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Critical factors in fatal collisions of adult cyclists with automobiles

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ABSTRACT

This article evaluates, by means of multivariate regression, critical factors influencing the collisions of motor vehicles with adult (over 17 years) cyclists that result in fatal injury of cyclists. The analysis is based on the database of the Traffic Police of Czech Republic from the time period 1995–2007. The results suggest that the most consequential categories of factors under study are: inappropriate driving speed of automobile; the head-on crash; and night-time traffic in places without streetlights. The cyclists' faults are of most serious consequence on crossroads when cyclists deny the right of way. Males are more likely to suffer a fatal injury due to a collision with a car than females. The most vulnerable age group are cyclists above 65 years. A fatal injury of a cyclist is more often driver's fault than cyclist's (598 vs. 370).

In order to reduce the fatal risk, it is recommended to separate the road traffic of motor vehicles from bicyclists in critical road-sections; or, at least, to reduce speed limits there.

1. Introduction

Collisions of cyclists with motor vehicles (MVs) can result in serious injury or even death of a cyclist. Based on data-analysis of collision forms as drawn up by the Traffic Police of Czech Republic, this study aims at identifying critical factors and their categories, under which the death of cyclists due to a motor-vehicle collision is most frequent.

A collision of a MV with a cyclist can have many different causes, including a car driver not detecting a cyclist. Räsänen and Summala (1998) claim that only 11% of car drivers that had hit a cyclist on a crossroads said that they had actually seen the cyclist. The validity of this statement might be questioned because the testimony of drivers after collision may be consciously slanted by drivers' speculation on the imminent penalty. Even with that proviso, the percentage given above seems to be very low.

Not detecting of a cyclist by a car driver can occur also at night-time. Conspicuity of a cyclist can be enhanced not only by mandatory lighting but also by type of dress and appropriate accessories to both dress and bike (Hagel et al., 2007; Kwan and Mapstone, 2004). In a survey, Thornley et al. (2008) found that the collision number was significantly lower with cyclists who wore fluorescent clothing, which probably meant their being spotted earlier by car drivers.

High speed of a MV is quoted as a highly prominent factor in fatalities (Stone and Broughton, 2003). According to Kim et al. (2007), it is the high speed of a MV that plays the role of the principal factor bearing on the seriousness of cyclist's injury in a motor-vehicle collision. If the speed exceeds 80 km/h, the death rate increases 16 times in comparison to the speed of 32 km/h. In towns the traffic tends to be denser and there is usually less space available than outside of towns. McCarthy and Gilbert (1996) studied fatal injuries of cyclists in London and its surroundings. They identified lorries as the main risk factor for cyclists in urban areas. Also, more cyclists commute within a town than between towns, as the bicycle is more often used for commuting at shorter distances (Vandenbulcke et al., 2009). Therefore, attention should be paid to speed limits in those areas where MV's are present along with cyclists and where there is less space. Kim et al. (2007) specified the speed of 32 km/h as maximum for automobiles in residential areas where, in addition, more bicycling children can be expected.

Besides the width of a roadway and the density of traffic in the opposite direction, the movement of a motor-vehicle overtaking a cyclist is also influenced by the way how the driver perceives a cyclist. Walker (2007) measured these distances pertaining to overtaking a cyclist. Evidence showed that buses and heavy goods vehicles leave the cyclist with the minimum side space.

Räsänen and Summala (1998) also claim that there exists a large proportion of cyclists (68%) who saw the approaching car but assumed it would respect their right of way. Cyclists obviously underestimated the fact that the car driver did not see them. In this case it should also be taken into consideration that it is more difficult for the slower cyclist to estimate the speed of an incoming MV and the time it takes it to reach the crossroads.

For the sake of cyclists' protection, each society should try to identify all the critical factors that lead to serious consequences

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of collisions under regular traffic, and to concentrate primarily on their reduction. Regarding safety of cyclists, the situation in the Czech Republic (CZ) has been gradually improving. Since the mid 90s there is an increase, particularly in urban areas, in cycling paths constructed as separate from roadways for MVs, whereby the risk of collision with a MV is reduced. However, this is not true on crossroads between two sections of a cycling path where a collision with a MV can occur, especially if a car driver, going on a roadway parallel to a cyclist, turns right on a crossroads (CZ stipulates traffic on the right) and intersects the direction of a cyclist.

Outside of settlements the cyclists can ride along with MVs only on roadways of a lower class (1st to 3rd class), with the speed limit normally set at 90 km/h. There are many narrow sections on roadways, especially the 3rd class ones. For example, the minimum width of a 3rd class roadway is defined as 5.5 m, which may cause problems in overtaking a cyclist. In this article we focused on identification of critical factors (i.e. concomitant circumstances), the occurrence of which leads to the most serious consequences of traffic accidents for cyclists in Czech Republic.

