Effects of building a bypass highway on road safety: A case study of a rural road in Serbia

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Abstract

Highways are safer because of higher construction standards, a smaller number of head-on crashes that are actually typical for single carriageways, and less standard deviation of speeds. Higher speed limits or speeds of traffic flows increase the risk of road crashes, and that risk has been clearly recognized in literature. The present study has made a research into effects that building of a highway has on a road network safety, as well as into effects of changes in traffic flow conditions on rural road safety. A highway that is parallel to the rural single carriageway road was constructed in Serbia in 2016, allowing drivers travelling from the place of Preljina to the place of Ljig (around 50 km) to choose between using the single or dual carriageway. After the completion of the dual carriageway, the smaller values of AADT on the single carriageway have been associated with the higher mean speed of the traffic flow, which has been consequently linked to the higher involvement of commercial vehicles in road crashes with fatalities, and finally, to the higher risk of occurrence of fatal road crashes. This study has shown that the odds of involving commercial vehicles in fatal road crashes on a single carriageway were 2.5 times higher with the increasing mean speed of a traffic flow by 3.2 km/h. The odds of a risk of all road crashes on a single carriageway was around 4 times as high as that on a dual carriageway, while the odds of a risk of fatal road crashes was up to 9 times as high as that on the same road type. The study has shown that increasing the mean speed of traffic flow by 1.5 km/h on single carriageway has led to the increased number of fatal road crashes by 30%.

Keywords: bypass highway, AADT, traffic flow speed, road crashes, rural single carriageway, dual carriageway.

1. Introduction

The efficiency of road infrastructure transformation cannot be often observed properly by monitoring only the values of the number of road fatalities and serious injuries. Accidents have their spatial and temporal determinants that can be related to road conditions present on a certain portion of road network. In literature, road safety has been associated with numerous road features. On the one hand, there are many research studies that have investigated into effects that road geometry or road network safety performance indicators have on road safety (Barua et al. 2010, Belmont and Forbes 1953, Labi 2006). Another aspect of such research studies is the connection between the conditions of a traffic flow and road safety. Most frequently surveyed conditions of a traffic flow include the following ones: volume of traffic, speed and density, as well as commercial vehicles (Aljanahi et al. 1999, Ceder and Livneh 1982, Martin 2002). The level of development of road networks is most often expressed as a percentage of appropriate roads within a road network, which is one of the most significant indicators of road network development, and consequently of road safety (EC, 2004).

A state road network consists of different road types, starting from highways, to roads in urban areas. Highways are considered the safest road type as, unlike other road types, they account for rare cases of crashes, if the exposure, or the road travelled, is taken into account. Reasons for such facts should be sought in divided roads (physically separated carriageways, in both directions), in the existing full access control, in specific intersecting (grade-separated) methods that are reducing the number and severity of conflicts, etc.

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Unlike highways, single carriageways in rural areas are a riskier road type. Elvik and Vaa (2004) state that the number of road casualties occurring on highways is very small when compared to other road types and that the highest risk of road fatalities is on single carriageways (4 to 6 times higher than it is on highways). In addition, lower design and maintenance standards increase the risk of accidents on single carriageways. Cross-section elements of a road have been subject to research studies carried out by the European Commission, in 2004 and 2016. According to the research results, single carriageways have been rated poorly for road safety when compared to dual carriageway roads (EC, 2004; EC, 2016).

The existing road network in Serbia has not been developed sufficiently to meet the needs for fast movement. That is why building new roads that are carrying higher speeds of traffic flows is underway. One example of building a fast road dates back to 2016, when a highway that is parallel to the single carriageway, was built, including physically separated carriageways, and higher vehicle speeds. The highway in question is the section of the future highway state road A2, connecting Belgrade, Serbia with Montenegro. The completed part of that highway has not been connected with the larger urban centers yet, and is now an alternative for travelling only on a shorter section of that road network (around 50 km). Before the construction of the highway, travelling from the place of Preljina to the place of Ljig was only possible using the rural single carriageway. After the completion of the highway, drivers have been able to use both the highway and the single carriageway. The construction of the highway enabled the redistribution of traffic flows on both roads and changes in conditions of the traffic flow on the single carriageway. The traffic flow on the single carriageway has been expected to decrease since some users would chose travelling on the highway, regardless of the toll they have to pay.

