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PROFESSIONAL PAPER

The Effects of ITS Application in Speed Management on State Road From Mali Pozarevac to Kragujevac

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Abstract: The application of intelligent transport systems (hereinafter ITSs) on roads enables continuous monitoring of road users during a whole year with the aim to collect good-quality data based on which the more complex analyses could be done, such as monitoring of certain traffic safety indicators. Automatic traffic counters are one of the most commonly implemented ITSs for collecting traffic flow parameters that are relevant for traffic management on state roads in Republic of Serbia. This paper presents one of the possible ways to collect, analyze and present data on road users' speeds using automatic traffic counters, where certain traffic safety indicators are analyzed in terms of road users' compliance with the speed limit on the road section from Mali Pozarevac to Kragujevac. Based on the analyses of data downloaded from automatic traffic counters, it is observed that an extremely high percentage of vehicles drive at speed higher than the speed limit, indicating clearly to higher traffic accident risk, as well as to the need for a tendency to implement speed management on roads using ITS in the forthcoming period.

Key words: ITS, speed, automatic traffic counters, traffic safety, indicator.

INTRODUCTION

Nowadays most of developed countries tend to collect as much as possible information on road users that would be used in all stages of planning, designing, construction, exploitation and traffic safety management on roads, with the aim to establish safe and undisturbed movement of all road users. Higher design vehicle speeds and speed limits on roads have brought numerous positive effects and one of the most obvious among them is the travel time reduction, implying greater mobility of people. This progress in recent decades has significantly reduced travel time, leading to a large extent to the development of national economics and easier travel for road users from an origin to a destination on road network. However, besides the all mentioned advantages enabled by higher travel speed of road users, there are also negative effects caused by speed increasing.

Increased number of traffic accidents, caused by an inappropriate and irregular speed, the severity of traffic accident consequences, number of fatalities and injured persons, great material damage caused by high speed are only some of the reasons why each road user, especially a driver, before he/she takes the attitude to increase the speed in order to get to the destination earlier, should wonder what is the price. Moreover, if we note that higher speeds lead to increased environmental pollution, noise level and human health impact, it is clear that there is a reasonable need to limit vehicle speeds. Namely, besides the speed limits, the research and various studies show that the largest part of drivers still drive at speed higher than speed limit. As a consequence, speeding on roads is a big problem of public safety and health, although it is difficult to determine precisely a causal role of speed in traffic accidents.

According to the statistical data, in the last decade 51% to 55% of total fatalities in Republic of Serbia died because of an inappropriate and irregular speed and this fact makes this factor one of the leading factors of mortality in traffic accidents.[12]

Speed regulation is an ongoing operation, so the regular speed monitoring is essential. Engagement of permanent radar controls, consisting of police officers, requires enormous resources, both in terms of manpower and materials. Namely, in order to provide continuous vehicle speed monitoring, it is necessary to set up permanent measuring sites, i.e. to provide wide range of high technologies for traffic monitoring, inductive loops and other detectors that are reliable and cheaper solution than permanent presence of traffic police. The high technology application in Republic of Serbia is still in the development stage and it is necessary to choose the application of well-known and internationally accepted terms describing the use of these technologies. Automatic traffic counters belong to the group of intelligent transport systems and they are collective systems based on one-way communication with the traffic system users.

ITS is a system of measures and technologies used in transport system which integrates information and telecommunication technologies with the aim to increase traffic safety level and to provide more efficient traffic with less congestions, as well as to reduce the level of environmental pollution.[16]

The components of various ITS subsystems are used on roads, in vehicles and in broader physical and information environment. Broader information environment, in which some of ITS applications operate and on which some of them rely when communicating, consists of Earth satellite systems, GSM and GPRS networks, radio-communication space etc. Besides detection of number of vehicles per categories and traffic lanes, average time headway and traffic lane occupancy, automatic traffic counters can also be used as systems for automatic control of traffic regulation compliance in terms of speed limit on the particular site or road section. In this way it is possible to collect information on speeds of road users passing the road cross section where these devices are installed, which, on the one hand, enables speed analysis with regard to vehicle categories, while on the other hand automatic speed control leads to the significant decrease of speeds on observed dangerous road section and therefore to the reduction of traffic accidents and consequence severity. Nowadays traffic police do not have an adequately made plan of radar speed control based on certain indicators, while collecting and processing of these data would enable to determine accurately the site where the highest percentage of drivers drive at speed higher than speed limit, i.e. to locate a site where the presence of traffic police is mandatory in order to establish continuous monitoring of road traffic safety.