2. Data and methods

2.1. Data

The source data for critical factor analysis was the database of the Traffic Police of Czech Republic for the time period 1995–2007 that includes cyclist accidents that took place on roadways and that were reported to the Police. As is true of all police databases of traffic accidents, neither this one is complete. Indeed, the majority of cyclist accidents do not result in serious injury, and often there is not even damage to property. This is true in particular with falls from a bicycle (Aultman-Hall and Kaltenecker, 1999), but can also hold for bicycle vs. motor-vehicle collisions at low speeds. These accidents are very likely not to appear in police records (e.g. Meuleners et al., 2007; Veisten et al., 2007).

Therefore, we have selected only such consequences that are highly probable to be recorded because they call for hospitalization of a cyclist. A fatal injury on a public roadway is very likely to be recorded by the Police. A complete record of all accidents, even just the fatal ones, is nevertheless unlikely (Elvik and Mysen, 1999).

The total number (65,804) of all traffic accidents of cyclists in 1995–2007 includes 1520 (2.3%) fatal accidents, and 8011 (12.3%) accidents that ended up with serious injury of a cyclist. In view of the orientation of this study, i.e. critical factors of MV vs. adult cyclist collisions, those records were removed from the original dataset of fatal and serious injuries that did not pertain to the task, i.e. juvenile accidents and accidents other than a motor-vehicle collision.

Children and teenagers behave differently on the roads (Lajunen and Räsänen, 2001), they are usually less experienced. Contrary to adults, they spend more time leisure-cycling, and less time commuting (Hansen et al., 2005). For this reason we concentrated on adult cyclists only, as these can moreover be expected to know the traffic rules, contrary to children. Accidents of children and young cyclist under 18 years of age accounted for 105 deaths and 1308 serious injuries.

Excluded were also any other causes of adult cyclist accidents that did not include a collision with a MV (a fall, a crash with a solid barrier, with an animal etc.), which totaled 443 deaths and 2199 serious injuries.

The police protocol on a traffic accident classifies causes of accidents into these main groups: inappropriate speed, faulty overtaking, denying the right of way, and faulty driving style.

Table 1
Consequences of a cyclist/MV collision vs. at-fault party.

At-fault	Fatality		Severe injury		Total
	n	%	*n*	%	
Car driver	598	62	2510	56	3108
Cyclist	370	38	1950	44	2320
Total	968	100	4460	100	5428

2.2. Methods

The attempts to evaluate significance of various types of accident and consequence meet with the problem of determining the number of cyclists on the roads and frequency of their riding according to sex and age. The knowledge, or at least the estimate, of these values makes it possible to calculate the “exposition” (e.g. Rodgers, 1995). As the pertinent data are missing, we are not able to do this directly. A possibility how to express relative importance of individual factors indirectly, is the ratio of fatal to serious injury (FI/SI) (Stone and Broughton, 2003). For each category of each factor it is thus possible to calculate the proportion of all accidents under study that are fatal.

The traffic accident dataset was analyzed by elementary descriptive statistics (sums and ratios) on the one hand, and by procedures to identify influential variables and categories on injury severity. The target variable was the consequence of cyclist vs. MV collision expressed as a dichotomous variable (1 = death, 0 = serious injury). A generalized linear model of logistic regression was used to describe the situation. Univariate models were employed to test significance of individual regression variables (factors), with significance level appropriately adjusted (lowered). These variables were then used to build the final model, which is multivariate and accounts for confounding effects. In this model odds ratios (with respect to a reference category) and 95% confidence intervals are calculated. Calculations were performed in R software (R, 2008).

3. Results

The dataset of fatal and serious injuries of adult cyclists resulting from a collision with a MV, contains 968 fatal accidents, which is 64% of all fatal accidents within the given period for all the cyclists. At the same time, this represents 69% of all fatal accidents of adult cyclists only. As far as serious injuries are concerned, these amount to 4460 cases (56% of all SI and 67% of all SI of adult cyclists).

Out of the total 5428 traffic accidents with the two types of consequence under study, 3108 accidents (57%) were car-driver’s fault, 2320 (43%) were cyclist’s fault.

The consequences of accidents (type of injury) depend on which of the participants is at fault. The mistake of a motor-vehicle driver leaves the cyclist much worse off than the cyclist’s own mistake (Table 1). The motor-vehicle drivers are 1.62-times as often at fault in fatal accidents than cyclists (598 vs. 370).

Table 2 shows the absolute numbers of consequences, odds ratios (OR) relative to the first (reference) category of a given factor, and 95% confidence intervals (CI).