The aim of this study has been to investigate into effects of a changed traffic flow on road safety, on the single carriageway section. There are several parameters relative to traffic flow that need to be considered. Firstly, reduction in the traffic flow may lead to increased speed on the single carriageway, which may result in a higher risk of road accidents. However, reducing the traffic flow means lower exposure, which may result in a lower risk of road accidents. Redistribution of the traffic flow onto two road types may result in a higher involvement of commercial vehicles travelling on the single carriageway, where tolls are not collected. A single carriageway is a classic two-lane rural road where lanes for opposite direction of traffic are not physically separated and where all the intersections are designed as at-grade junctions. There is no access control on a single carriageway so the traffic flow may involve bicyclists, working machines, in addition to cars and commercial vehicles. A single carriageway passes through several urban areas, meaning that the traffic flow is likely to include pedestrians or bicyclists.
Access control on the highway restricts access to road users. Intersections on a highway are grade-separated junctions, which help reduce the risk of road accidents. One of the consequences of highway conditions is higher flow speeds, which, along with other conditions of traffic flow, do not imply higher risks of road crashes. What may increase the risk of occurrence of accidents on highways are higher AADT values or density which is a consequence of new road users attracted by the highway.

Highways attract new road users, which on the other hand increases the AADT, and consequently brings about high risks of road crashes. Nevertheless, the studies have shown that the effect of increased AADT on the risk of occurrence of accidents can be differentiated according to road type (Milton et al. 2008; Anastasopoulos et al. 2008). The aim of this study was to investigate into the risks of occurrence of accidents on both road sections (single- and dual carriageway), after the completion of the dual carriageway, as well as into the effects of changes in AADT or traffic flow speed on the occurrence of road accidents.

2. Traffic flow features and risk of road accidents

The features of a traffic flow that are most often associated with the risk of occurrence of accidents are traffic flow, speed and density. Involvement of commercial vehicles has been attracting considerable attention of researchers over the last years. Dependence of the flow and risk of accidents has been subject to research studies since the mid 20th century. The flow is mainly expressed on an annual level, as a value of an average annual daily traffic (AADT). Other time intervals, such as hourly flows, are also used. Belmont and Forbes (1953) have shown that the risk of occurrence of accidents on a single carriageway increases linearly with the increase in volume of traffic. On the other hand, some studies have come up with different conclusions (Smeed 1955). Turner and Thomas (1986) considered the linear dependence of increasing volume of traffic and the occurrence of accidents on highways with two and three lanes.

After the initially determined linear dependences of the volume of traffic and occurrence of accidents, later research studies came up with the rules concerning the change in traffic flow and the occurrence of accidents, in a form of a parable that is still acceptable today.

Some studies have identified the link between the risk of collision type and the traffic flow. Ceder and Livneh (1982) have highlighted the higher risk of occurrence of single-vehicle collisions in cases of reduced traffic flows. Multiple-vehicle collisions are not included in that conclusion.

As for severity of road accidents, the conclusions are clearer. Studies indicate that severity of accidents is decreasing with the increase volume of traffic (Turner and Thomas, 1986). However, property damage crashes and crashes with injured reach their peak with the volume of traffic less than 400 vehicles per hour (Martin 2002). According to Labi (2006), the risk of accidents increases with the AADT of up to around 12.000, after which the risk decreases or remains the same. An interesting effect of a traffic flow on the risk of crashes has been presented by Milton et al. (2008) and Anastasopoulos et al. (2008). They have concluded that the effect of a changing AADT on the risk of accidents cannot be uniform and that in general, the number of crashes increases with the increased AADT, but that there are some exceptions though, characteristic for some road types.

