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The relationship between the travelling speed and motorcycle styles in urban settings: A case study in Belgrade

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ABSTRACT

This report examines the difference in the distribution of the speeds of different motorcycle styles and the difference in the distribution of speeds of particular motorcycle styles and cars. The relationship between the speed of motorcycles that possess and those that do not possess vehicle registration plates was also explored. The speed was measured at six different locations on main roads in the city of Belgrade, Serbia. The study confirmed that, on average, motorcyclists drive faster than drivers of cars, but extreme speeding is recorded 2.3 times more often by motorcyclists than by car drivers. In this research, the styles of motorcycles were divided into three different groups according to their average speeds. The first group consists of sport motorcycles, which were faster than the other styles. The second group consists of scooter motorcycles, which were slower. The third group consists of conventional, touring, enduro, and chopper motorcycles with speeds that were statistically not significantly different. According to the differences of the mean speed of motorcyclists who use and do not use vehicle registration plates, the use of the registration plates can be considered a significant indicator of traffic safety. By classifying motorcycles in the three different groups, the issue of "generalizing" motorcyclists as a unique group is avoided and can be taken into consideration for future studies of motorcyclist safety.

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1. Introduction

Traffic accidents with fatal consequences involving two-wheelers account for approximately 15% of total fatalities in the EU-24 in 2010 (ERSO, 2012). The risk of death and serious body injury for drivers of two-wheelers is significantly higher than for drivers of cars (DACOTA, 2013). The current definition of the term "two-wheelers" includes different motorcycle styles (mopeds, tricycles, and four-wheelers) (ACEM, 2012). This definition raises the question of the substantial differences between these categories in terms of risk. Namely, motorcyclists belong to the category of road users that are particularly exposed to the risk of injuries, notably death (Clabaux et al., 2012). Additionally, motorcyclists belong to the only means of transport in the EU-20 for which the recorded number of traffic accidents increased over the period of 2001–2010. The risk of death or accident with serious injuries in Europe for motorcyclists is 5–25 times higher per kilometer than that of car drivers (Phan et al., 2010).

The Republic of Serbia is a developing country with the potential of joining European Union. Together with this development, the number of registered motorcycles has grown quickly. In 2011, that number was more than three times greater than in 2003. Concurrently, Serbian traffic police and law enforcement were not trained to address this specific group of traffic participants.

According to the Serbian Road Traffic Safety Agency (ABS, 2013), speeding is the key factor in accidents of motorcycles. Speeding is even more applicable to the group of sport motorcycles. According to Antov et al. (2010), the percentage of sport motorcycles in Serbia is the highest in Europe. In their publication, the authors report that 66% of Serbian motorcycle drivers indicated speed enjoyment as an important motive for driving motorcycles. Generally; in Serbia, a significant number of drivers do not respect speed limitations, and according to a WHO report (2011), speed enforcement in Serbia is below the average. Additionally, the percentage of motorcyclists who complete advanced motorcycle courses in Serbia is the lowest among all European countries (5.6% versus Sweden, 55.1%).

The report by the Road Traffic Safety Agency (2012) stated that in the city of Belgrade, the capital of the Republic of Serbia, motorcyclists fall into a group with a high public and traffic

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accident risk with fatal consequences. In Belgrade, from 2006 to 2011, 108 deaths of and 1847 injuries to motorcyclists were recorded. In 2011, the number of motorcycle-related fatalities accounted for approximately 15.4% of the total fatalities, or 7.4% of the total casualties.

An indicator of traffic safety is a quantifiable metric that affects the level of transportation safety. The purpose of traffic safety indicators is to assess traffic safety in certain area under certain conditions and to identify potential safety hazards in their early stage before they result in accidents (Thomas et al., 2005). Chapter 3 of the dissertation by Al Haji (2007) provides a survey of theoretical frameworks for selecting traffic safety indicators. Recent studies recognized speed as an important indicator of traffic safety for motorcyclists (Yannis and Evgenikos 2007). In several papers (Vlahogianni et al., 2012; Walton and Buchanan, 2012; Blackman and Haworth, 2013; Haque et al., 2009; Mannering and Grodsky, 1995; Phan et al., 2010; Hurt et al., 1981), speeds notably exceeding the speed limit are emphasized as key risk factors for accidents involving motorcyclists. Unsafe and inappropriate speed is a major traffic safety problem in many countries (OECD, 2006) and is an often discussed topic (Bjørnskau et al., 2012).

The extent of injuries grows with excessive driving speed (WHO, 2008; Lin et al., 2003). Speed is monitored in most of the EU countries (Hakkert and Gitelman (2007)), and the speed of motorcyclists is significantly different compared to the other participants in accidents (DACOTA, 2013). In a previous study (Haque et al., 2012), the largest number of accidents was noted to occur between motorcycles and other vehicles. Speed differentials between vehicles and motorcycles have a great influence on the crash risks. Another study (ACEM, 2008) noted that in 61.6% of accidents with other vehicles, the collision speed of motorcycles was under 50 km/h. The study also noted that in 9.4% of accidents, the collision speed of motorcycles was greater than 100 km/h; whereas, the collision speed of cars exceeded 100 km/h in only 2.3% of accidents.