The most fatal situation for a cyclist is obtained when a car driver is at fault and exceeds the speed limit (OR = 8.27; 95% CI 5.78–11.82). This single cause represents 41% (243 out of 598) deaths of a cyclist due to a car driver’s fault. This is followed by a faulty driving style of a car driver (OR = 4.52; 95% CI 3.21–6.35). On the other hand, the least fatal situation for cyclists is when they are not given the right of way. If a cyclist is at fault, the most fatal for him/her is denying the right of way to a car. This single cause

Table 2
Results of multivariate logistic regression. Absolute numbers of consequences, odds ratios (OR) relative to the first category of a given factor, and 95% confidence intervals (CI).

	Accidents	Fatal	OR	(95% CI)
Cause				
Car driver at fault and denying right of way	1072	59	1.00	
Car driver at fault and inappropriate speed	636	243	8.27	(5.78–11.82)
Car driver at fault and faulty overtaking	427	66	3.21	(2.15–4.82)
Car driver at fault and faulty driving style	973	230	4.52	(3.21–6.35)
Cyclist at fault and denying right of way	1323	232	3.28	(2.41–4.46)
Cyclist at fault and inappropriate speed	67	5	1.52	(0.57–3.99)
Cyclist at fault and faulty overtaking	63	9	3.29	(1.50–7.22)
Cyclist at fault and faulty driving style	867	124	2.55	(1.79–3.63)
Place geometry				
Straight road	2277	530	1.00	
Curved road	637	105	0.65	(0.51–0.84)
Intersection	2467	331	0.88	(0.73–1.07)
Roundabout	47	2	0.30	(0.07–1.26)
Crash direction				
Lateral	1326	168	1.00	
Head-on	1104	220	1.91	(1.51–2.43)
From side	1958	286	1.52	(1.21–1.90)
From behind	1040	294	1.56	(1.23–1.99)
Visibility				
Day-time good	3603	516	1.00	
Day-time bad	477	98	1.40	(1.08–1.80)
Night-time with streetlights	639	104	1.07	(0.83–1.37)
Night-time without streetlights	709	250	2.16	(1.75–2.67)
Gender				
Male	3752	771	1.00	
Female	1676	197	0.55	(0.46–0.66)
Age group				
18–24	527	73	1.00	
25–34	772	107	0.97	(0.70–1.37)
35–44	861	138	1.11	(0.80–1.53)
45–54	1131	196	1.32	(0.97–1.79)
55–64	951	194	1.87	(1.37–2.56)
>64	1186	260	2.22	(1.63–3.01)
Alcohol (at-fault party)				
No	4043	695	1.00	
Yes	607	112	0.88	(0.69–1.12)
Not tested	778	161	1.23	(1.00–1.51)

represents 63% (232 out of 370) deaths of a cyclist due to his/her own fault. Faulty overtaking has this same value of OR but due to larger standard error in estimated parameter the confidence limits are much broader (OR = 3.29; 95% CI 1.50–7.22).

In terms of roadway topology, the most fatal are, regardless of at-fault party, collisions in straight sections. As far as direction of impact is concerned, the most fatal is the head-on crash (OR = 1.91; 95% CI 1.51–2.43).

If a collision takes place after sunset (reduced visibility due to day-time) in places without streetlights, the consequences are the worst (OR = 2.16; 95% CI 1.75–2.67). The most benign consequences of a collision are at day-time under good visibility, when 66% of these two types of accident occur (3603 out of 5428) but only 53% of accidents with fatal consequence for a cyclist (516 out of 968).

Among injured cyclists, there were 3752 (69%) men and 1676 (31%) women. Men have higher ratio of fatal injuries (80%, 771 cases) than women (20%, 197 cases). Fatality rate is higher for men (the OR for women is 0.55; 95% CI 0.46–0.66). The most death-prone age group is older people above 65 years (OR = 2.22; 95% CI 1.63–3.01). This vulnerability increases with age.

As regards the alcohol status of at-fault party, the most fatal come out accidents with no test on alcohol (OR = 1.23; 95% CI 1.00–1.51). There is almost no difference between accidents with the presence of alcohol and those without. The values for alcohol present are OR = 0.88, 95% CI 0.69–1.12, the interval being rather broad.

4. Discussion

The results of multivariate regression identify critical factors of traffic accidents with the worst consequences for cyclists, and lend themselves to recommendation for both groups of participants to a collision, but also for the society at large and for transportation policy.

The consequences of accidents are more serious for males. This is in accordance with findings of others (e.g. Rodgers, 1995; Valent et al., 2002). It can be speculated that men drive less safely, more recklessly than women, and also, that car drivers perceive men as better cyclists than women, and therefore leave them less room on the road (e.g. Walker, 2007).