As far as the density of a traffic flow is concerned, the results are more obvious and indicate the higher risk of occurrence of accidents as a consequence of a higher interaction among vehicles. On the other hand, severity of accidents reduces with lower speeds of vehicles travelling in conditions of congestions, which results in smaller consequences of accidents (Zhou and Sissiopiku, 1997; Shefer and Rietveld, 1997).

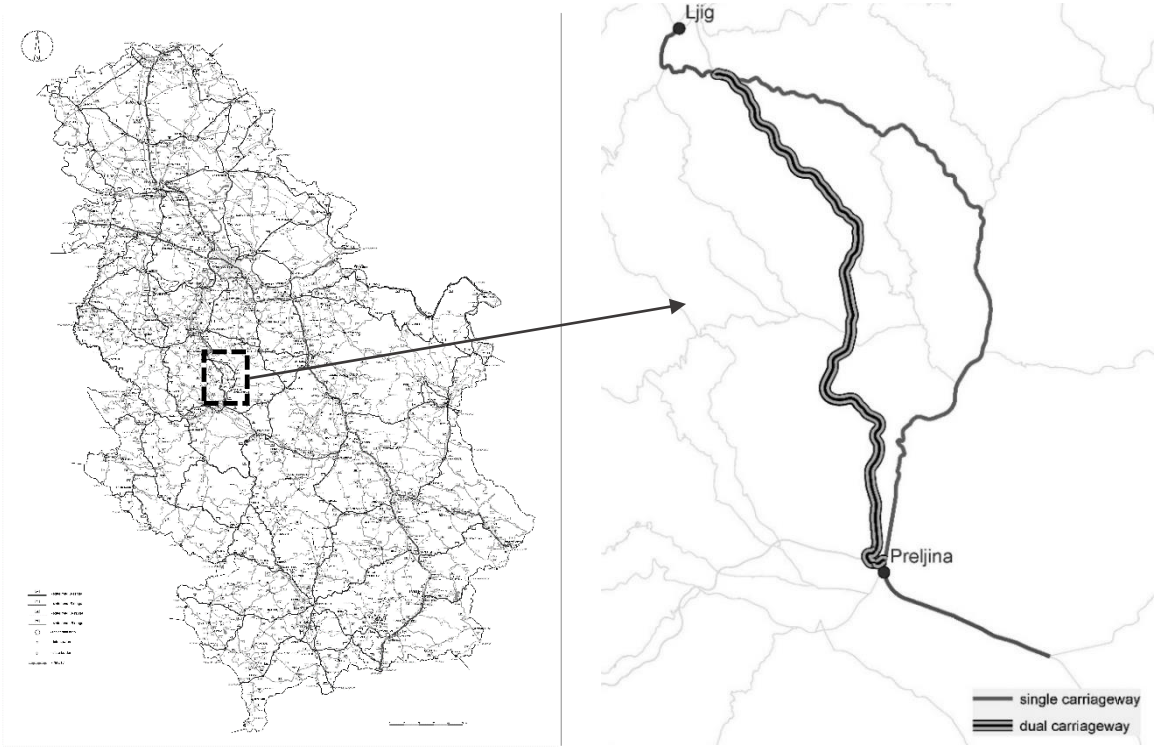
The effect of vehicle speed on accidents attracts researchers' attention to a great extent. Traffic flow parameters, such as mean speed and speed dispersion, have been subject to the majority of research studies. Taylor et al. (2002) have shown that the increase in the mean speed by 10% results in the increased number of casualties by up to 30%. Likewise, the increase in speed dispersion leads to the increase in the risk of occurrence of accidents (Lave, 1985; Aljanahi et al. 1999). In general, the majority of studies have revealed a positive correlation between higher speeds and higher risk of occurrence of road crashes, where the effect of traffic flow speed dispersion is more significant.

