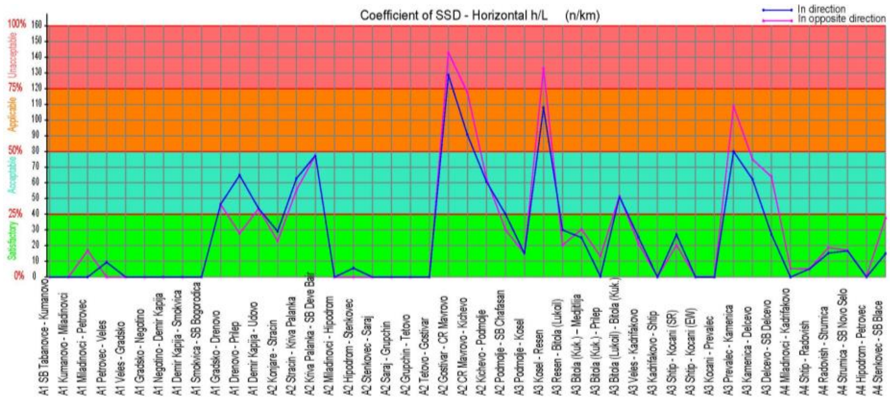

Fig. 7 Coefficient of Horizontal SSD

Using the already established practice for road management in the Republic of North Macedonia [8], an economically acceptable percentage of visibility of 25% has been defined, i.e., a percentage threshold has been specified through which the total span in the diagram can be divided into four levels:

- 0% - 25% - Satisfactory,
- 25% - 50% - Acceptable,
- 50% - 75% - Applicable,
- 75% - 100% - Unacceptable.

The total span of the currently unexamined locations is determined by defining the maximum and minimum size of the coefficient, which is treated as the total length for distribution. According to this distribution, the limit of the levels of the SSD coefficient for vertical visibility is 3.75%, while the levels for horizontal visibility and the summary view are 40%.

From the shown diagrams, Figure 8, it can be concluded that the vertical SSD coefficient is significantly higher than the horizontal. In general, in places where reduced SSD was not expected (motorways and expressways), locations where construction or traffic improvement should be made in the future were specified.

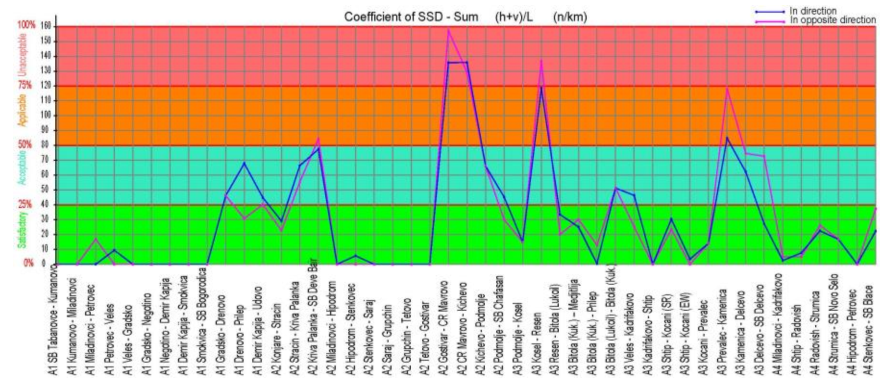

Fig. 8 Summary Mean SSD Coefficient

Through the elaboration of the data and the defined SSD coefficients, differences can be roughly defined in relation to several aspects (Table 2):

Table 2 Summary Mean SSD Coefficient differences in relation to road characteristics

	Summary Mean SSD Coefficient	Inequality	Summary Mean SSD Coefficient
Timeline	Old roads	>	New roads
Terrain Category	Mountainous and coastal	>	Hilly and flat
Geometric Cross Section	Two lane roads	>	Motorways and Expressways

However, if reconstruction is to be done, it should be noted that, although it seems that the roads of the highest rank should be treated first, the priority in terms of visibility should be given in the reverse order, i.e., the roads with two traffic lanes should be repaired first, and the Motorways should be repaired last. The Road Safety aspect can be cited as the reason for the defined priorities, which indicates that two-lane roads are far less safe than motorways and expressways. Additionally, the fact that motorways and expressways are fenced while two-lane roads are not can be added [9].

6. Conclusion

Visibility for stopping is a key safety factor when braking in the event of an obstacle appearing while driving.

With the current statistics, a large number of traffic accidents caused by a direct collision with an obstacle (rockfall, object, vehicle, animal etc.) have been determined on the roads, which are attributed to the stopping sight distance.

No adequate database has been created for SSD in the current road management practice. This paper answered that question by presenting a relevant database that refers to all main roads in the territory of the Republic of North Macedonia.

The research was conducted on the entire national network, which is divided into 45 sections defined according to the type of the cross section, AADT and the connection to fixed points.

The mean limit speeds and the average longitudinal slopes of each section were taken as basis for the analysis, and an authoritative ray of visibility was defined for them, based on which the SSD is checked.

The analysis established that the highest coefficients of SSD were obtained on older roads, on roads with two traffic lanes and on roads in distinctly mountainous terrains.

This approach to checking the visibility of a stop can be the basis for a methodology with a GIS platform in the future that would be mostly used by the Public Enterprise for State Roads to identify unsafe locations and remediate them through project programs for road reconstruction and rehabilitation.

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PRISTUP DEFINISANJU GRANIČNE VREDNOSTI ZAUSTAVNOG VIDNOG RASTOJANJA NA PUTEVIMA U REPUBLICI SEVERNOJ MAKEDONIJI

Veći deo postojeće putne mreže u Republici Severnoj Makedoniji sastoji se od deonica koje su u prošlosti projektovane da pruže najdugotrajnija i najstabilnija inženjerska rešenja za kolovoz, sa minimalnim akcentom na geometriju puta. Vidljivost na putu je ključni uslov koji značajno doprinosi boljoj dinamici vožnje kao i bezbednosti saobraćaja. U okviru rada sprovedena je analiza zaustavnog vidnog rastojanja (Stopping Sight Distance - SSD) na svim magistralnim putevima. Vidljivost je istovremeno proverena putem video snimaka i CAD crteža, a podaci su tabelarno zabeleženi po deonicama. U analizi su provere tretirane u dve projekcije sa dodatnim podtipovima: horizontalno rešenje (otvorene trase i raskrsnice) i vertikalno rešenje (za konveksne i konkavne krivine). Dobijene vrednosti su kvantifikovane prema dužini svake deonice, čime su određene pojedinačne veličine za svaki tip. Prema rezultujućem dijagramu svih deonica i rasponu od minimalne do maksimalne vrednosti, definisana je ekonomski prihvatljiva granična vrednost vidljivosti na osnovu koje se vrednuju svi postojeći i budući putevi, kako bi se utvrdilo da li imaju zadovoljavajuću vidljivost ili ne.

Ključne reči: *vidljivost, putevi, dinamika vožnje, bezbednost, deonice*