With the increase in the number of motorcycles and the number of accidents, an increasing need for identifying differences in the distribution of the speed between the motorcycles and other forms of transportation has arised. Most of the published studies focused on identifying differences in the distribution of the speed between the means of transport, i.e., the difference between motorcyclists and other road users. These studies did not detail categorizations within the group of motorcyclists. A survey regarding speeds in Israel states that compared to the other participants, motorcyclists usually drive over the speed limit on both rural and urban roads during both day and night conditions (Gitelman et al., 2010). According to the report by the Department for Transport (DfT, 2006), the average speed of motorcyclists is generally higher than the average speed of cars on an identical road. In a project conducted in Australia, monitoring sections over which the speed limit is 100 km/h descriptively showed that motorcyclists ride faster than car drivers. The percentage of motorcyclists who drove 10 km/h and above over the speed limit was approximately 3.3 times higher compared to car drivers (Baldock et al., 2010).

Observing motorcycles as a unique group does not disclose the actual situation about the distribution of speeds because of the significantly different categories of motorcycles. Authors often use two or three categories of motorcycles, grouping them by different criteria (power, capacity, legal categorization, etc.), such as in Chen and Chen (2011). However, a smaller number of studies in which a more detailed categorization of motorcycles was performed to determine the connection between speed and certain categories of motorcycles. One of the methods to divide motorcycles is by style. By style we refer to a group of motorcycles with similar performance, appearance, and purpose, similar to previous research (Antov et al., 2010). Table 4 given in the Appendix A, shows the division of motorcycles by style and their characteristics based on the European Commission project SARTRE 4. In some studies (Teoh and Campell, 2010), instead of the term "style", the term "type" was used. However, by the type of motorcycle we refer to a specific brand of motorcycle, similar to other studies (Kraus et al., 1988). Teoh and Campell (2010) analyzed accidents and indicated that motorcycles are significantly different with respect to style and design, particularly in terms of size, weight, and performance (top speed, acceleration, power, maximum angle "overthrow" in the curve, etc.), and the results are analyzed in relation to the six styles of motorcycles. The existing studies mainly focused on sport motorcycles.

Sport motorcycle accidents are mentioned as a specific problem (Van Elslande and Elvik, 2012). Speeding by drivers of sport motorcycles is most commonly reported (Elliott et al., 2003; Phan et al., 2010). Sport motorcycles are considerably more at risk of being involved in accidents with serious consequences compared to other styles of motorcycles (Bjørnskau et al., 2012). The rate of casualties of sport motorcycle drivers is four times higher than of drivers of touring motorcycles (Kraus et al., 1985). Nine out of ten drivers who drive at high speeds are street racers on replicas of racing motorcycles (Strandroth and Person, 2005). In the state of Serbia, 33% of registered motorcycles are sport motorcycles; however, sport motorcycles were involved in 49% of fatal traffic accidents (ABS, 2013).

On the streets of Belgrade, motorcyclists often ride vehicles with registration plates that are intentionally placed so that they cannot be clearly seen or they do not have registration plates at all. Our subjective estimation was that these riders drive faster and more "aggressively" than those who have regular registration plates. We included in our analysis the parameter "having proper registration plates", expecting to detect differences in the distribution of speed between motorcyclists who have registration plates and motorcyclists who do not have registration plates. The potential benefit of this analysis could be that the use of the registration plates on motorcycles, depending on the style, can be regarded as a significant indicator of traffic safety.

The key questions to be answered about motorcycle styles are the following: What is the extent of differences between styles of motorcycles considering the distribution of speed? Can the style of motorcycles be systematically related to the distribution of the speed? The answers to these questions would enhance further research in terms of better determining the difference between motorcycles and other modes of transport and within the group of motorcycles.

A significant number of studies used methods to determine the distribution of speeds between different modes of transportation and different styles of motorcycles that were based on questionnaires (motives and attitudes) and an analysis of collision speed (from accident data). In this paper, a significantly different approach was used. All data were collected by direct observation and speed recording on streets.

The present study examines the statistical significance of differences in the distribution of speeds between six styles of motorcycles and between motorcycles and cars. This study also examines the relationship between the speed distribution of motorcycle styles and the possession of vehicle registration plates on motorcycles.

2. The research method

According to Serbian Traffic Safety Law which is in accordance with laws in European Union countries, driving 50 km/h faster than the official speed limit within urban areas is considered to be a rough violation of traffic safety. Such speeding usually implies the most severe sanctions. The speed limit on all sites for which measuring took place was 50 km/h. Therefore, we adopted 100 km/h as the limit above which we considered the speeding as "extreme speeding".

The study included a sample of $N = 1080$ motorcycles. This sample can be considered to be large enough given that the total number of registered motorcycles in the city of Belgrade is approximately 11,000. Additionally, a sample of $N = 1080$ cars was randomly selected, and their speed was measured to compare our data to results obtained from other studies which show that motorcyclists on average drive faster than car drivers.