LITERATURE REVIEW

The speed is one of the key factors contributing to fatalities and injuries in traffic accidents across Europe. According to ICF Consulting study conducted in Europe, better application of speed limits on roads could save 5,800 fatalities and 185,000 injured persons in traffic accidents where the speed was a leading factor of the accident. First speed measuring in public traffic in Europe were recorded 150 years ago when speeding-relating public notices were delivered to the citizens of Hamburg and only in 1924 the allowed horse speed was established to be 18 km/h.

World Health Organization (WHO) recognizes the motor vehicle speed as one of the key factors related to injury severity in traffic accidents, so it impacts on traffic accident risk, as well as on consequences of a traffic accident. According to WHO, “excessive speed” is defined as driving at speed higher than the speed limit on given site, while “inappropriate speed” means the speed which is necessary to enable a driver to overcome road and traffic conditions.[20]

During 2011 it is conducted a research in Canada dealing with the improvement of speed limit efficiency in school and playground zones (Lina et al. 2011), where the road user speed is limited to 30 km/h. Based on the 30-minutes observation, the sample of 4,580 vehicle was collected. In this case, 85th percentile of speed was used for statistical analysis. The research was aimed to perceive the total percentage of vehicle exceeding 30 km/h and the percentage of vehicles exceeding the speed limit by 10 km/h. The results based on the sample showed that the average speed on all locations was 31.96 km/h, standard deviation was 6.61 km/h, while 85th percentile speed was 38.81 km/h. The research showed that it is very high and has value of 54.43% of vehicles driving at speed higher that speed limit, while the percentage of vehicles exceeding the speed limit by 10 km/h was only 10%.

Besides Canada, speed limit on highways and rural roads in Australia, in the Melbourne region, was increased from 100 km/h to 110 km/h in 1987. Just two years after, it was returned to 100 km/h. In relation to control region where speed limit remained unchanged, after increase of speed limit by 10 km/h in Melbourne the traffic accident rate per kilometre travelled increased for 24.6%, while after reduction of speed limit the traffic accident rate decreased for 19.3%.[9]

Something similar happened in New Zealand. In 1973 the Government of New Zealand reduce the speed limit on all rural roads from 55 mph to 50 mph (1 mph = 1.609 km/h), resulting in average speed reduction by 5 to 6 mph. In the time period when the speed limit reduction occurred, the percentage of injuries in traffic accident participants was decreased in relation to the period when speed limit of 55 mph was valid. In this way the number of fatalities was reduced by 27%, the number of seriously injured persons by 24%, while the percentage of drivers who sustained light injuries was reduced by 22%. The speed limit reduction on rural roads was in average from 4% to 15%.[3]

In USA (United States of America) the investigation of speed limit change effects, in relation to fatalities on rural roads in certain countries, has being conducted. The research has shown that in certain countries where the speed limit was changed from 65 to 70-75 mph the number of fatalities increased by 38% and 35%, respectively, in relation to the countries that did not change speed limit. Namely, in period 1987-1988 the speed limit was increased by 55 to 65 mph in 40 USA countries, resulting in average speed increasing by about 3 mph and the number of fatalities on these roads increased by 20-25%.[19]

There are numerous studies in which the likelihood of an accident occurrence, including injuries, was proportional to the square of speed and the likelihood of an accident with serious injuries was proportional to the cube of speed, while the likelihood of an accident with fatalities was proportional to the fourth order of speed.

Empirical evidence from certain studies on speed in different countries indicates that the average speed increase by 1 km/h increases the likelihood of injuries in an accident by about 3%, i.e. it increases the likelihood of fatality in a traffic accident by 4-5%. Speed reduction by 1 km/h reduces the likelihood of injuries in an accident by about 3%, while it decreases the likelihood of fatality in a traffic accident by 4-5%.

