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PROFESSIONAL PAPER

Analysis of the Impact of no Passing Zones on Fuel Costs

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Abstract: The primary task of traffic and transportation planning is to improve the conditions of traffic and level of service on the entire road network. On three sections, which were analyzed in this paper, the possibility of reducing the precentage of no passing zones was noticed, by changing the horizontal signalization on the segments of road section where the clear visibility for overtaking was determined for one direction of the two-way highway. In the first part of the paper, the analysis of traffic conditions on the existing and on the newly designed variants of all three observed road sections was performed. Analysis of the level of service on the intersections that are part of this research are done in chapter 2. Increasing the speed on the newly designed section results in a reduced travel time and this leads to savings in fuel costs as shown in chapter 3. Traffic forecast for the planning 2029 is done in chapter 4, the forecasted traffic load implies future traffic volumes for which adequate capacities of the road network need to be provided. Chapter 5 is based on determination of the relationship between the benefits brought by the newly designed variant and the costs that are realized during its construction. The results of this analysis were used as input data for the economic evaluation of the project solutions, where the savings in fuel costs were analyzed.

Keywords: no passing zone, horizontal signalization, fuel costs.

INTRODUCTION

The roads that are the most common elements of the road network of every country, including Serbia are the roads that consist of two lanes, which are also traffic lanes, which are not physically separated and are intended for the movement of vehicles from opposite directions. Due to the role and character standard categories of vehicles are represented in the traffic flow, where, in addition to passenger cars, trucks, buses and recreational vehicles are also represented, whose technical characteristics differ from each other. The consequence of this is the need to overtake a slower vehicle, which is one of the most dangerous and demanding actions while driving. The main difference between the overtaking maneuver relation to other roads (freeway and multi-lane highway) is that the vehicles cross the traffic lane when overtaking, which is intended for the movement of vehicles from the opposite direction. Therefore, the basic parameter for the analysis of traffic conditions and service levels on this kind of roads is the possibility of overtaking and reducing the driving time in the column behind slower vehicles. [1]

The subject of research in this paper is to examine the impact of no passing zones on the basic indicators of the level of service of roads Ruma - Irig, Aljinovići - Sjenica and Krst - Zavlaka. After calculating the passing visibility in individual curves, the engineers determined that there are segments of these sections, which are marked as no passing zones, and on which there is optimal passing visibility for safe execution of passing maneuvers in one direction of the observed road. The traffic solution for this problem is to change the horizontal signalization on those segments.

The main goal of this part of the paper is to check whether the newly designed variant solutions will lead to the improvement of traffic conditions on the observed sections, and at the same time the results of this analysis served as input data for the second part of the paper. In the first part of the paper, a capacitive analysis and analysis of the service level of the observed stock variants were performed. Third chapter gives fuel cost analysis, while fourth chapter analyses traffic volume in 2029. Fifth chapter analyses costs of implementation of simple solution. Results showed what could brings savings in fuel costs, which bring with them newly designed solutions.

ANALYSIS OF LEVEL OF SERVICE THE OBSERVED SECTION

Existing and newly designed variant of the section of road Ruma – Irig

Determination of key parameters for the analysis of the level of service was done according to the HCM 2000 methodology (Highway Capacity Manual) using HCS software (Highway Capacity Software) which was developed according to the HCM 2000 methodology. [2] Due to the specifics issues in this paper, the method of analysis of each direction was separately used.

The paper used data on average annual daily traffic (AADT) on the observed sections of roads Ruma - Irig, Aljinovići - Sjenica and Krst - Zavlaka, which were taken from the website of the Public Enterprise "Roads of Serbia" These data represent the basis for determining the relevant traffic load.