2.1. The criteria for the selection of locations for which the speed was measured

The speed was recorded on the main roads (2×2 and 2×3) of the city of Belgrade. Six locations were selected on sufficiently long sections over which drivers could drive above the speed limit and on which there has been at least one accident involving a motorcyclist in the last 5 years. Other common characteristics of the selected locations included the following:

- The minimum length of the section between the major intersections is at least 500 m.
- The vehicles' speed can be measured from a distance of approximately 150 m.
- The sections have a low slope (<5% at least 500 m before the section).
- The distance from traffic calming systems is at least 500 m.
- The distance from construction areas, parking lots, important buildings next to the road is at least 500 m.
- The road surface is in good condition.
- The distance from the police traffic control is at least 2000 m.
- The location enables safe speed measurements without affecting the behavior of drivers; and
- The traffic lights, when they exist, are line coordinated along the sections over which the locations reside.

2.2. The time period for measuring

The time allotted for speed measurements (month, week, and hour) was determined based on historical analyses of accidents in which the largest number of motorcyclists were killed at the selected sites. With this in mind, research was conducted during the month of July on Fridays, Saturdays. and Sundays from 12 pm to 6 pm (considered as day-time) and from 6 pm to 12 am (considered as night-time).

2.3 The conditions under whichthemeasurementswere performed

The speed limit for all six locations was 50 km/h. The traffic intensity at all six sites at the time of speed measuring was less than 600 vehicles/h during the day-time and less than 500 vehicles/h during the night-time. The weather during the day-time was sunny, with an average temperature of approximately 31.5 °C, and during the night, the weather was clear, with an average temperature of approximately 27 °C.

2.4. Speed-measuring equipment

For research purposes, a portable hand-held laser detector, ProLaser III, was used. According to the technical documentation of the device and measuring conditions, the average measuring error is under 1%. In addition to displaying the speed, this detector also provides precise information on the distance. By targeting a single point, one can reliably measure the speed of a predetermined vehicle traveling individually or in a column. The detector does not use a microwave transmission as a traditional radar system, but employs rays of higher frequency and shorter wavelength, which can easily form a narrow laser beam suitable for the identification of small-sized vehicles.

2.5. Speed-measuring procedure

Before the study began, a two-person team had been trained (the training involved the ability to recognize the style of a motorcycle, to use the measuring device and to record data). For each measurement, several types of data were recorded: location characteristics (speed limits and traffic intensity), climate conditions (temperature, weather conditions, etc.), speed of the selected vehicle, motorcycle style, and the possession of registration plates. The style of motorcycle was classified in accordance with Table 4. Motorcycles with illegible registration plates were treated as cases without registration plates.

The speed of all motorcycles that passed the measuring locations in one direction was recorded. At the identical locations and at the identical time, the speed of randomly selected cars was measured. The speed measuring was performed in a safe and unobtrusive manner because the vehicles were "leaving".

2.6. Data processing

Data from all six locations were systematized in the SPSS program into a single table, after which an analysis of the pooled samples was conducted. The normality test of data revealed that the measured speeds are not subject to the normal distribution. Therefore, we adopted two nonparametric statistical tests, as suggested in the literature. The Mann–Whitney test was used to compare two groups of samples. This test is a nonparametric alternative to a *t*-test of independent samples. The Kruskal–Wallis test is a non-parametric method for testing whether two or more independent groups of samples originate from the identical distribution. The parametric equivalent of this test is one-way analysis of variance (ANOVA). In both tests, the parameter p presents the significance level of the primary hypothesis; i.e., that different groups of samples originate from the identical population. If this value is less than or equal to 0.05, then the alternative hypothesis that tested groups are significantly different is adopted.

2.7. Limitations

Despite the proper training of the team members, in 7 cases with drivers of sport motorcycles (5 in the night-time and 2 in the daytime), the team did not promptly measure the speed because of the extreme speeding. By the subjective assessment of the research team, these motorcycles were moving much faster than the highest recorded speed of any motorcycle in this study (164 km/h).

The category of "moped" (light motorcycle with an engine capacity of less than 50 cm^3 and a maximum speed of less than 45 km/h) is not included in this research given the significant difference in performance (speed, acceleration, etc.) and should be further investigated.

3. Results

3.1 The differences between means of transport

Many studies have shown that the mean speed of motorcycles is slightly greater than the mean speed of other means of transport (Walton and Buchanan, 2012). To check the validity of this hypothesis on the streets of Belgrade, we collected a relatively small, randomly chosen sample of cars at the identical locations for

Table 1
Descriptive statistics of speeding (motorcycles/cars).

Mode of Transport	N	Mean	Sd	$\%V_{>50\,km/h}$	$\%V_{>100\,km/h}$
Car	1080	66.9	13.6	94.1%	2.7%
Motorcycle	1080	69.6	18.9	91.2%	6.2%
Total	2160	68.2	16.5	92.6%	4.4%

which the speed of motorcycles was measured. The speed of cars was measured in the identical way as for motorcycles.

The mean speed of motorcycles was $M = 69.6$, with a standard deviation Sd = 18.9, and the mean speed of cars was $M = 66.9$, with a standard deviation Sd = 13.6 (Table 1). Although the difference was only 2.7 km/h, the Mann–Whitney test revealed that the significance of the difference is equal to the marginal value $p = 0.05$ at which the alternative hypothesis for their difference can be accepted.