Also, based on the analysis of accidents on different road types in United Kingdom, it was concluded that every speed reduction by about 1 mph results in the reduction of traffic accident number up to 6%.[13]

The use of automatic traffic counters in Republic of Serbia is based on measuring certain traffic flow parameters on state roads, while this type of data collection on traffic flow is not in use at the local level, except Novi Sad. There are 24 automatic traffic counters in Novi Sad providing information that are also available at the web site of Public Enterprise for City Construction and Development of Novi Sad. The list of automatic traffic counters is automatically updated on every 15 minutes and then some of the collected parameters are presented in tabular form at the web site.[1]

SPEED AS A LEADING FACTOR OF TRAFFIC ACCIDENT OCCURRENCE

Spatial distribution of traffic accidents with fatalities of ABS indicates that road users are the most vulnerable at state roads of I and II order passing through the settlements that account for 34% of total number of fatalities in traffic accidents. An irregular and inappropriate road user speed is a leading and most commonly influential factor contributing to the number of casualties in these traffic accidents.

Data indicate that speed factor was identified in more than 50% of traffic accidents with fatalities.[11] Of course, these absolute indicators should not be taken with great confidence considering that some traffic accidents have been identified by the police as the accidents where the speed is the main influential factor even in the case when it is not, but it is related to the possible contribution in terms of traffic accident consequence severity.

In many developed countries traffic accident experts use in-depth traffic accident analysis in order to determine accurate share of speed as an influential factor of traffic accident occurrence, so the police do not provide information on traffic accident cause. Namely, in Republic of Serbia there are not accurate and in-detail analyses in which it is determined the number of fatalities and injured drivers caused by speed as a main factor contributing traffic accident occurrence.

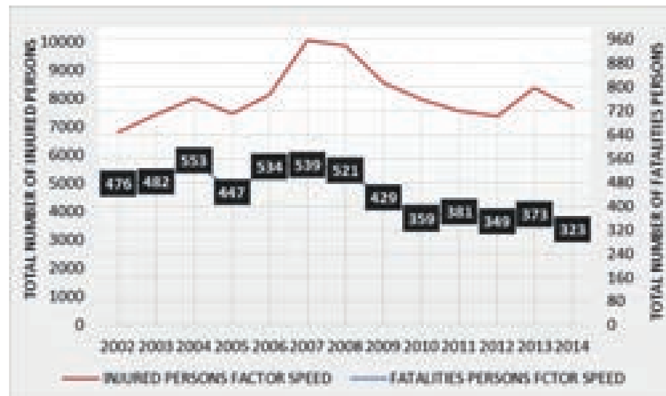


Figure 1. Speed as an influential factor by years[12]

RESEARCH METHODOLOGY

For the purpose of determination of certain traffic safety indicators in terms of road users' speed limit compliance on state road of IB order number 22, from Mali Pozarevac to Kragujevac, the detailed reports on recorded speeds of vehicles passing by installed automatic traffic counters on April 8, 2015 were used; i.e. the reports for time period from 0-24 h were taken from nine road sections on which automatic traffic counters were installed. Downloaded data were analyzed on the basis of data on speed limits provided by Ministry of Interior for location on which automatic traffic counters were installed. After downloading data from automatic traffic counters it was created a database in Microsoft Excel, which is used to calculate certain speed-related traffic safety indicators. Speed-related traffic safety indicators, analyzed on the road from Mali Pozarevac to Kragujevac, include:

- Average vehicle speed,
- 85th percentile of speed,
- Standard deviation of speed,
- % of vehicle exceeding the speed limit,
- % of vehicle exceeding the speed limit by more than 10 km/h,
- Average speed of vehicles exceeding the speed limit,
- Minimum and maximum speed.

