

# Analysis of the Overtaking Behaviour of Motor Vehicle Drivers

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**Abstract:** Overtaking is considered to be a hazardous subtask. Possible solutions to make overtaking manoeuvres safer are overtaking lanes and intelligent systems in the vehicles that can assist drivers with the overtaking manoeuvre. To be able to design or develop these solutions, accurate overtaking manoeuvre data are required. These data are also useful for the development of traffic micro simulation models that include many assumptions to model overtaking manoeuvres. The task of this article is collecting all information about the overtaking process to prevent overtaking accidents and to reduce the collision risk of overtaking – as an important key to the reduction of head-on collisions. This study aims at acquiring qualitative empirical insights into overtaking behaviour on two-lane rural roads. To this end, an observation study with an instrumented vehicle is carried out.

*Keywords:* driver's behaviour, overtaking, speed, speeding

## 1. The overtaking problem

Overtaking is considered to be a hazardous subtask: transportation experts estimate that lane change crashes, including overtaking and merging, account for 4 to 10% of all crashes [1, 2].

Heterogeneous speed among vehicles leads logically to more overtaking and a higher accident rate. Overtaking itself is a risk factor, and other safety risks also result from speed variations. Speed dispersion is strongly related to fatality rates, in particular on interstate highways, rural roads and urban arterial roads. Overtaking is particularly difficult and dangerous on two-lane rural roads, with oncoming traffic and relatively high speeds.

Possible solutions to make overtaking manoeuvres safer are overtaking lanes and intelligent systems in the vehicles that can assist drivers with the overtaking manoeuvre. To be able to design or develop these solutions, accurate overtaking manoeuvre data are required. These data are also useful for the development of traffic micro simulation models that include many assumptions to model overtaking manoeuvres. The base of this article is the measurements of the Institute for Transport Sciences. [3]

## 2. The most important parameters of the overtaking manoeuvre

Using the instruments of the measuring car, it was possible to make video-recordings on the vehicles moving behind and before it, as well as to measure the speed of the measuring car ( $V_m$ ) and the overtaking car ( $V_e$ ), the distance between the two vehicles ( $s_1, s_2$ ), the length of the road travelled by the measuring car ( $s$ ), and that of the time of overtaking ( $t$ ), respectively. It was also possible to record the behaviour of the overtaking car's driver before overtaking, as well as when the manoeuvre started. The driver's head-motions, gestures, mimics, the vehicle spacing and the changes of its lateral movements could be observed. The diagram of the measurement and parameters taken are shown in Figure 1.

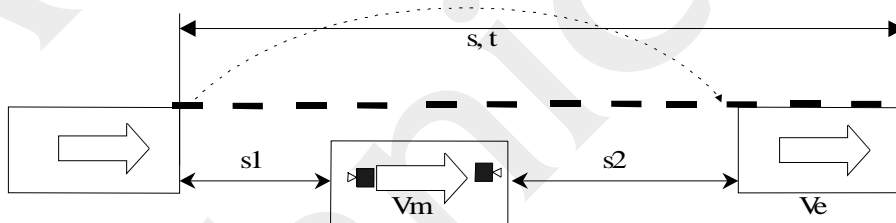


Figure 1 Diagram of the measurement and parameters

As an example, a complete overtaking process is presented. In Figure 2 it can be seen in the rear view mirror that the passenger car, preparing for overtaking just crosses the median line. Figure 3 shows the moment when the overtaking is ended and the passenger car gets back to the right side of the road. As against the speed limit, the 110 km/h value measured at the end of overtaking is rated as significant speed exceeding. The cause of speeding can be seen in Figure 3: the oncoming vehicle drove already aside to the edge of the road in order to avoid frontal collision.