Fig. 1 illustrates the difference in the distribution of the speed of motorcycles and cars (the interval being 10 km/h).

3.2 The differences between motorcycle styles

The data concerning speed distribution among motorcycle styles are summarized in Table 2.

The two most common styles of motorcycles in Belgrade are scooters (44%) and sport motorcycles (25%). Based on the Kruskal–Wallis test, we concluded that the mean speed significantly differs ($p < 0.05$) among motorcycle styles. Based on the results of the Mann–Whitney test, we conclude that the mean speed of sport motorcycles ($M = 86.2$) was significantly higher in relation to all of the other styles, i.e., scooter, conventional, touring, enduro, and chopper styles. The mean speed of scooter motorcycles ($M = 60.4$) was significantly lower in relation to all other styles. No significant speed differences were noted in the mutual comparison of conventional, enduro, touring, and chopper styles, except for the slightly higher speed of the enduro style compared to the chopper style.

On the basis of this analysis, groups were formed by motorcycle styles. The first group consists of sport motorcycles (fastest), the second consists of scooters (slowest), and the third\\consists of conventional, enduro, touring, and chopper styles because no statistically significant difference in the distribution of speed was noted in this group. The observed significant differences between the enduro and chopper styles can be considered extreme; whereas, being in the identical group. Analyzing other indicators can corroborate this claim, and this group is hereinafter further discussed in detail.

Fig. 2 shows the differences in the distribution of speed between the three groups of motorcycle styles (interval 10 km/h). At intervals up to 50 km/h, the percentage of scooters is higher than the other styles, and the percentage of sport motorcycles that range within the speed limit is small. When observing just the

Table 2
Descriptive statistics of speeding (motorcycle styles).

	Motorcycle style	*N*	*%N*	Mean	Sd	$\%V_{>50\,km/h}$ [a]	$\%V_{>100\,km/h}$ [a]
Day	Sport	144	24%	82.7	20.9	97.9% (23.5)	14.6% (3.5)
	Scooter	257	42.8%	58.8	11.0	84.8% (36.3)	0%
	Conventional	33	5.5%	64.3	11.4	93.9% (5.2)	0%
	Touring	21	3.5%	65.7	8.8	90.5% (3.2)	0%
	Enduro	73	12.2%	71.6	14.2	97.2% (11.8)	5.5% (0.7)
	Chopper	72	12%	65.1	14.7	84.7% (10.2)	0%
	Group three	199	33.2%	66.7	12.3	91.4% (30.4)	2.1% (0.7)
	Total	600	100%	67.4	17.5	90.2%	4.5%
Night	Sport	123	25.6%	90.2	22.6	100% (25.6)	29.7% (7.5)
	Scooter	214	44.6%	62.3	14.3	85.5% (38.1)	1.4% (0.6)
	Conventional	27	5.6%	70.0	11.3	99.0% (5.6)	0%
	Touring	23	4.8%	70.9	13.4	95.6% (4.6)	4.4% (0.2)
	Enduro	68	14.2%	74.7	14.2	95.6% (13.5)	1.5% (0.2)
	Chopper	25	5.2%	65.9	15.0	96.0% (5.0)	4% (0.2)
	Group three	143	29.8%	70.4	13.5	96.3% (28.7)	2.1% (0.6)
	Total	480	100%	72.2	20.1	92.5%	8.7%
Total	Sport	267	24.7%	86.2	21.9	98.9% (24.4)	21.3% (5.3)
	Scooter	471	43.6%	60.4	12.7	85.1% (37.1)	0.6% (0.2)
	Conventional	60	5.6%	67.0	11.6	96.7% (5.4)	0%
	Touring	44	4.1%	68.5	11.6	93.2% (3.8)	2.3% (0.1)
	Enduro	141	13.1%	73.1	14.3	96.4% (12.6)	3.5% (0.5)
	Chopper	97	9.0%	65.3	14.7	87.6% (7.9)	1.0% (0.1)
	Group three	342	31.7%	69.2	13.1	93.5% (29.7)	2.0% (0.7)
	Total	1080	100%	69.6	18.9	91.2%	6.2%

[a] The given values are percentages relative to the number of motorcycles of a certain style group, and the values in brackets are relative to the total number of motorcycles during the day or night.

motorcycles that violated the speed limit, drivers of scooters more commonly produced minor speeding violations (at approximately 65 km/h). Riders in group three incurred higher speeding violations (the peak is at approximately 70 km/h). For intervals above 85 km/h, the percentage of sport motorcycles is far higher than the other groups. This trend continues for all intervals of extreme speeding. Based on the data from Table 2, the highest percentage of extreme speeding, in relation to the group (21.3%) and the total number of motorcycles (5.3%), was recorded in the sport motorcycle group.

The mean speed of vehicles of any type is higher during night-time than during day-time (see for instance Antov et al., 2010).