There are no clear conclusions in terms of effects of traffic flows on road safety. This is also largely affected by methodological limitations and various regression postulates. Methodological problem of research into the effects of traffic flow is also reflected in the use of aggregated data on traffic flow conditions that cannot be connected with concrete conditions in a reliable manner, because of which it is not possible to analyze the short-term effects related to traffic flow.

3. Data

Two databases have been included in this study. The first group of data consists of data on accidents occurred on the analysed roads and of data collected in investigations carried out by police authorities. Data on accidents used in the study include those road crashes that occurred on two roads, during the period of four years. 2015 and 2016 include only those accidents that occurred on single carriageways, while another two years (2017 and 2018) concern those crashes that occurred both on single- and dual carriageways. Both roads observed are linked by the same places and are actually alternative travelling routes for drivers.

The second group of data concern road and traffic flow data, recorded in Serbia by the Public Enterprise "Roads of Serbia". Data are collected from automated traffic counters in operation on both roads. There are three automated traffic counters on the single carriageway, and one automated traffic counter on the dual carriageway. Traffic counters collect data on traffic flow, vehicle type and speed, and these data are used in this study. Automated traffic counters collect data on vehicle type and speed for each vehicle. Traffic flow data for certain classes of vehicles are obtained by aggregating vehicle type data. Traffic flow speed used in this study is the mean speed representing the arithmetic mean of all speeds within the cross-section. Data used in this study for the single carriageway are mean values from three existing counters.



a) b)

Figure 1: State roads in the Republic of Serbia (a) and position of the single- and dual carriageway (b)

This research study includes 368 road crashes records, of which number 328 occurred on the single carriageway and 40 on dual carriageway. The single carriageway consists of two lanes that are not physically separated, and is equipped with at-grade intersections. The speed limit on the single carriageway is up to 80 km/h, except on the road sections passing through urban areas, where the speed limit is up to 50 km/h.

The dual carriageway consists of two roadways, physically separated by a median barrier. The roadways consist of two lanes and an emergency lane. There are grade-separated intersections on the dual carriageway, having acceleration and deceleration lanes. The speed limit on the dual carriageway is up to 120 km/h, except in tunnels located on the road section, where the lowest speed limit is 80 km/h.

3.1. Methodology

Research into effects of building a highway includes the analysis of changes that affected the single carriageway. The study comprises data on road crashes that occurred in the period of four years, i.e. from 2015 to 2018. In 2015 and 2016, the traffic between the places of Ljig and Preljina was carried out only on the single carriageway, i.e. there was no alternative road. The use of the dual carriageway started a few days before January 1, 2017. Therefore, this study includes data on road crashes that occurred on the dual carriageway between January 1, 2017, and December 31, 2018.

Accidents recorded on the single carriageway can be unique only for that road. Driving conditions on the single carriageway differ considerably from the highway, and because of that, accidents of certain type or severity can be associated only with that road. The study has been designed with the aim to consider how the changes in traffic flow conditions affect road safety on a single carriageway. It is therefore important to consider the change in the risk for several road accident types: accidents with property damage only, with injuries or with fatalities.

The relative risk is the odds ratio (OR) of the crash severity (property damage only, injuries and fatalities) for the analysed flow conditions, which is similar to the risk defined by Abdel-Aty et al. (2011). Before building a dual carriageway, all vehicles were flowing on the single carriageway. After the completion of the dual carriageway, the traffic flow from the place of Ljig to the place of Preljina has been divided into two roads.