Figure 2 The passenger car is preparing for overtaking



Figure 3 The overtaking is ended

Overtaking was considered as completed when the overtaking vehicle's left rear wheel crossed the median line and the vehicle moved back to the right lane pursuant to traffic direction. During the evaluation process, the data of 230 overtaking cases have been elaborated. These cases were divided into 2 parts: **one vehicle** (accelerating and continuous) and **multi-vehicle overtaking**,

Table 1 Main characteristics of accelerating and continuous overtakings

	Mode of overtaking	Average	Standard deviation	Lowest value	Highest value	Signif. level
$s_1$ - vehicle spacing when the overtaking starts (m)	Accelerating	12.3	4.7	5.0	28.0	p<0.01
	Continuous	27.7	8.3	17.0	64.0	
s - length of overtaking (m)	Accelerating	200.6	59.3	80.7	369.7	Not signif.
	Continuous	214.3	44.7	122.7	323.7	
t - duration of overtaking (sec)	Accelerating	8.5	2.7	4.0	17.0	Not signif.
	Continuous	7.9	2.0	4.0	15.0	
	Continuous	99.7	12.5	71.9	124.3	
$V_m$ - the overtaken vehicle's average speed (km/h)	Accelerating	70.8	10.0	41.8	90.0	Not signif.
	Continuous	73.4	9.0	51.8	101.8	
speed difference (km/h)	Accelerating	15.4	5.6	5.2	37.5	p<0.01
	Continuous	26.4	9.3	9.8	54.9	
$V_e$ - the overtaking car's speed at the end of overtaking (km/h)	Accelerating	86.8	11.8	63.0	119.0	p<0.01
	Continuous	96.3	14.6	63.0	128.0	
$s_2$ - distance of moving back to the lane (m)	Accelerating	16.8	6.9	4.0	43.0	p<0.01
	Continuous	21.8	9.1	10	48.0	

### 3. Characteristics of accelerating and continuous one-vehicle overtaking

The one vehicle overtaking is the basic case of overtaking, when the overtaking distance and the time of overtaking are mainly determined by the value of the speed difference between the vehicle which is overtaking and the vehicle overtaken. From 230 cases, 127 (55%) overtakings have been of accelerating type. Overtaking is of the accelerating type if the vehicle moving faster pulls up to the vehicle to be overtaken, takes up its speed then as the possibility arises starts speeding. The number of continuous overtakings was 46 (20%). In continuous overtaking, the vehicle moving faster pulls up to the vehicle to be overtaken, does not slow down to its speed but without significant changing of the speed starts overtaking. Table 1 contains the main characteristics of **accelerating and continuous overtakings**.

In continuous overtaking the average speed of the overtaking vehicle is significantly higher than in accelerating overtaking. In accelerating overtaking and in continuous overtaking the average difference between the average speed of the vehicle that is overtaking and of the vehicle to be overtaken is 15.4 km/h and 26.4 km/h, respectively. This difference is significant.

#### 3.1. Vehicle spacing when the overtaking starts

In case of accelerating overtaking, the driver preparing for the operation is approaching in a certain distance to the vehicle to be overtaken and takes up its speed. Such a vehicle spacing should be chosen which shortens the length of the overtaking road section, but makes possible the avoidance of rear-end collision if a powerful braking occurs.

The length of the spacing is not dependent on the overtaking vehicle's category. According to vehicle categories the average value of the spacing was as follows: 12.1 m for passenger cars, 13.6 m for light commercial vehicles, 10.0 m for lorries, 12.6 m for trucks with trailers. The difference is not significant. Spacing is not influenced considerably by the speed of the vehicle to be overtaken, either. When the measuring car (the vehicle to be overtaken) moved at 70 km/h, passenger car drivers kept a 12.0 m average spacing, which practically did not change, it was 11.9 m at 80 km/h speed.

Before overtaking is started, the value of spacing is changing between rather rigid, narrow limits that hardly comply with the speed and the vehicle's running characteristics. The higher the speed of the vehicle to be overtaken, the more probable that the spacing prior to overtaking is shorter than the safety would call for.