One of the leading criteria when choosing road direction for which the research will be conducted was the position of automatic traffic counters on road and it had a great impact. The road direction from Mali Pozarevac to Kragujevac consists of thirteen road sections with length of 78.9 km in total, so it is mainly covered by automatic traffic counters. Automatic traffic counters were installed on nine road sections, collecting data during a whole year, while on 3.2 km long section, between Gornja Trnava and Vlakca, data interpolation based on the data taken from adjacent road section was used. On road section Mali Pozarevac – Mali Pozarevac (settlement), with total length of 0.7 km, traffic flow data were downloaded from highway tool booth, while they were not collected for road sections passing through the settlement. Bearing the above in mind, on sections passing through the settlement, section where data interpolation was used and on section where data were downloaded from highway toll booth, the data on road user' speeds were not collected, so this is also a limitation of the conducted research. Namely, if we take into account a total length of road sections for which data were not collected, it could be concluded that 90% of the road direction from Mladenovac to Kragujevac was covered by automatic traffic counters and this is a good sample for given road direction.

Bearing in mind the impact of "an inappropriate and irregular speed" on total number of fatalities in traffic accidents, the aim of this research was based on indication to the opportunities to continually monitoring certain traffic flow parameters, i.e. road users' speeds during a whole year. Based on the above, this paper presents one of the possible ways to collect, analyze and present data on road users' speeds using reports downloaded from automatic traffic counters where certain traffic safety indicators were analyzed in terms of speed limit compliance in traffic flow on road direction from Mali Pozarevac to Kragujevac.

Principle of automatic traffic counter operation

There are 396 automatic traffic counters of QLTC-10C series installed on state road network of Republic of Serbia that enable at every moment to collect, monitor and analyze traffic flow parameters per pre-defined time intervals during a whole year. One of the basic reports consists of recording the number of vehicles, vehicle travel direction, vehicle category according to the European norm EEC 1108/70 (motorcycle, passenger car, van, light duty vehicle, medium duty vehicle, heavy duty vehicle, heavy duty vehicle with trailer, truck tractor with semitrailer, bus, articulated bus and uncategorized vehicles), minimum and maximum vehicle speed in chosen time interval, vehicle classification into 16 speed classes, headways, lane occupancy and other relevant parameters for road traffic monitoring. The benefit of this report is reflected in the fact that the total number of vehicles driving at particular speed class could be calculated based on the report on the number of vehicles classified into certain speed class (classes: up to 10 km/h, 10-20 km/h, 20-30 km/h, ..., 140-150 km/h and higher than 150 km/h) for the period during a whole year.

Another type of report is very complex compared to the basic one. This kind of reporting is related to one day, i.e. 24 hours, where separate .txt files are created for each day. The structure of this report consists of recorded data: category of a vehicle passing over an inductive loop, ordinal number of vehicles per direction during a day, number of passed inductive loop depending on vehicle travel direction, vehicle speed (km/h) and recorded vehicle length (cm). This report could be used when it is necessary to conduct some more detailed research, as in the case of research conducted in this paper, i.e. when it is necessary to determine a speed of each vehicle passing certain cross section of the road or to define certain speed-related traffic safety indicators. These ITSs operate on the principle of distance-time and inductive loops installed into the carriageway.

The most commonly used detectors are inductive loops. An inductive loop consists of a coil, commonly copper wire, which is put into the grooved carriageway surface, sealed and connected to automatic traffic counters located beside the road. Considering that cables are located under the road surface, there is no fraying caused by the traffic. In the case where there is only one loop per direction, that counter construction could not record speeds, but only traffic volume, vehicle presence and lane occupancy. If there are several loops, as in traffic counters in our examples, it is also possible to record vehicle speed on the basis of distance travelled and real time provided by server.

Figure 2. The spatial layout of QLTC-10C automatic traffic counter[2]