Due to the impossibility of field measurements of certain parameters required for the analysis of the service level, their recommended values were adopted:

- Base free flow speed BFFS = 80 km / h
- Peak hour factor PHF = 0.88
- Flow distribution in directions d = 60/40
- Percentage of recreational vehicles RV = 0%
- Qm = 12% AADT

Figure 1. Separate segment of the existing variant of the section Ruma- Irig, where it is possible to change the horizontal signalization

From this road route, 1 km of the section Ruma - Irig was singled out, which is specific for the analysis of the issues in this paper (Figure 1). The width of the road on the section Ruma - Irig is 6.5 m. The width of the traffic lane is 3.25 m and the width of the free side space is 1.5 m. On the analyzed section of the section, there are two access points per kilometer, through which vehicles from other roads are connected to the analyzed road. The road stretches across the plain terrain. [4]

On the existing variant of the observed part of the section of the road Ruma - Irig, there is a large representation of no passing zones. The length of the unbroken line, which separates the directions of the observed section and marks no passing zone, is 731 m, which is 73% of the length of the road.

Based on the obtained results gained with the help of HCS software , it is concluded that the level of service on the existing variant of the observed road section is LOS = E. The ratio of flow rate and capacity is V / C = 0.5 in direction A and V / C = 0.33 in direction B.

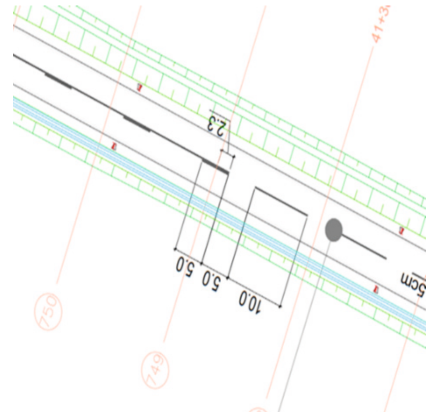

Figure 2. Expert proposal for modification of the horizontal signalization on the selected segment of the section from the previous figure

Based on the graphic documentation of the newly designed variant of the section Ruma - Irig (drawing from AutoCad), with the changed horizontal signalization, a new calculation of the percentage of no passing zones was performed. The length of the uninterrupted line marking no passing zones, for direction A is 471 m, which is 47% of the length of the observed section, while for the opposite direction B is 546 m, or 55% of the length of the observed section.

After obtained results gained with the help of HCS software it is concluded that the level of service on the newly designed road variant remains LOS = E (in both directions). The percentage of time spent following the slower vehicle decreased by 4.1% in direction A and in direction B it decreased by 1.5%.

Existing and newly designed variant of the section of the road Aljinovići - Sjenica

Figure 3. Segment of the existing variant of the section Aljinovići – Sjenica

The observed section extends over hilly terrain. The width of the traffic lane is 3.25 m and the width of the free side space is 1.5 m. One access point per kilometer appears on the analyzed section of the section. In the structure of traffic flow on the observed section, the share of trucks is 12%. The average annual daily traffic is only 878 vehicles per day. The relevant traffic load is 106 pa/ h in both directions. It was adopted that the distribution of traffic flow in the directions is 60/40, so the traffic load in the A direction is 64 pc/ h, and in the less loaded direction 42 pa/ h.

On the existing variant of this section, the length of the continuous line marking of no passing zone is 1638 m, which is 91% of the length of the observed section.

After obtained results gained with the help of HCS software it is concluded that the level of service on the existing variant of the observed road section is LOS = C. The ratio of flow rate and capacity is V / C = 0.04 in direction A, and V / C = 0.05 in direction B .

In the continuation of the chapter, the results of the parameters ATS and PTSF on the modified variant of the section Aljinovići - Sjenica are presented, where the percentage of zones with overtaking is reduced, by designing a double combined dividing line shown in Figure 4. marked in red.

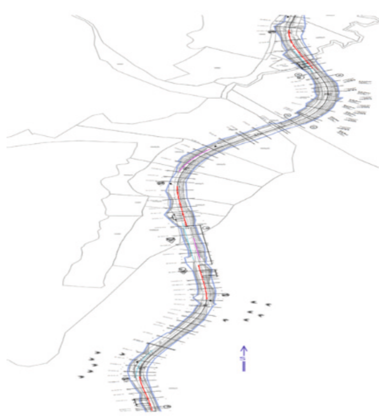

Figure 4. Modified horizontal signalization on the newly designed variant of the section Aljinović – Sjenica

In Figure 4 is shown newly designed variant of the section where the percentage of no passing zones is reduced, by designing a double combined dividing line shown in Figure 4. marked in red.