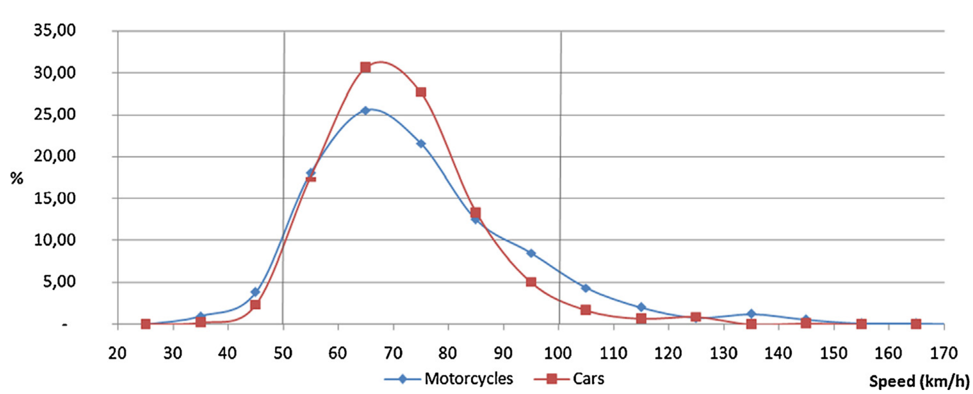

Fig. 1. The differences between modes of transport.

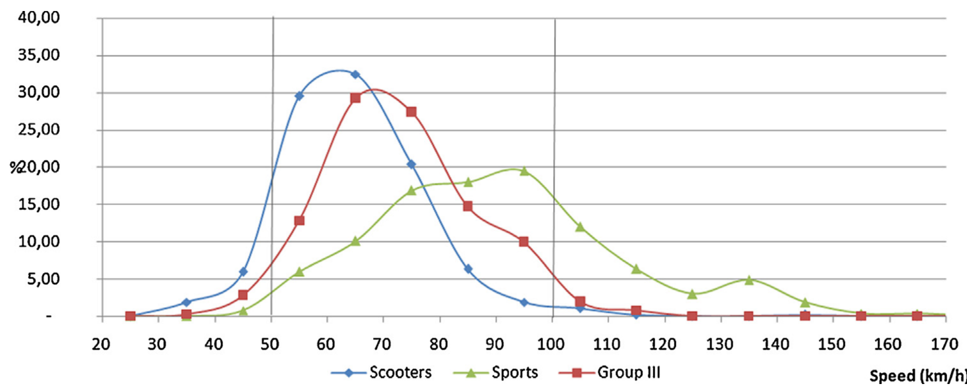

Fig. 2. The distribution of speed by motorcycle styles.

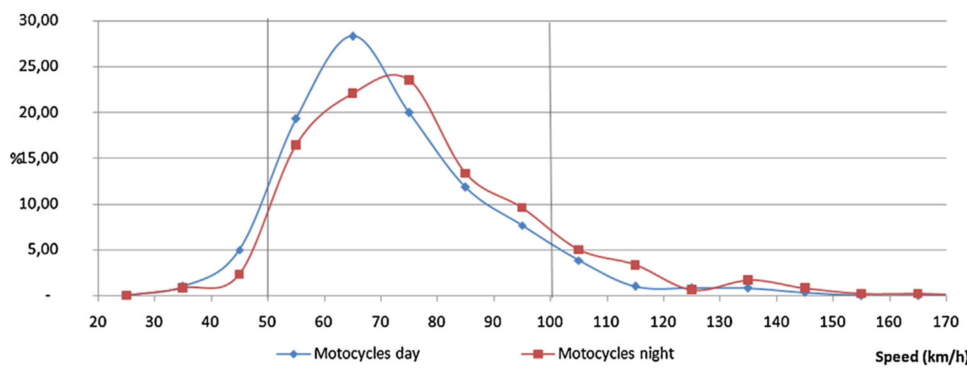

Fig. 3. Distribution of speed by time of day.

Based on our measurements, we claim with high statistical significance ($p < 0.05$) that on the streets of Belgrade, the speed of motorcycles at night-time ($M = 72.2$) is higher than the speed of motorcycles during the day-time ($M = 67.4$). The percentage of speeding motorcycles at night-time (92.5%) is higher than the percentage at day-time (90.2%); whereas, the percentage of extreme speeding in night conditions (8.7%) is almost double the day conditions. Fig. 3 shows the distribution of speed for all motorcycles regarding the time of day.

We also checked the speed distribution of the three groups of motorcycles separately during the day and night-time.

Observing just the day-time sample (Fig. 4), a statistically significant difference is noted in the mean speed between motorcycle styles ($p < 0.05$). The results of the Mann–Whitney test showed that the speed of sport motorcycles ($M = 82.7$) was significantly higher in relation to the other styles. The speed of scooter motorcycles ($M = 58.8$) was significantly lower in relation to all other styles, except in relation to the conventional style, which can be considered extreme within its group. No statistically significant differences were noted in the mutual comparison of conventional, enduro, touring, and chopper styles. The highest percentage of extreme speeding in relation to the style (14.6%) and the total number of motorcycles (3.5%) is noted for sport motorcycles.