The OR has been applied to evaluate the correlation between the traffic flow conditions and crash severity; the correlation between the new traffic flow and crash severity; the correlation between the single- and dual

carriageway and crash severity; the types of road crashes and crash severity. The OR ratios have been calculated using the Equation 1 for the relation between the single- and dual carriageway, or Equation 2 for changes in condition on the single carriageway, as follows:

$$OR = \frac{Type(SC_i)/Type(DC_i)}{All(SC)/All(DC)} \quad (1)$$

where Type (SCi¬¬) is type i – a road crash on the single carriageway; Type (DCi¬¬) is type i – a road crash on the dual carriageway. All (SC) or all (DC) represent all the crashes on the single- (SC) or dual carriageway (DC).

$$ORsc_i = \frac{Type(BDC_i)/Type(ADC_i)}{All(BDC)/All(ADC)} \quad (2)$$

where sci is the analysed impact i characteristic for the traffic flow on the single carriageway; Type (BDCi) is the type i – a road crash on the single carriageway before the construction of the dual carriageway; Type (ADCi) is the type i – a road crash on the single carriageway after the construction of the dual carriageway. All (BDC) or all (ADC) values represent all the crashes on the single carriageway before and after the construction of the dual carriageway, respectively.

The aim of the study was to analyse the odds of occurrence of accidents depending on severity and changes in conditions of a traffic flow. The correlation analysis before and after the changes in traffic flow has enabled a correct estimate of an impact of a change in AADT and traffic flow speed on the risk of occurrence of accidents.

The relative risk (OR) has been calculated for the single carriageway, before and after the construction of the dual carriageway, for the risk of single- and dual carriageway, for the risk of crash types on the single- and dual carriageway. The OR is a statistical measure of association between an exposure variable and an outcome. The OR represents the odds for a result with certain exposure compared to the odds for a result which occurs in the absence of exposure (Hosmer and Lemeshow, 2004).

4. Analysis and Results

Construction of the highway resulted in the increase of the AADT by 34% on the road section Ljig-Preljina, i.e. the ADDT value grew from 9,316 to 12,451. During the two-year period of highway operation, the total number of reported accidents on both roads was reduced by 35%, i.e. from 96 to 62. However, the number of road crashes with fatalities increased. Thus the number of crashes with fatalities rose by 200% during that two-year period.

The question is why the number of accidents with fatal injuries grew? Firstly, a far larger number of accidents occurred on the single carriageway after the completion of the dual carriageway, for which reason the answers must be sought in the changed traffic flow conditions on the single carriageway. Two thirds of vehicles involved in accidents with fatalities are passenger cars, while around one third are commercial vehicles. The share of passenger cars in accidents with fatalities in 2018 grew by around 40%, while the share of commercial vehicles increased by around 70% (i.e. was 2.5 times higher).

If conditions of the road surface are considered, the largest number of crashes on both roads occurred on dry roadways. Wet roadways or those covered by snow and ice on the dual carriageway have more often been the cause of road accidents, i.e. in 43% of cases, when compared to the single carriageway, which accounted for 27% of road crashes that occurred in the same conditions (Table 1).

The analysis of commercial vehicles circulating in a traffic flow has shown that the share of commercial vehicles using the single carriageway before the completion of the dual carriageway amounted to 16-17%, while 15% of commercial vehicles “remained” on that single carriageway after the dual carriageway had been built. The results indicate that a small number of commercial vehicles decided to travel on the fast toll road, instead of driving on a rural single carriageway road with no toll collection.

Significant results have been obtained on the basis of analysis of a relationship between AADT and speed. Reduced AADT on the single carriageway by 34% has led to the average traffic flow that grew by 4.6%, or 3.2 km/h (Figure 2).

The analysis of the risk of accidents in relation to AADT has shown that the risk of accidents on the single carriageway is significantly higher when compared to the dual carriageway. The odds of a risk of accidents on the single carriageway (in 2017 and 2018) was around 4 times as high as that on the dual carriageway.

Table 1: The sample of characteristics of the road accidents

Variables	Property damage	Injury	Fatal	Total
Dual carriageway	25	14	1	40
no intersection	25	14	1	40
dry	14	8	1	23
wet	7	6		13
snow or ice	4			4
Single carriageway	143	166	19	328
no intersection	132	150	18	300
dry	90	117	13	220
wet	33	25	4	62
snow or ice	9	6		15
unknown		2	1	3
intersection	11	16	1	28
dry	6	11	1	18
wet	5	4		9
snow or ice		1		1
Total	168	180	20	368

The risk of occurrence of accidents on the single carriageway was the highest for road crashes with fatalities (the risk was higher by 13.35) and with injuries (the risk was higher by 5.56), while the risk of accidents with property damage was slightly higher (by 2.58) (Table 2).