The new values of no passing zone percentage for individual directions are:

- np A = 78%
- np B = 73%

After obtained results gained with the help of HCS software, it is concluded that the service level on the newly designed road variant remains LOS = C (in both directions). The percentage of time spent following the slower vehicle decreased by 6.5% in direction A and in direction B it decreased by 7.6%.

Analysis of the section Krst – Zavlaka

The last section analyzed in this paper is the section of Krst – Zavlaka. From this road route, 1 km of section was also allocated, which is specific for the analysis of the issues addressed in this paper.

The observed section extends over hilly terrain. The width of the traffic lane is 3.25 m and the width of the free side space is 1 m. One access point per kilometer appears on the analyzed section of the section. In the total structure of traffic flow on the observed section, the share of trucks is 7%. The average annual daily traffic on the section Krst - Zavlaka is 3774 vehicles per day. The relevant traffic load is 453 pc / h in both directions. It was adopted that the distribution of traffic flow in the directions is 60/40, so that the traffic load in one direction is 272 pc/ h, and in the opposite, less loaded direction is 181 pc/ h.

On the existing variant of the observed section of Krst - Zavlaka, the length of the uninterrupted line, which marks the zone of prohibition of overtaking vehicles, is 760 m, which is 76% of the length of the observed section.

Figure 5. Road direction Krst-Zavlaka

Based on the obtained results in HC software, it is concluded that the level of service on the existing variant of the observed road section is LOS = E. The ratio of flow and capacity is V / C = 0.22 in direction A, and V / C = 0.14 in direction B.

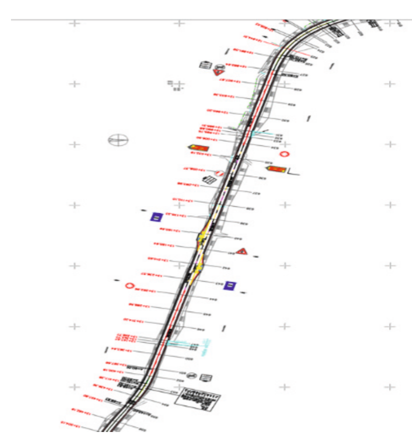

Figure 6. Modified horizontal signalization on the newly designed variant of the section

The new values of the overtaking prohibition zone percentage for individual directions are:

- np A = 63%
- np B = 63%

Based on the obtained results, it is concluded that the service level of the newly designed variant of the observed road section was improved to LOS = D in direction B, while in direction A it remained at level E. The percentage of time spent following a slower vehicle was reduced by direction A by 2, 8%, and for direction B it was reduced by 2.4%.

FUEL COST ANALYSIS IN 2019

Based on the results of the capacitive analysis, changes in the average vehicle speeds on existing and newly designed variants road sections were observed. Increasing the speed of vehicles on newly designed variants of sections results in a reduction in travel time, which entails savings in fuel costs. The length of the section adopted for the calculation of fuel cost savings on the newly designed variant variants in relation to the existing ones is 10 km. For each section, the vehicle travel time was calculated on the existing and newly designed variants of the section, in order to determine the time losses expressed in seconds per vehicle. The form used to calculate fuel cost savings is as follows:

$$\Delta Ti=(\Delta t/3600*AADTi*365)*Pgi*Cg$$

ΔTi - vehicle category fuel cost savings expressed in € / year
Δt - time losses
Pgi - average fuel consumption of a certain category of vehicle expressed in l / h
Cg - unit price of fuel expressed in € / l

For the calculation of the total fuel costs in 2019, the fuel consumption for individual categories of vehicles that appear on the observed section was analyzed. In the calculation of fuel costs, the fuel consumption values of individual vehicle categories were used, converted into values expressed in liters per hour.