Additionally, a statistically significant difference ($p < 0.05$) was noted in the speed between motorcycle styles during the night-time (Fig. 5). The results show that the speed of sport motorcycles ($M = 90.2$) is significantly higher in relation to all other styles. The speed of scooter motorcycles ($M = 62.3$) is significantly lower in relation to all other styles, except in relation to the chopper style, which can be considered extremely slow within its group. No statistically significant difference was noted in the mutual

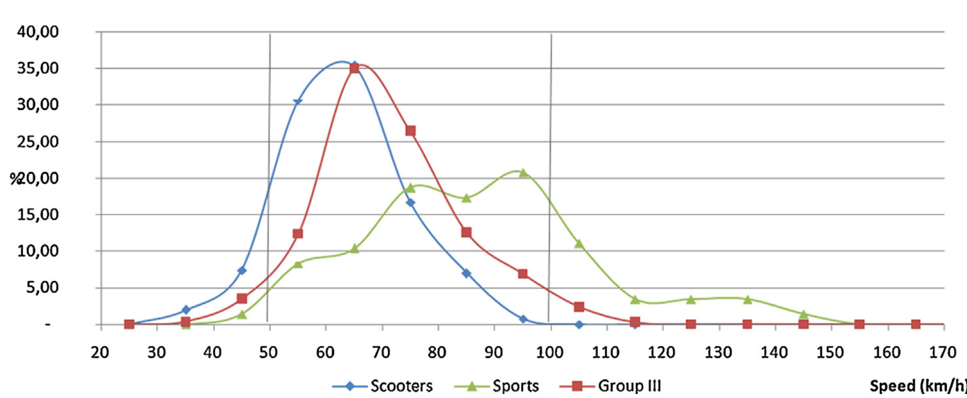

Fig. 4. Distribution of speed by style–day-time.

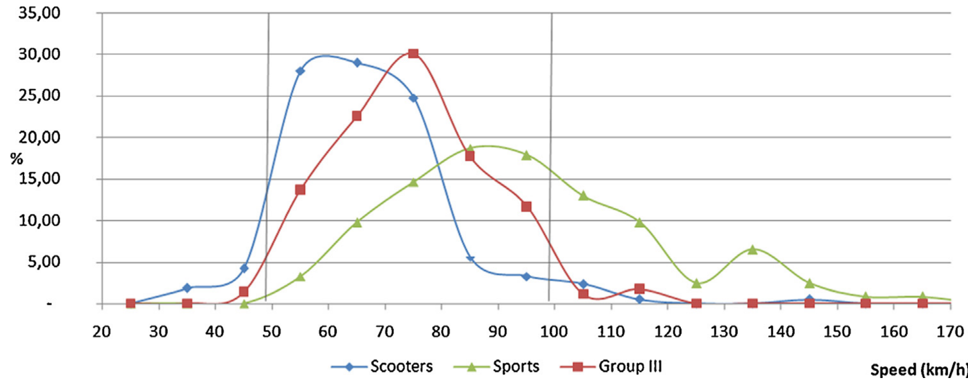

Fig. 5. Distribution of speed by style–night-time.

comparison of the conventional, enduro, touring, and chopper styles. The highest percentage of extreme speeding, in relation to the style (29.7%) and the total number of motorcycles (7.5%), is noted for sport motorcycles.

Figs. 4 and 5 show the difference in the distribution of speed between the three groups of motorcycles by motorcycle styles (interval 10 km/h) in relation to the time of day.

3.3 The use of registration plates

Generally motorcyclists have a significantly lower percentage of vehicle registration plates (84.9%) in relation to car drivers (100%). Observing only the group of vehicles that have registration plates, we found no statistically significant difference between the speed of motorcycles and speed of cars. Among all styles of motorcycles, drivers of sport motorcycles (59.5%) have the lowest percentage of registration plates.

Based on the Mann–Whitney test, we conclude that the speed of motorcycles without registration plates ($M = 85.7$) is significantly greater than the speed of motorcycles with registration plates; ($p < 0.05$). The results are displayed in Table 3 and show that the speed of sport motorcycles without registration plates ($M = 92.6$) is significantly greater than the speed of sport motorcycles with registration plates; ($p < 0.05$). For other styles, no significant difference is noted. Approximately 53% of all motorcycles that displayed extreme speeding had no registration plates visible. This percentage was even more emphasized for drivers of sport motorcycles. In total, 60% of sport motorcyclists who displayed extreme speeding did not have registration plates visible.

4. Discussion

In the recent literature, many factors that influence speeding can be found, e.g., both cognitive and affective attitude components (Parker et al., 1992; Rothengatter, 1993); road geometry, conditions and environment (Goldenbeld and van Schagen, 2007); and the level of police enforcement (Elliott and Broughton, 2005; Stanojević et al., 2013).

Table 3
Descriptive statistics of speeding (the use of registered licence plates).