#### 3.2. Length of one overtaking

The average of the whole road length of overtaking (Figure 4) is longer in continuous overtaking, however the difference is not significant (due to the high dispersion values).

Consequently, it is characteristic for continuous overtakings that the overtaking vehicle approaches the vehicle that is to be overtaken with a relatively high speed. The driver does not want to reduce the speed to the level of the vehicle to be overtaken, therefore at a relatively high distance has to pull out from behind the vehicle that is to be overtaken and must start getting to the left side of the traffic direction. Because of the high approaching speed the driver has to decide promptly whether the conditions of overtaking are given. Given a mistaken decision, correction is hardly possible, because,

due to high speed it is dangerous to interrupt the process of overtaking and to get back behind the vehicle to be overtaken.

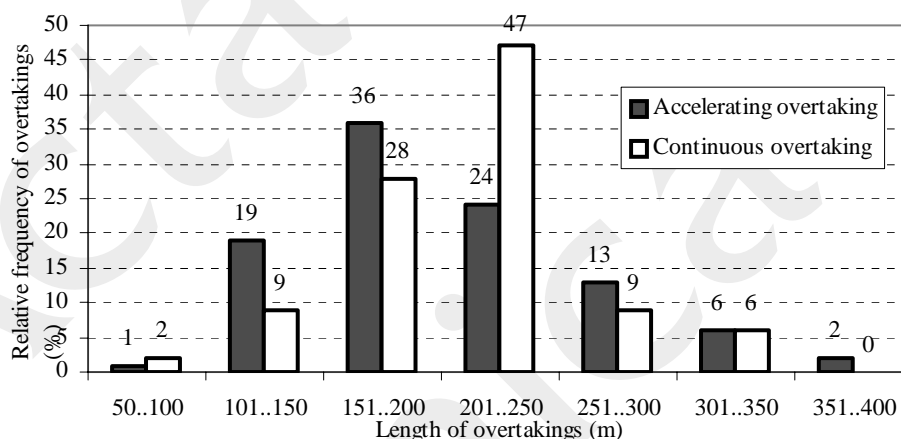


Figure 4 Length of one vehicle overtakings

Overtaking takes place at high speed, the difference of the average speed between the vehicle that is overtaking and the vehicle to be overtaken is essentially higher than in case of accelerating overtaking. As a consequence, the overtaking ought to end within a shorter period than in case of accelerating overtaking. However, in respect of the overtaking time there is no significant difference between the accelerating and continuous overtaking. The reason for this is that the total length of the overtaking road section is also significantly longer in case of continuous overtaking. As the spacing of the vehicle and its distance of getting back to lane become longer, the total length of the overtaking section will also be longer. Due to the high overtaking speed, a sweeping round is necessary for getting back, as a result of which the distance of returning to the lane increases.

### 3.3. Length of overtaking time

The average time of overtaking was 8.5 sec for overtaking with acceleration, and 7.9 sec for continuous overtaking. There is no significant difference between the duration of the accelerating and the continuous overtaking either, the average is 8.3 sec. for both of them.

The test results of Farber have shown that the average of the overtaking time is 8.0 sec that in critical cases may decrease to 5-6 sec. According to Grobe and Stollz the average overtaking time is 7.2 sec. [4]

### 3.4. Speed difference among vehicles

The value of the speed difference between the  $V_e$  and  $V_m$  the vehicle overtaken presents important negative correlation with the total length of the section of overtaking and its duration. There is positive correlation with the vehicle's average speed and its distance of getting back to lane. For overtaking with acceleration, 15.4 km/h is the

average of the speed difference that is essentially higher for continuous overtaking: 26.4 km/h.