The results of the capacitive analysis of the section of the road Ruma - Irig showed that the average driving speed on the existing variant of the section in direction A VPA = 56.1 km / h, while on the newly designed variant the speed was increased to VNA = 56.9 km / h. In direction B the speed was also increased from VPB = 54.8 km / h to VNB = 55.5 km / h. By including these speeds in the calculation of vehicle travel time on both section variants (length 10 km), savings (Δt) of 9 seconds per vehicle in direction A and 8 seconds per vehicle in direction B on the newly designed variant were achieved. How are these time savings the travel of individual vehicles affected the savings in total fuel costs.

Based on the results it can be noticed that on the newly designed variant of the section Ruma- Irig, savings in fuel consumption of 61,138 l / year were achieved. Multiplying by an average unit fuel price of € 0.97 / l), results in fuel cost savings of approximately **€ 60,000 / year.**

According to the same methodology, the calculation of fuel costs on the section Aljinovići - Sjenica was performed. Based on the results of the capacitive analysis (Chapter 3), small changes in vehicle speeds were observed on the existing and newly designed variant of the section Aljinovići - Sjenica. The average travel speed on the existing variant of the section in direction A is VPA = 70.1 km / h, while on the newly designed variant the speed is increased to VNA = 70.2 km / h. In direction B, the speed is increased from VPB = 70.1 km / h to VNB = 70.4 km / h. This change in the average speed of the vehicle results in savings in travel time of 1 second per vehicle in direction A, and 3 seconds per vehicle in direction B.

Based on the results it can be noticed that on the newly designed variant of the section Aljinovići-Sjenica, savings in fuel consumption in the amount of 909.6 l / year were achieved. Multiplying by the average unit price of fuel of 0.97 € / l, you get savings of about **1,000 € / year.**

Also, the calculation, according to the same methodology, obtained the total savings in fuel costs, on the newly designed variant of the section Krst - Zavlaka, in 2019. The average travel speed on the existing variant of the section Krst - Zavlaka in direction A is VPA = 61.5 km / h, while on the newly designed variant the speed has been increased to VNA = 62 km / h. In direction B, the speed is increased from VPB = 60.6 km / h to VNB = 61.2 km / h. The reduction of the average speed of the vehicle on the newly designed variant of the observed section also conditioned the reduction of the travel time of the vehicle, namely 4 seconds per vehicle in direction A and 6 seconds per vehicle in direction B.

Results shows that on the newly designed variant of the section Krst - Zavlaka, savings in fuel consumption in the amount of 10,296 l / year were achieved. Multiplying by the average unit price of fuel of € 0.97 / l, you get savings in fuel costs, worth **€ 10,000 in 2019.**

Based on the results of the analysis of fuel costs on all three sections, it can be seen that the reduction of the percentage of overtaking zones on the newly designed variants of shares would affect the reduction of fuel costs in the base year 2019. The next task is to determine the amount of money that would be saved on the newly designed variants of shares in relation to the existing variants of shares, in the next ten-year period of exploitation, more precisely in the period from 2019 to 2029. To analyze the costs of vehicle operation in the future, it is necessary to first forecast future traffic loads on the observed sections.

TRAFFIC FORECAST FOR THE PLANNING 2029

Traffic load is the number of vehicles that pass or are expected to pass through a certain road section in a certain time interval. From the aspect of analysis and evaluation of traffic projects, data on the existing traffic load on the observed road sections are necessary, as well as data on the future condition of the road network. Existing traffic loads on the road network are easily obtained by counting the traffic on the field. Data on the average annual daily traffic and categorization of traffic on the roads of the first and second order in the Republic of Serbia are obtained with the help of automatic meters that are distributed on the road network throughout Serbia. The forecasted traffic load implies future traffic volumes for which adequate capacities of the road network need to be provided. The main problem of forecasting the future situation is that there are a large number of factors that affect the forecast (demography, country development policy, spatial planning, construction, increase production and consumption, transport policy of the state and so on), which makes traffic forecasting complex and risky procedures. The representation of trucks on the road network is, for example, directly related to production and consumption in a given area. Public transport vehicles for passenger transport mostly depend on the number of inhabitants, the purpose of land areas, the purpose of travel and the level of income of the population [5].