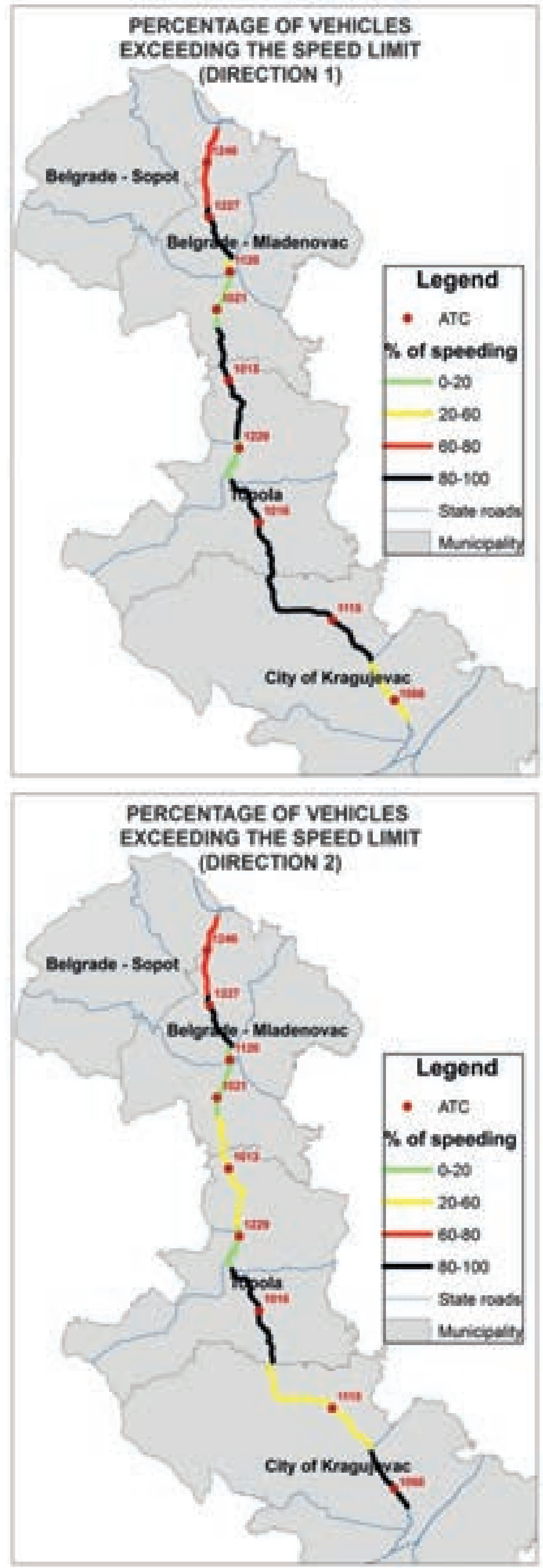
Vehicle detection is based on measuring inductance change of wire loop, i.e. vehicle is detected when it enters loop's magnetic field and when it leaves the loop. Storage capacity will depend on the traffic volume at certain location. If vehicle simultaneously covers all four loops in the carriageway (it drives on the middle of the road), QLTC-10C device has integrated intelligent software for detection and elimination of double counting.

It is preferred that they record the traffic during a whole year, as it is the case in traffic counters owned by Public Enterprise "Roads of Serbia". A server enables access to each of these counters and downloading some of the reports. Some of speed-related technical conditions recommended by device manufacturer are related to the percentage of errors which is 2% at speed of 50 km/h, while it is less than 3% at speed of 160 km/h. Time of sampling is 2 ms per cycle, while GSM module in these ITS devices could operate in the temperature range from -35 to 75 Celsius degrees.

RESEARCH RESULTS

When analyzing obtained results, the directions of observations defined in Tables 1 and 2 were adopted, i.e. direction 1 is a road direction from Mali Pozarevac to Kragujevac, while direction 2 is a road direction from Kragujevac to Mali Pozarevac. The research was conducted on nine road sections whereby recorded vehicle speeds for both directions were analyzed separately. The positions of automatic traffic counters are shown on the map as ACT. Based on the conducted research, the average vehicle speed on certain number of analyzed road sections is higher than the speed limit. The highest average speed compared to the speed limit was observed on the road section Topola 1 – Gornja Trnava, long 11.4 km, where the average speed is 35.54 km/h higher than the speed limit. On this road section even 85% of drivers drive at speed up to 92 km/h, while the percentage of vehicle exceeding the speed limit is 96.92% and it is the highest one in comparison with other given road sections in this direction and percentage of vehicle exceeding the speed limit by more than 10 km/h is 93.85%. Besides this road section, an extremely high percentage of vehicles exceeding the speed limit, 80-100%, was observed on road sections Vlasko Polje– Mladenovac 1 (95.16%), Medjuluzje – Krcevac (89.18%), as well as Vlakca – Cerovac (87.08%).