The most serious consequences occur with oldest cyclists. Higher fatality rate of old people-cyclists compared to other groups is mentioned also by Ekman et al. (2001) who found that in Sweden in 1967–1996 the ratio of senior-citizen fatalities after a traffic accident was 47% (out of a total of 1830 fatalities). The reason for higher fatality of senior citizens is probably an increased overall fragility of body, although e.g. Maring and Van Schagen (1990) claim the high risk for old people is due to changes in their cognitive and perceptual processes that make their reactions to imminent dangers less ready.

Car drivers cause almost twice as many fatal injuries to cyclists than cyclists do to themselves (598 vs. 370). This study identifies as the most fatal those situations when the car driver is speeding. The same conclusions are drawn elsewhere (e.g. Stone and Broughton, 2003; Kim et al., 2007). For this reason the society should, first and foremost, identify these locations and give the highest priority to complete separation of cycling traffic from motor traffic in these dangerous roadway sections by constructing parallel cycling paths. These recommendations that are given elsewhere (e.g. Konkin et al., 2006; Richter et al., 2007; Yeung et al., 2009) can lead to a marked decrease in cyclists fatalities. Although the existence of a cycling path need not necessarily mean the lower total number of cycling accidents (e.g. Aultman-Hall and Kaltenecker, 1999), the probability of a collision with a car is very low. A cheaper solution than cycling path construction may be to impose lower speed limits on MVs in critical sections.

In terms of day-time and visibility, the most fatal are consequences of accidents that happen at night in places without streetlights. To enhance passive safety of cyclists at night-time we can recommend wearing reflective jackets, reflective elements, and powerful lights and tail-lights.

As regards the influence of alcohol on the outcome of traffic accident, these results must be seen within the context of the dataset from which they were derived. This dataset does not include falls from bicycle where the presence of alcohol would probably show itself more markedly, which is what other studies imply where the influence of alcohol was assessed and falls included (e.g. Andersson and Bunketorp, 2002). Also Olkkonen and Honkanen (1990) claim that drunk-cyclists more frequently suffer a fall from a bike than a crash with a MV. Therefore, it can be suspected that drunk-cyclists ride more slowly than sober cyclists and if they hit a car, this happens at a lower speed, which makes the consequences generally less fatal.

The present analysis has its limitations in the quality of data. It should be remembered that the fatality values presented here reflect only those accidents that ended up in death or serious injury of a cyclist and were recorded by the Police. They are not to be understood as a probable outcome of every cyclist vs. MV collision. However, they do have explanatory value in relative comparisons of factors.

In the next research step, efforts will need to be made to interconnect the police traffic accident database with medical data which would make possible to identify a given accident in both databases and match the exact type of serious injury or cause of death. At present, this is not possible.

5. Conclusion

Critical factors of collisions between motor vehicles and cyclists were evaluated that occur under regular traffic on roadways in CZ. To insure maximum homogeneity of the input dataset, only adult cyclists were selected for identification of critical factors from the original accident data. The adult cyclist dataset contained 5428 entries (968 fatal and 4460 serious cyclist injuries).

The results suggest that mistakes of car drivers have the worst consequences for cyclists on straight sections. Speeding, particularly on straight sections, was the most fatal single factor. Construction of cycling paths in places with frequent severe accidents or along the narrow roads can reduce the proportion of fatal injuries. Complete separation of cycling traffic from automobiles on a large scale is not feasible. Although more kilometers of cycling paths in CZ are added every year, their total length between settlements makes up but a fraction of the length of roadways. Many cyclists in CZ are thus forced to use inappropriately narrow roadways with the speed limit of 90 km/h. It is at least possible to reduce the speed limit for cars in these sections.

If cyclists are at fault, the most frequent among severe accidents are collisions on crossroads when the cyclists deny the right of way to a car. These collisions tend to be of most serious consequence for the cyclist.

The age group at highest risk is the group of old people who suffer, to a much larger extent than young ones, from ostheoporosis, atherosclerosis, or muscular degeneration, which can lead to both greater general fragility of body and decreased reactivity.

The above results should be considered with regard to the quality and size of input data. As was mentioned earlier and also elsewhere in literature (e.g. Veisten et al., 2007), the statewide police data, by their nature, cannot be complete. What is missing are, first of all, light injuries of cyclists, and also accidents without serious damage to vehicle. Moreover, police records do not cover those severe consequences that do not occur on roadways. The conclusions are thus valid for this group of 5428 injured cyclists who were in the given period participants to a traffic accident – a collision with a motor vehicle.

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