Reduced values of AADT on the single carriageway by around 38%, from 2015 to 2018, may have been the indication of an increasing risk of accidents by 1.16 odds (after/before). Likewise, reductions in the AADT may be related to the 1.16 times larger number of road crashes with property damage. The risk of fatal crashes grew most if related to the change in AADT, meaning that the reduction in AADT by 38% may be associated with the odds of up to 2.67 higher risk of road accidents (Table 3). However, the impact of the AADT and speed on the number of road crashes was mutually connected and also complex, which is the reason why the impact of the AADT parameter can be easily separated from the speed parameter.

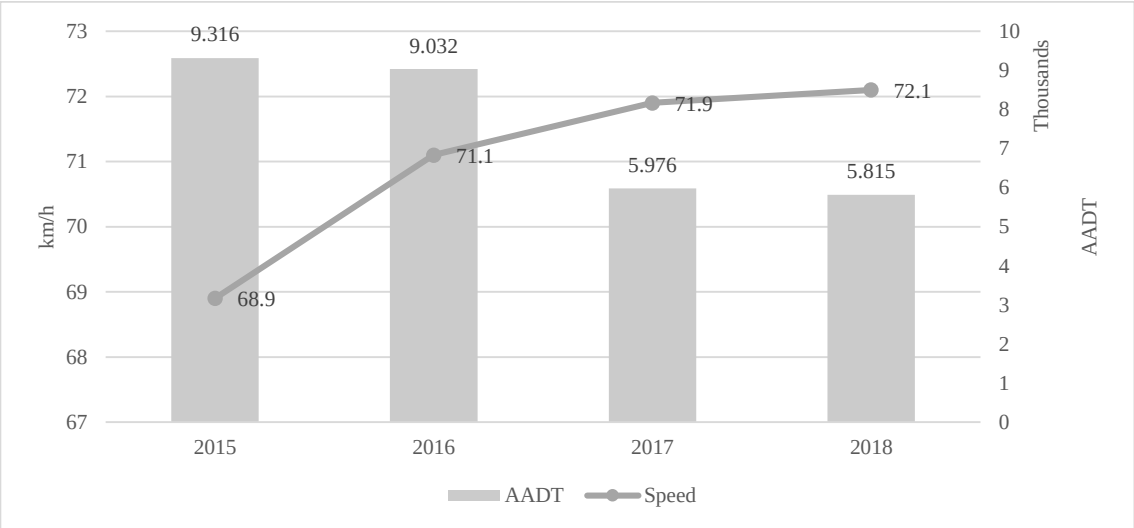


Figure 2: Changes in AADT and speed of traffic flow on the single carriageway

Table 2: The risk of road crashes on a single carriageway and compared to a dual carriageway

	Dual carriageway		Single carriageway		OR
	crash	AADT	crash	AADT	
∑	40	6,558	140	5,896	3.89
Damage	25		58		2.58
Injury	14		70		5.56
Fatalites	1		12		13.35

Table 3: The risk of road crashes after the reduction in traffic flow on the single carriageway

	before bulding dual carriageway		after bulding dual carriageway		OR_{sc}
	crash	AADT	crash	AADT	
∑	188	9,174	140	5,896	1.16
Damage	85		58		1.06
Injury	96		70		1.13
Fatalites	7		12		2.67

The impact of speed on a higher risk of accidents may be comprehended by considering the risk of accidents that are depending on the mean speed of a traffic flow. The relationship between the odds of occurrence of accidents due to changes in the speed of a traffic flow indicates that the risk involving road fatalities was significantly higher. Thus the odds of a risk of accidents involving fatalities has been 1,67 times higher after increase of traffic speed. (Table 4). It is certainly necessary to include other factors in the risk change. One of the risks concerned is the AADT that has been discussed in the paper. By reducing the AADT and increasing the mean speed of the traffic flow, the total number of accidents decreased, while the number of road crashes with fatalities grew significantly.