The listed road sections are designated by black colour on the map, which clearly indicates that these are road sections with higher traffic accident risk where an inappropriate and irregular speed could be one of the contributing factors. Maximum speed of 180 km/h was recorded on the road section Mali Pozarevac – Vlasko Polje, while minimum speed of 11 km/h was recorded on the road section Cerovac – Kragujevac 1. The lowest percentage of vehicles exceeding the speed limit on road sections in direction 1, 0-20%, are designated by green colour and they include road sections Mladenovac 2 – Medjuluzje (8.08%) and Krcevac – Topola (15.57%).



Figuire 3. Percentage of vehicles exceeding the speed limit per directions

If we consider the road from Kragujevac to Mali Pozarevac, road sections where significant percentage of vehicles exceeding the speed limit (80-100%) are Kragujevac 1 – Cerovac (89.62%), Gornja Trnava – To-

Table 1. Research results

Road section	Section length (m)	The observed sample vehicles (8.4.2015.)	ID counters	Direction	Speed limit (km/h)	Average vehicle speed (km/h)	85th percentile of speed	Standard deviation of speed	exceeding the speed limit	exceeding the speed limit by more than 10 km/h	Average speed of vehicles exceeding the speed limit (km/h)	Minimum speed (km/h)	Maximum speed (km/h)
Mali Pozarevac - Mali Pozarevac (settlement)	0,7	No data - traffic flow data were downloaded from highway tool booth											
Mali Pozarevac (settlement) - Mali Pozarevac	0,7												
Mali Pozarevac (settlement) - Vlasko Polje	7,8	4 691	ATC 1246	direction 1	80	93,14	109,00	16,85	0,76	51,84%	99,58	21,00	180,00
Vlasko Polje - Mali Pozarevac (settlement)	7,8	4 719		direction 2	80	88,28	106,00	16,40	0,64	38,00%	97,01	28,00	172,00
Vlasko Polje - Mladenovac 1	6,0	5 968	ATC 1227	direction 1	50	66,47	77,00	11,21	0,95	70,29%	67,57	15,00	124,00
Mladenovac 1 - Vlasko Polje	6,0	5 996		direction 2	50	66,39	78,00	12,38	0,93	69,28%	67,97	15,00	150,00
Mladenovac 1 - Mladenovac 2	2,1	4 512	ATC 1120	direction 1	80	72,15	84,00	12,50	0,21	7,03%	90,27	19,00	138,00
Mladenovac 2 - Mladenovac 1	2,1	4 338		direction 2	80	70,48	82,00	12,12	0,17	4,56%	89,40	12,00	150,00
Mladenovac 2 - Medjuluzje	5,1	4 160	ATC 1021	direction 1	80	63,85	77,00	13,08	0,08	1,80%	88,12	12,00	120,00
Medjuluzje - Mladenovac 2	5,1	4 124		direction 2	80	63,80	75,00	13,73	0,08	2,62%	89,48	11,00	133,00
Medjuluzje - Krcevac	12,3	2 145	ATC 1013	direction 1	60	77,15	92,00	16,09	0,89	67,88%	80,41	15,00	151,00
Krcevac - Medjuluzje	12,3	2 100		direction 2	80	79,79	95,00	17,19	0,45	23,00%	94,02	11,00	164,00
Krcevac - Topola	4,6	3 347	ATC 1229	direction 1	80	68,37	82,00	13,64	0,16	4,30%	89,17	14,00	157,00
Topola - Krcevac	4,6	3 327		direction 2	80	68,54	82,00	13,98	0,16	5,11%	89,89	12,00	124,00
Topola - Topola 1	1,0	No data - road sections passing through the settlement											
Topola 1 - Topola	1,0												
Topola 1 - Gornja Trnava	11,4	1 885	ATC 1016	direction 1	40	75,54	92,00	16,47	0,97	93,85%	76,94	16,00	133,00
Gornja Trnava - Topola 1	11,4	1 895		direction 2	60	78,85	95,00	15,81	0,90	74,04%	82,06	17,00	144,00
Gornja Trnava - Vlakca	3,2	No data - interpolation based on the data taken from adjacent road section											
Vlakca - Gornja Trnava	3,2												
Vlakca - Cerovac	12,4	2 160	ATC 1115	direction 1	60	75,69	90,00	15,11	0,87	64,44%	79,17	14,00	133,00
Cerovac - Vlakca	12,4	2 100		direction 2	80	79,13	95,00	14,75	0,42	19,48%	92,67	18,00	150,00
Cerovac - Kragujevac 1	9,6	4 326	ATC 1066	direction 1	60	53,46	65,00	11,94	0,25	8,21%	68,43	11,00	109,00
Kragujevac 1 - Cerovac	9,6	4 324		direction 2	40	56,41	69,00	12,79	0,90	69,15%	58,98	12,00	100,00
Kragujevac 1 - Kragujevac 3	2,8	No data - road sections passing through the settlement											
Kragujevac 3 - Kragujevac 1	2,8												