Motorcycle styles	Without registered plates				With registered plates			
	N	%*N*	Mean	Sd	*N*	%*N*	Mean	Sd
Scooters	33	7.0%	65.2	22.3	438	93.0%	60.1	11.8
Sport	108	40.5%	92.6	21.7	159	59.5%	81.8	21.1
Conventional	4	6.7%	76.3	6.3	56	93.3%	66.5	11.6
Touring	3	6.8%	71.7	14.4	41	93.2%	68.3	11.6
Enduro	9	6.4%	78.5	14.5	132	93.6%	72.8	14.2
Chopper	6	6.2%	79.8	21.9	91	93.8%	64.3	13.7
Group three	22	6.4%	77.5	16.1	320	93.6%	68.7	13.8
Total	163	15.1%	85.7	23.6	917	84.9%	66.8	16.4

Those roads in which the locations for speed measuring took place were selected to allow drivers to drive unhindered, including at speeds faster than the speed limit (see Section 2). The selection was conducted with the assumption that drivers are assumed to set their driving speed based on their perception of the appropriate speed for the road environment, as stated in (Martens et al., 1997; Lewis-Evans and Charlton, 2006).

A new law on traffic safety applies in Serbia since January 2010. This law has brought new rules for speed limits. In urban areas, the speed limit was reduced from 60 km/h to 50 km/h because of compliance to the European legislation. Because no serious work on a consistent application of these regulations or on changing attitudes and behaviors of drivers occurred, we can discuss the factor of "past behavior", which has a significant effect on the current degree of speeding (De Pelsmacker and Janssens, 2007).

Our analysis confirmed previously published results that between the mean speeds of motorcycles and cars, a small, but significant, difference exists. These results are in accordance with the research of the DfT (2006), where it is stated that the mean speed of motorcycles is higher than the mean speed of cars. The difference between the mean motorcycle speed and the mean car speed in our research ($M = 2.7$) is similar to the difference in the article by Walton and Buchanan (2012), which stated 3.3 km/h. This similarity is noted even despite the fact that in the above mentioned research, speed was measured closer to the intersection zone. Additionally, their study showed that the standard deviation of the speed of motorcycles (Sd = 10.9) is significantly higher than the standard deviation of the speed of cars (Sd = 8.9). That result is in accordance with the results of this study, in which the standard deviations were Sd = 18.9 and Sd = 13.6 (Table 1). The higher dispersion of motorcycle speeds is an additional confirmation for treating motorcycles as a heterogeneous group.

By analyzing the results shown in Table 1 and Fig. 1, we conclude that the main difference in the speed distribution between motorcycles and cars is in and near the range of extreme speeding. This fact is often neglected in the analysis of the speed of motorcycles as a single group. A more nuanced analysis of the differences in the speed distribution between styles of motorcycles can provide a true picture of the situation and may indicate which motorcycle styles contribute to speeding the most.

The analysis of the results related to the distribution of speed depending on the style of motorcycles is based on three distinctive groups of motorcycles. The results that characterize the sport style as the fastest ($M = 86.2$) are similar to the results presented by Elliott et al. (2003). Irregularities in speed distribution associated with sport motorcycles (shown in Fig. 2) may be explained by the existence of different groups of drivers of sport motorcycles with significantly different attitudes about speed. Further investigation is necessary to divide this style into clusters and analyze them separately from different points of view (psychological, social, etc.). This dispersion within the group of sport motorcycles is supported by the performance of these motorcycles (acceleration, top speed, etc.), which allows larger fluctuations in speed for each particular vehicle.

Scooter motorcycles compose another group, and they drove significantly slower compared to all other styles ($M = 60.4$). The highest number of speeding incidents was recorded in the interval of up to 10 km/h over the limit. These results were expected for scooters because most of them have little power and limited performance.

The third group consists of conventional, touring, enduro, and chopper style motorcycles, in which no evidence of a statistically significant difference in speed distribution was recorded. The average group speed is $M = 69.2$ km/h. The highest percentage of speeding in this group is in the interval from 60 km/h to 80 km/h. In this group, enduro motorcycles have the highest percentage of extreme speeding. Irregularities in speed distribution in this group are significantly lower compared to those of sport motorcycles.

The differences of the speed distribution of different motorcycle styles are a confirmation of the studies in which the connection of speed and motorcycle style is determined based on the motives and attitudes of drivers. The behavior of sport motorcycle drivers can be caused by the motives of enjoying speed and sporty driving (Shulz et al., 1991). Motives such as cost control, mobility, and safe driving that are typical for the behavior of scooter drivers and drivers of conventional motorcycles categorize the aforementioned styles as less risky in terms of speed. The survey conducted by Sexton et al. (2004) similarly noted that the maximal speeds of sport motorcycles were connected with motives of pleasure, fun and tendency to speed. Considerably lower speeds of touring and chopper motorcycles in research conducted by Joshi S. et al. (2011) are associated with the motive of driving pleasure (travel, driving enjoyment, and a sense of freedom), as indicated by significantly lower speeds in relation to sport motorcycles.

In the introduction, we mentioned that the largest number of accidents occur between motorcycles and cars. These accidents are a reason why we compare the speed distributions of different motorcycle styles to the speed of cars. Excluding the group of sport motorcyclists from the analysis and comparing the differences in the speed distribution of the other two groups of motorcycles ($M = 66.7$, $Sd = 13.0$) and cars ($M = 66.9$, $Sd = 13.6$), no statistically significant difference was noted, not even in the standard deviation. This confirms that the main difference in the speed distribution between motorcycles and cars is in the range of extreme speeding and speeds close to extreme speeding.