Table 4: The impact of the increase in traffic flow speed on the risk of occurrence of road crashes

	crash	Average speed flow	crash	Average speed flow	OR_{sc}
∑	188	70.0	140	72.0	0.72
Damage	85		58		0.66
Injury	96		70		0.71
Fatalites	7		12		1.67

Reduced values of AADT and increased traffic flow speed have led to the smaller risk of occurrence of crashes with property damage on single carriageway. On the other hand, the risk of occurrence of accidents with casualties rose significantly in the mentioned conditions. The risk of occurrence of crashes with fatalities on single carriageway for two or more vehicles is 3.26, while the same risk of single-vehicle accidents is 1.36 after increasing the speed of the traffic flow (Table 5).

Table 5: The odds ratio for single-vehicle crashes and crashes involving several vehicles after decreasing the AADT and increasing the speed of the traffic flow on the single carriageway

	Before dual carriageway		After dual carriageway		OR_{sc} (MV)	OR_{sc} (SV)
	MV	SV	MV	SV		
Property damage	28	13	37	21	0.96	0.73
Injury	36	7	45	20	0.91	1.30
Fatal	2		9	3	3.26	1.36

MV – crashes with two or more vehicle; SV – single vehicle accident.

5. Discussion

This study has considered the impact that building of a highway has had on road safety, on road sections where the changes in the traffic flow conditions have occurred. Construction of the dual carriageway has resulted in reductions in AADT values on road sections representing the alternative route to the dual carriageway. It has been expected intuitively to improve road safety on the section in question due to reduced AADT values. However, the link between the AADT and road safety is complex, having a shape of a parable, because of which it was not possible to simply comprehend the impacts on road safety.

The total AADT on the road section Ljig-Preljina, on both roads (single- and dual carriageway) grew in the period from 2015 to 2018 by 34%, while the number of accidents dropped in the same time period by 35%. The number of fatal road crashes reported in the same period was tripled. The majority of road crashes occurring on the road section Ljig-Preljina has been reported on the single carriageway. The share of fatal crashes occurred on the single carriageway is 89%, while it is 11% on the dual carriageway.

In 2018, a significantly higher number of commercial vehicles involved in fatal accidents on the single carriageway was recorded, while the share of commercial vehicles in traffic flow concerned has not changed significantly. Moreover, the share of commercial vehicles after the completion of the highway dropped by 2%, while the number of such vehicles involved in fatal crashes was 2.5 times higher. Commercial vehicles are vehicles with considerable masses, due to which their involvement in road crashes, together with cars, brings along severer consequences. A higher speed of traffic flow makes cars more vulnerable in crashes with heavy goods vehicles.

Reduced AADT values on the single carriageway have resulted in the increased average speed of the traffic flow. The study has shown that the reductions in the AADT by 15% have led to the increase in the mean speed of the traffic flow by around 1 km/h. Many researchers in this field indicate that the number of accidents with fatalities increases with the increase in the mean speed of a traffic flow by 1 km/h. This study has shown that increasing the mean speed by 1.5 km/h resulted in a bigger number of fatal crashes, by 30%. Study on European rural single-carriageway (Taylor et al, 2002) shown that the increase the mean speed by 10% results increase crashes up to 30%, which is the similar those results of this study. Higher mean speed of traffic flows is the key factor of the occurrence of a larger number of fatal crashes.

The study has also shown some conclusions that have been expected intuitively. The odds of a risk of road crashes on the single carriageway is 4 times as high as that on the dual carriageway. Higher risk of road crashes on the single carriageway is associated with higher severity of consequences. Thus the risk of road crashes with property damage only is 3.85 odds higher, while the risk of fatal crashes is even 9.13 odds higher. A controlled-access road, grade-separated intersections and divided roads may represent the reasons for higher risk of accidents on the single carriageway.