pola 1 (89.97%), as well as Mladenovac 1 – Vlasko Polje (93.31%). The abovementioned road sections are designated by black colour on the map. Maximum speed of 172 km/h was recorded on the road section Vlasko Polje – Mali Pozarevac (settlement), while minimum speed of 11 km/h was recorded on two road sections: Medjuluzje–Mladenovac 2 and Krcevac – Medjuluzje. Road sections in direction 1 with the lowest percentage of vehicles exceeding the speed limit, 0-20%, are designated by green colour and they include road sections Mladenovac 2 – Mladenovac 1, Medjuluzje – Mladenovac 2 and Topola – Krcevac.

If we take into account common values in both directions, it could be concluded that the percentage of vehicle exceeding the speed limit on road section Vlasko Polje – Mladenovac 1 is between 80% and 100% for both directions. Slightly higher percentage of vehicles exceed the speed limit in direction towards Topola, while maximum speed recorded in direction Kragujevac – Mali Pozarevac was 150 km/h, which is two times higher than the speed limit on this road section. Also, the percentage of vehicles exceeding speed limit by 80% up to 100% in both directions also appears on road section Topola 1 – Gornja Trnava. Table 1 shows all research results.

DISCUSSION

The results of speed-related traffic safety indicator research clearly indicate that the highest percentage of drivers drive at speed higher than the speed limit. On six out of nine road sections, in both direction for given day, more than 40% of drivers exceeded speed limit and this is a very high value of traffic safety indicator, while on even five road sections this value is higher than 80% of drivers. Bearing in mind the speed limit on given road direction, on almost all road sections the average vehicle speed is higher than the speed limit. A worrisome fact is that maximum speed on all road sections of given road direction is almost two times higher than speed limit.

On this road section there are several different speed limits, i.e. 40, 50, 60 and 80 km/h. This fact and the fact about the settlement through which given road direction passes indicate that it spreads through the built-up areas. Namely, we should not forget a statement that pedestrian and other road user frequency is extremely high in settlements compared to the other road categories, implying that there is a very high risk of traffic accident occurrence in circumstances obtained based on the results. Besides the speed recorded by automatic traffic counters, there are also other traffic flow parameters that could be analyzed. Namely, this type of data collection for 24 hours during a whole year enables in-depth analysis of road users' speeds in all time periods. The operational accuracy of this type of ITSs provided by the manufacturer is 96% when it comes to classification accuracy, while it is 99.9% for vehicle detection accuracy. Maximum speed detectable by these devices is 260 km/h and the measuring error at speed of 50 km/h is less than 2%, while it is less than 3% at speed of 160 km/h. The most common errors may occur when measuring the speed of uncategorized vehicle and motorcycles.

Nowadays the schedule of traffic police patrols is based on the estimate of authorized police office when choosing locations for traffic control. Analysis of data downloaded from automatic traffic counters could lead to accurate percentage of speeding on state roads for particular time period, which could greatly help when choosing locations of radar controls and therefore there is reduced possibility for increase of traffic accident risk in circumstance of an irregular and inappropriate speed. In this way it could be achieved savings in time and available resources spent on police officer engagement in radar traffic control. Also, it enables to determine speed limit change possibilities on particular road sections based on 85th percentile of speed, as it is the case in other developed countries. One of the current limitations in application of these ITSs is low coverage of road network by automatic traffic counters, where the percentage of network coverage is about 40%.

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