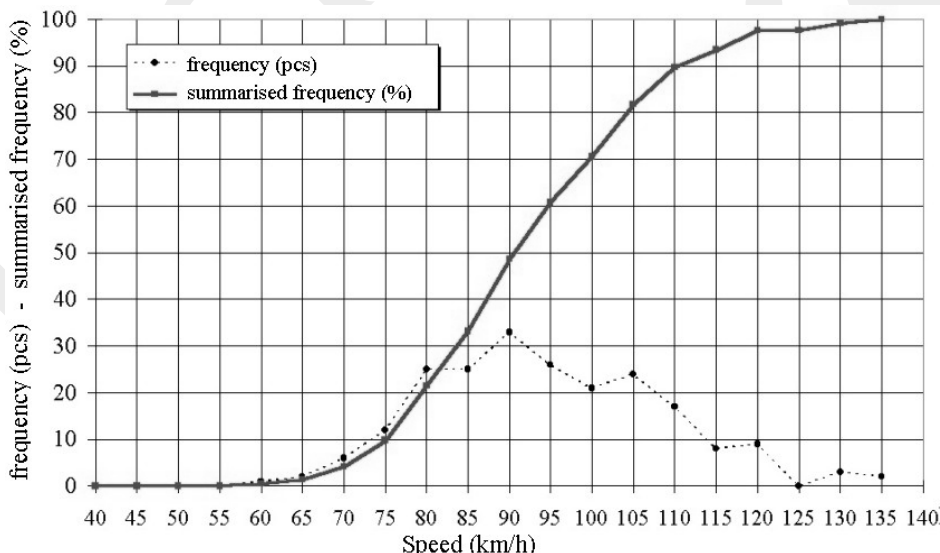
In case of overtaking with acceleration the difference of speed is influenced by the category of the overtaking vehicle. The speed difference was the greatest when overtaking was implemented by a passenger car (16.2 km/h). When a light commercial vehicle was the overtaking vehicle, the average speed difference was 13.2 km/h; while for the category of lorries and heavy trucks it was 11,9 km/h and only 9.9 km/h, respectively.

The minimum value of the speed difference for the overtakings with acceleration and the continuous ones were 5.2 km/h and 9.8 km/h, respectively. According to Prisk in average the speed difference is equal to 16 km/h; overtaking at a difference of 8 km/h is already very rare. [4]

The minimum values in respect of the distance and time of overtakings can be seen at 22 km/h for overtakings with acceleration and at 41 km/h for continuous overtakings. Therefore a differentiation of 22 km/h would be practical between the speeds of overtaking and overtaken vehicles at the end of manoeuvre.

**3.5. The overtaking vehicle’s speed at the end of the manoeuvre**

80% of the overtaking vehicles exceeds speed limitation (it was 80 km/h generally) when overtaking is finished (Figure 5). It should be necessary to make the drivers understand that if the speed limit is exceeded in the course of overtaking that is also considered speeding.



(speed data classified into categories with 5 km/h difference, the value indicated on x is the upper limit of the categories)

Figure 5 The frequency and summarised frequency of the overtaking vehicle's speed at the end of overtaking, outside built-up area

### 3.6. The distance of moving back to lane

This distance indicates how far is the measuring car at the end of overtaking from the overtaking vehicle. The distance of getting back to lane is longer for accelerating overtaking and shorter for continuous overtaking than the vehicle spacing measured at the moment when overtaking starts.

Ending of overtaking may be constrained, when the proximity of the oncoming vehicle forces the overtaking driver to move to the right side of the road as soon as possible. It has been studied how the distance of getting back to lane changes in function of the safety interval (that period is called safety interval which starts at the moment of the overtaking vehicle is getting back to lane and ends at the moment when the overtaking vehicle meets the oncoming one). The ending of overtaking has been considered as constrained if the safety interval did not exceed 1 second.

From the accelerating overtakings and the continuous overtakings there were 10 (8.5%) and 5 (10.7%) cases, respectively, when the safety interval did not exceed 1 second. The average distance of the moving in to lane was slightly shorter for constrained overtakings, nevertheless neither for accelerating nor for continuous overtaking is this difference significant.