General form for traffic forecast.

AADTi = AADTBAZ * FRi

AADTi- average annual daily traffic in the planning year
AADTBAZ- average annual daily traffic in the base year
FRi- traffic growth factor in the observed time period

There are various methods for forecasting the future state of traffic. One of them is the growth rate method, which is a relatively simple forecasting method, and which was applied in this paper to forecast traffic load in the next 10 years, on the observed sections. The growth rate is calculated according to

$$i = \left[\sqrt[n]{\frac{AADT_n}{AADT_{BAZ}}} - 1 \right] * 100$$

Where n is the number of years for which the degree of traffic growth is determined.

The traffic growth factor in the observed time period was obtained on the basis of next equation

$$F_R = [1 + \frac{i}{100}]^n$$

Based on the obtained values of average traffic growth factors on the observed sections in the period from 2015 to 2019, and assuming that such traffic growth trend will continue in the next ten years AADT values were predicted based on a pattern based on the formula above.

The forecasted values of AADT on the observed sections, in 2029, are given in Table 1

Table 1. Average annual daily vehicle traffic on the observed sections, in the planned 2029

Sections	Ruma – Irig	Aljinovići – Sjenica	Krst – Zavlaka
AADT2019 [veh/day]	10.130	878	3.774
AADT2029 [veh/day]	12.504	1.386	5.021

Based on the data from Table 1. it is concluded that in the planned year 2029, there was an increase in the load on all observed sections, which also affects the change in the conditions of vehicle movement on those sections. In order to obtain the most representative results of the analysis of fuel costs on the observed sections in the planned ten-year exploitation period of the sections, a new analysis of the parameters (with the help of HCS software) was performed, with data for 2029. The paper presents only data on new average vehicle speeds on existing and newly designed variants of the observed sections, because these data are necessary for further calculation of vehicle operating costs in 2029.

Based on the results it can be noticed that on the newly designed variant of the Ruma - Irig section, savings in fuel consumption in the amount of 61,938 l / year were achieved. Multiplying by a unit fuel price of € 0.97 / l results in fuel cost savings of € 60,100 in 2029. Comparing these results with the results of the cost analysis in the base year 2019, it is concluded that on average, € 60,000 can be saved annually on the Ruma - Irig section. For the planned exploitation period of ten years, **€ 600,000** would be saved on the Ruma - Irig section by implementing the newly designed solution of the section.

Variant of the section Aljinovići - Sjenica, savings in fuel consumption in the amount of 1,748 l / year were achieved. Multiplying by a unit fuel price of € 0.97 / l results in fuel cost savings of € 1,700 in 2029. Comparing these results with the results of cost analysis in the base year 2019, it is concluded that an average of € 1,400 can be saved per year on the observed share. For the planned period of exploitation of ten years, on the section Aljinovići - Sjenica, **€ 14,000** would be saved, by implementing the newly designed solution of the section.

Based on the results. it can be noticed that on the newly designed variant of the section Krst - Zavlaka, savings in fuel consumption in the amount of 16,546 l / year were achieved. Multiplying by a unit price of fuel of € 0.97 / l will result in savings in fuel costs of € 16,100 in 2029. Comparing these results with the results of the cost analysis in the base year 2019, it is concluded that an average of € 13,100 can be saved annually on the section Krst - Zavlaka. For the planned exploitation period of ten years, **€ 131,000** would be saved on the Krst - Zavlaka section, by implementing the newly designed solution of the section.

COSTS OF REALIZATION OF NEWLY DESIGNED VARIANTS

When designing new variants of road network sections, it is necessary to determine the relationship between the benefits brought by the newly designed variant and the costs that are realized during its construction. Practice has shown that in order to improve the quality of traffic conditions on the road network, it is often necessary to build new or reconstruct existing parts of the road network, carrying out construction works that require high costs (replacement of road construction, change of road geometry, reconstruction of intersections, construction of bridges and tunnels). similar to).