The impact of reduced AADT values on the risk of accidents indicates a lower mean speed of a traffic flow than the average one. The results also indicate that lower values of AADT have an effect on higher numbers of road accidents, which confirmed the results of studies Milton et al. (2008), Anastasopoulos et al. (2008). However, the impact of AADT and the mean speed of a traffic flow could not have been clearly divided in this study. Higher risk of accidents on the single carriageway is primarily the consequence of the higher speed of the traffic flow, while the reduced AADT values can be, before all, associated with the increase in the mean speed of traffic flow, meaning that the higher mean speed of a traffic flow results in a higher risk. Reduced values of the AADT and increased mean speed together have a significantly higher impact on the growing risk of occurrence of fatal crashes.

6. Conclusions

Construction of a highway has two strong effects on traffic flow: firstly, it increases AADT, and secondly, it redistributes traffic flows on the road network. This study has shown that an increase of AADT on a highway does not increase the risk of occurrence of accidents. The study therefore supports earlier conclusions that road safety and the AADT differ in road type. Building a highway improves road safety on that road, as indicated by the results of this study.

This study has shown that the second effect, redistribution of traffic flows from the rural single carriageway roads onto highways has a negative impact on road safety of the existing road network. Reductions in the AADT on rural roads lead to the increase in mean speed of the traffic flow on such roads. There is a positive correlation between the risk of occurrence of road crashes and the mean speed of the traffic flow.

The study has revealed that the increase in speed of a traffic flow by 1.5 km/h on rural roads results in the risk of fatal crashes by 30%. The redistribution of road traffic is a consequence of highway construction, meaning that a portion of vehicles is transferred onto the highway, which results in an increasing mean speed on rural roads and a higher risk of road crashes.

The study has proved the facts that were subject to previous research studies, and according to which mean speeds and the risk of road crashes are mutually connected. Additional findings of this study to be used with the existing conclusions indicate the connection between the mean speed of the traffic flow and involvement of commercial vehicles in road crashes. The study has found that the involvement of commercial vehicles in fatal crashes is 2.5 times higher in conditions of the increased mean speed of a traffic flow by 3.2 km/h. The increase in the share of trucks in traffic accidents is a consequence of avoiding the toll of these vehicles. After the construction of the highway, up to 2% of existing trucks are moved on the highway.

Higher involvement of commercial vehicles in fatal crashes, at higher mean speeds, may be the consequence of the longer reaction time and reduced manoeuvring capabilities of those vehicles. On the other hand, their involvement in road crashes can result in more serious consequences for cars and other road users involved in crashes. Smaller values of AADT on the single carriageway are associated with the higher mean speed of the traffic flow, which is consequently linked with the higher involvement of commercial vehicles in crashes, and finally, with the higher risk of occurrence of fatal road crashes.

The results of this study are of importance not only for Serbia, but also for other road sections in the world where construction of an alternative highway road connecting two towns is taking place. It is necessary to conduct additional research studies for different lengths of section roads.

The limitation of this study is in aggregating data on an annual basis. AADT values have been used on an annual basis, as shown by the AADT value at the time of a road accident concerned. That is why the results of the study are a reliable indicator of common effects of AADT and speed on safety of the given road. On the other hand, the relationship between the AADT and the mean speed of the traffic flow remains unclear due to the limitation concerned. Future research studies should tackle determining the AADT at the time of a road accident, which may constitute the basis for identifying the link between the AADT and the mean speed of the traffic flow. In addition, future research studies should include the number of intersections on single carriageways. The research into the effects of changes in the road network on road safety should be conducted for various types of roads, in order to consider possible negative effects in detail. This study has shown that there are negative effects on road safety in cases of reducing the AADT on single carriageways, which should be in the focus in the stages of designing and constructing new highway corridors.

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