It is surprising that no remarkable speed reduction is experienced from drivers' part even if the oncoming traffic is very near. There is no significant correlation between the safety interval and the distance of getting back to lane. The research carried out by Draskóczy and Ruppert resulted in the same findings. They pointed out that "given the road's appropriate width, drivers are rather more inclined to force the oncoming vehicle's pulling to the edge of the road than to approach as near as possible the  $V_e$ ". [4]

### 3.7. Comparison of "free" and "following" overtakings

Both among the overtakings with acceleration and the continuous ones are likely to occur the "free" and the "following" types of overtaking. An overtaking is called free, when before the vehicle that is overtaking – on the left side of the road – no other vehicle is moving, nothing obstructs its progress. Following overtaking means that before the vehicle that has started to overtake, another vehicle – which is also overtaking – is moving. The second vehicle already started overtaking when the vehicle moving before it did not get back yet to the right side of the road.

In case of overtakings with acceleration, considering the main characteristics of the free and the following overtakings, significant difference was only noticed in respect of the length of vehicle spacing at the moment of overtaking. The following can be the explanation for this difference: as soon as the driver perceives that the vehicle moving ahead is preparing for overtaking, starts getting to the left side of the road and tries not to fall behind. The driver of the second vehicle doesn't draw near to the vehicle to be overtaken, but endeavours to follow closely the vehicle moving ahead, which has started the manoeuvre of overtaking.

Surveying the continuous overtakings we experienced that in case of the following overtakings the difference in the speed of the overtaking vehicle and the vehicle to be overtaken is significantly lower, and the current vehicle speed at the end of the

manoeuvre is essentially lower than at free overtakings. These data imply that the other vehicle moving ahead was impeding that vehicle's progress, which was involved in the following overtaking and forced it to decrease its speed.

The vehicle moving ahead usually started overtaking in the accelerating mode and then the one using the continuous overtaking mode pulled up to it. If the driver of the vehicle in continuous overtaking mode neglects the possibility that he may be forced to braking by the vehicle moving ahead of him, since both the distance and the time of overtaking will increase, he may become endangered.

#### **4. Multiple overtakings**

In case of multi-vehicle overtaking, the complete overtaking distance and the overtaking time depend mainly on the number of the vehicles that have to be overtaken and their length.

In 57 occasions (25% of all overtakings) the overtaking vehicle passed more than one vehicle, before moving back to the right side traffic lane. In this mode of overtaking the involvement rate of passenger cars is the highest (89.5%) among the overtaking vehicles. The average length of the whole overtaking distance was 335.5 m, the duration of the average overtaking time was 13.5 sec. The longest being 556 m - in this latter case the passenger car overtook 4 vehicles: 2 passenger cars, 1 heavy duty and 1 light duty commercial vehicle.

In case of multiple overtaking, the driver involved is highly motivated to pass each vehicle moving ahead, before he gets back to the right side of the road. By the end of overtaking the driver usually picks up a considerable speed value. The average speed of the vehicles that were overtaking was 97.0 km/h and the average value measured at the end of the manoeuvre was 99.4 km/h. The rate of the occurrence (8.7%) of those cases when at the end of the manoeuvre moved back to the right side of the traffic direction crossing the continuous white line was the highest in this mode of overtaking.

#### **5. Monitoring the attitude of the vehicle driver preparing for overtaking**

In the so-called "decision period" the vehicle driver preparing for overtaking:

- tries to gather information about the distance and speed of the oncoming vehicle; assumes a characteristic,
- slightly inclined to the left carriage of the head,
- trying to look far by the ahead moving vehicle's side.

Majority of drivers do not watch continuously the oncoming traffic, but sometimes they are taking "samples". In such a case they move close to the median line (especially in a right curve when visibility is even more obstructed). It happens very rarely in the course of measurements that in the period of the decision the vehicle's left side wheels touch or cross the median. If the driver has seen that the oncoming vehicle was approaching, withdraw from the median and somewhat increased his/her spacing. As soon as the traffic passed he/she again reduced the spacing and tried to collect further information about the distance and the speed of the oncoming vehicle.