The difference in speed between day and night conditions is a consequence of a higher percentage of extreme speeding during the night-time. This can be interpreted with the assumption that the significantly lower intensity of traffic during night provides a greater opportunity for excess speed. Additionally, we assume the self-control of a specific group of drivers weakens during the night (i.e., they are more likely to embark on driving at extreme speeds), which needs to be examined separately.

The results showed a statistically significant difference between the speed of motorcycles that have registration plates ($M = 66.8$) and motorcyclists who do not display registration plates ($M = 85.7$). This difference is significantly more apparent within the group of sport motorcycles drivers; whereas, in other styles, statistical significance was not determined.

Based on the differences in speed distribution, a relationship is noted between the speed of and the use of the registration plates on motorcycles. Drivers who drove at extreme speeds had the lowest percentage of displayed registration plates, notably in the group of sport motorcycles. The obtained results represent a confirmation of the research by Antov et al. (2010), which showed that the highest percentage of written tickets for speed (28.7%) was recorded for sport motorcycles. This value was significantly higher than for other styles and associated with the motive of enjoying fast driving. On this basis, the motive for hiding registration plates is assumed to be to intentionally avoid a ticket.

5. Conclusions

Speed is a significant risk factor for motorcyclists. The small number of studies that included the more detailed categorization of motorcycles and the lack of clear guidelines when grouping different categories of motorcycles created the need for researching the differences in the distribution of speed among motorcycles and cars (mode of transport) and differences in the distribution of speed between six styles of motorcycles. We have recognized the group of sport style motorcycles as the group with the most significant effect on the difference in the distributions of speed between modes of transport. With the exclusion of the sport style motorcycles, no significant difference between the distribution of speed of motorcycles and cars was noted.

The use of registration plates has been recognized as another important indicator of risk. We concluded that a significant relationship exists between the speed and the use of registration plates on the motorcycles. Because drivers of sport motorcycles have the lowest percentage of displayed registration plates, they actually represent the highest risk group. Removal or hiding of the registration plates can be explained as an attempt to avoid a penalty. Defining the indicator as a measure of traffic safety could be important in the prevention of risky behavior.

A more detailed categorization of motorcycles by style when researching speeding is desirable. However, by using the proposed division of the three groups, the common problem of "generalizing" motorcycles is avoided. Additionally, significant information about extreme speeding is given, although only three categories are formed.

The theoretical contribution of this paper is that two characteristics have been recognized as important indicators of traffic safety. These indicators are whether a motorcycle belongs to the group of sport style or not and whether a motorcycle has a properly mounted registration plate or not. Both of these characteristics are tightly correlated with speeding and extreme speed violations. These characteristics and the grouping of motorcycles by styles proposed in this paper should be incorporated in the planning of all future studies in the domain of traffic safety and notably for the safety of motorcycle drivers.

The practical benefits from this research might be the special attention of police and law enforcement to drivers of motorcycles with the mentioned characteristics that indicate potentially unsafe behavior. Media campaigns for traffic safety that target these drivers might produce better results than those targeting all motorcycle drivers. Additionally, specialized training for drivers of sport motorcycles and enforcement to pass such trainings can decrease the potential risk of improper speeding.

Further research is necessary to determine the precise relationship between the speed, motorcycle style, and motives of risky behavior and the effects of other significant characteristics (experience, training, socio-demographic characteristics, lifestyle, etc.). The method should include direct measurements of the speed on different types of road networks along with interviews of drivers.

Appendix A.

Classification of motorcycles by style, adopted on the basis of the European Commission, SARTRE 4.

Table 4
Descriptive criteria for the classification of motorcycles by style (Teoh and Campell, 2010).

Categorization of motorcycles/Code	Image
Scooter style SC Specific technical and operational characteristics, which usually includes smaller wheels and a specific position of the legs of the driver and passengers. Engine capacity of 50 cm^3 to over 850 cm^3. It is intended primarily for urban areas.	
Conventional style CO Designed for urban environments and is characterized by good handling, stability, mirrors, etc. Suitable for the upright posture of the driver, economy, etc.	
Sport style SP Technical and operational characteristics adapted for achieving maximum (sport) performance–racing and driving; notable for its relative strength, capacity and torque. Typical driver seating positions, the body bowed forward, are not suitable for longer trips.	
Touring style TR Characterized by comfort when driving (comfortable seating position of the driver and passengers, luggage space, reliability, etc.). Suitable for longer trips. Outline often higher than other styles. The capacities of these motorcycles are rarely below 1000 cm^3.	
Enduro style EN Technical and operational characteristics adapted to the stability, maneuverability, visibility, etc. Often used on unpaved terrain (off-road).	
Chopper style CHO Distinctive design, often with extended front forks, specific frame and parts. Position of the driver's hand and seating position significantly different than other styles of motorcycles. Most frequently modified style.	

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