The newly designed variant solutions of the observed sections of Ruma - Irig, Aljinovići - Sjenica and Krst - Zavlaka provide the possibility of improving the quality of traffic conditions with the performance of small-scale works. The new stock variants only involve changing the horizontal signaling on certain segments of the stock. The existing geometry of the road sections remains unchanged thus avoiding high construction costs. Modification of the horizontal signalization implies the construction of a dashed dividing line 5 + 10 m (width 0.15 m) along an unbroken line, which gives a combined double dividing line, as shown in Figure 7.

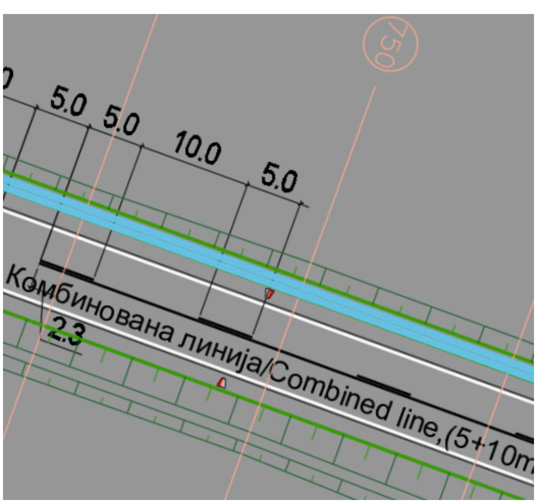

Figure 6. Combined double dividing line

Works on the change of horizontal signalization are performed as part of regular maintenance and protection of roads. The method of calculating the costs of making horizontal signalization, which was used in this paper, is based on the unit price of works and the unit price of materials per meter of road. According to the "Price list of works on regular road maintenance" issued by the PE "Roads of Serbia", the price of construction of central and edge lines on the road is 7.31 dinars per meter. This price includes the transport of paint, thinner and laundry, then the machine for marking the horizontal signalization as well as the price of transporting workers from the point to the marking, paint preparation and marking the line itself [2]. The unit price of the material used to make road markings depends on the type of material used. Markings can be made with paint, hot and cold plastic, application tapes, wedges and markers. For a broken line (5 + 10m) 0.15m wide, a unit price of 22.24 dinars per meter was adopted.

The length of the dashed line (5 + 10m) that needs to be marked on the section Ruma - Irig 10km long, according to the project solution, is 4,350 m. The costs of changing the horizontal signalization on this section are:

T = 4,350m * 7.31 dinars / m + 4,350m * 22.24 dinars / m ≈ **130,000 dinars**

On the section Aljinović - Sjenica it is necessary to mark 1,650m with a dashed line 5 + 10m. The costs of changing the horizontal signalization on the newly designed variant of this section are:

T = 1,650m * 7.31 dinars / m + 1,650m * 22.24 dinars / m ≈ **50,000 dinars**

On the section Krst - Zavlaka, it is necessary to change the horizontal signalization by marking the dashed line 5 + 10m on the length of 2,650m. The costs incurred due to the change of the horizontal line on the newly designed variant of the section Krst-Zavlaka are:

T = 2,650m * 7.31 din / m + 2,650m * 22.24 din / m ≈ **80,000 dinars**

The total cost of changing the horizontal signalization, which occurs on all three sections that are analyzed in this paper, is about € 2,200.

CONCLUSION

In the first part of the paper, a capacitive analysis and analysis of the service level of the observed stock variants were performed. The task of this part of the paper was to check whether the newly designed variant solutions will lead to the improvement of traffic conditions on the observed sections, and at the same time the results of this analysis served as input data for the second part of the work stock.