In the decision phase the drivers' head-motions are inexpressive, they are looking straight ahead, sometimes using the left side mirror. We noticed one case only when the driver before starting the overtaking manoeuvre with his head-motions also controlled whether the vehicle behind him did not start overtaking.

We had not experienced that in the decision phase the driver would have been strongly involved in some conversation with his passengers. There was no occasion that before the manoeuvre the driver would get involved in some conversation on hand-held mobile phone.

Though the measuring car was moving with the maximum allowed speed, outside built-up area most passenger car drivers tried to overtake it. This also shows that outside built-up areas the speed limit is not really respected by passenger car drivers. It seems that speed exceeding in the course of overtaking is considered as fully acceptable by most drivers, despite of the fact that the Highway Code does not permit it.

However it is favourable that inside built-up areas the 50 km/h speed limit was usually respected. No overtaking was initiated not even when the measuring car's speed decreased to 30-40 km/h. But the disposition for overtaking increased as soon as the built-up area has been left. The most frequent offence was that the vehicle driver did not respect the continuous line and crossed it while overtaking if the other conditions of the manoeuvre existed.

It happened in two occasions that the driver of a light duty vehicle in the intersection moved to the left turning lane then proceeded straight ahead, while overtaking one or more vehicles. No miscarried overtaking was registered, but dangerous overtakings were.

## 6. Conclusions

In case of continuous overtakings there is a significantly higher difference in the average speed of the vehicles than in the overtaking with acceleration. At the same time with respect to the overtaking time the accelerating and the continuous overtakings do not differ significantly because the whole overtaking distance is also essentially longer for continuous overtaking.

In overtakings with acceleration and in continuous overtakings the rate of the dangerous cases was 2.4% and 6.1%, respectively. (Overtaking with a safety interval under 1 sec was considered as dangerous.) It means continuous overtaking is much more dangerous type of overtaking, than overtaking with acceleration.

In overtaking with acceleration the value of the vehicle spacing measured at the starting moment of the overtaking is not dependent on the vehicle's category and the speed of the vehicle to be overtaken does not influence it significantly, either. The value of the vehicle spacing is rather rigid, changing between narrow limits which hardly complies with speed and the characters of the vehicle's running dynamics. The higher the speed of the vehicle to be overtaken, the more probable that pre-overtaking spacing is shorter than safety would require.

In case of accelerating overtakings such optimum of the speed difference (22 km/h) is provable that ensures the shortest overtaking time and road length. A speed difference

higher than the optimum already increases the vehicle spacing and the distance of moving back to lane (the whole overtaking road length because of which the overtaking time does not decrease any more already). This should be made known in road safety propaganda and drivers' training.

80% of the overtaking vehicles were exceeding the speed limit on rural roads when the operation has been finished. Vehicle drivers should be made aware of the fact that speed violation in the course of overtaking falls also into the category of speeding.

In drivers' training the main characteristics of accelerating, continuous and multiple overtaking should be explained. The risks of following overtaking should be described as well. Practice of continuous and multiple overtaking is not recommended for novice drivers.

Drivers do not decrease significantly the distance of moving back to lane not even if the safety interval is not longer than 1 sec. During drivers' training, attention of trainees should be drawn that given a dangerous situation decrease the distance of moving back to lane rather than run into the possible risk of a frontal collision. Frontal collision must be avoided by making use of all the possible means.

When approaching to the end of the built-up area, motivation for overtaking increases, the vehicles congested are already being taken over against prohibition; noticeably more overtakings are carried out in well visible left curves, in the direction of the downgrade, than on the sections where the perception of the oncoming traffic is obstructed. Data show that overtakings are performed in shorter time, on shorter length, in poorly visible curves.

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