The section Ruma - Irig is part of the state road IB order, number 21, which connects Novi Sad and Belgrade with tourist destinations in Western Serbia, so it is very busy. The relevant traffic load in 2019 was 1216 pc/ h. On the existing variant of the section, the percentage no passing zone is 73%, while on the newly designed variant this percentage is reduced to 47% in the direction of Ruma-Irig and to 55% in the opposite direction. The results of the capacitive analysis showed that on the newly designed variant of the section, the percentage of time that vehicles spend in convoy driving was reduced by 4.1% in the Ruma-Irig direction and 1.5% in the opposite direction.

Section Aljinovići - Sjenica is lightly loaded, the average annual daily traffic in 2019 was 878 pc / day, or 106 pc/ h. In the observed section of the section, the percentage of no passing zones is prohibited is 91% of the section. With the proposal to change the horizontal signalization, this percentage of zones was reduced to 78% in the direction Aljinović-Sjenica, and 73% in the direction Sjenica-Aljinović. This measure resulted in a decrease in PTSD by 6.5% in one direction and 7.6% in the other.

One kilometer was also set aside from the section Krst - Zavlaka for the analysis of traffic conditions. On this section, an average of 453 pc/ h pass. Overtaking slower vehicles is prohibited at 76% of the length of the analyzed section of the section. With the newly designed variant solution, this percentage would be reduced by 2.8% in the direction of Krst-Zavlaka and 2.4% in the opposite direction.

On the Ruma - Irig section, the average travel speed was increased from 56.1 km/h on the existing variant to 56.9 km / h in the Ruma-Irig direction, and from 54.8 km/h to 55.5 km/h in the opposite direction. The savings in fuel costs that would result from increasing the speed of the vehicle amount to € 60,000 / year on the section Ruma - Irig. Fuel costs of all vehicle categories on the section Aljinovići -Sjenica are significantly lower than the costs on the section Irig - Ruma, which is a consequence of lower traffic load. The savings that would be made on this section, by increasing the possibility of overtaking vehicles, amount to about 1000 €/year. On the last section analyzed in this paper, an increase in speed from 61.5 km/h to 62 km/h in the direction Krst- Zavlaka and from 60.6 km/h to 61.2 km/h in the direction Zavlaka ka Krst was observed. These changes in speeds resulted in savings in total fuel costs of € 10,000/year.

The degree of motorization in Serbia is growing from year to year, which causes the appearance of a larger number of vehicles on roads across the country. Increasing the flow requirement negatively affects the speed of the vehicle, and thus the travel time of the vehicle. In the planned 2029, the traffic load on all three observed sections will be higher compared to the base year 2019, which would affect the change of conditions prevailing on the observed sections, which is why a new capacitive analysis was performed with data for 2029 and determined are the new values of vehicle speeds.

The results showed that due to the increased load on the roads, the speed of vehicles decreased compared to the base year 2019. Savings in fuel costs, which would occur on the section Ruma-Irig, in 2029, amount to 60,100 € / year, on the section Aljinovići - Sjenica 1,700 € / year and on the section Krst-Zavlaka 16,100e.

Finally, by adopting the average annual savings in fuel costs on the newly designed share variants, a savings of around € 745,000 in the ten-year exploitation period on all three observed shares are obtained. The obtained results are relative, but essentially prove that on all three observed sections there would be savings in fuel costs that are incomparably higher than the costs of project solutions. Newly designed variant solutions of observed sections Ruma - Irig, Aljinovići - Sjenica and Krst -Zavlaka offer the possibility of saving in fuel costs, and their implementation is possible with the performance of small-scale works and with small financial investments.

The results of this research can serve as an initiative for further, more detailed research on this issue on the road network of Serbia. The road network of Serbia consists of 16,844,287 km of state roads of the first and second order.. The paper analyzes only 3 sections on the territory of Serbia, and it was determined that in the next ten-year period, savings in fuel costs of € 754,000 could be brought about by the implementation of newly designed solutions. On the entire road network of Serbia, there are certainly other sections with the same problem described in this paper, so the savings in fuel costs, which bring with them the newly designed solutions, would be many times greater for society as a whole.

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