# IMPORTANCE OF PROPER DETERMINATION OF VEHICLE DECELERATION FOR TRAFFIC ACCIDENT ANALYSIS

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## INTRODUCTION

Traffic accident experts are often faced with the problem related to precise definition of vehicle deceleration, which was involved in a car accident. Defining of deceleration, that the vehicle had at the time of traffic accident occurrence, enables accurate calculation of important parameters of the expertise of traffic accident, such as the speed of the vehicle at the time of driver's reaction, the speed at the beginning of the skid marks, the speed at the moment of impact, characteristic positions of accident participants in certain phases of the collision and determining the possibility of accident avoidance. On the other hand, there are situations where precise speed identification is crucial for accurate determination of the collision spot. The above parameters of traffic accident analysis are important for definition of omissions of accident participants, so it can be concluded that determination of the deceleration represents one of the most important elements for traffic accident expertise.

Reliability of the analysis of traffic accidents is proportional to the quality of the investigation documents and conducted investigations. In some cases, certain results are a comparative analysis injury, damage, marking, or statements of participants of a traffic accident. In some cases, the precise conclusions require a comparative analysis of the two elements (for example, damage or injury), but not rare situations to be only one of the above analysis (for example, on the basis of damage)can come to a conclusion or expect or confirm the occurrence of an accident in a certain way. The most common cases of this type are related to the determination of authenticity occurrence of traffic accidents.

In some cases of traffic accidents, based on the available documentation, it is possible to calculate the deceleration of the vehicle, and in some cases, so we can say that there are two possible directions of traffic accident analysis, depending on the available data. Therefore, an expert in the analysis of traffic accident, he must find the elements of the case file, which will enable him or determination, or more accurately calculate the deceleration of the vehicle.

For the analysis of traffic accidents, expert of traffic technical professions are obliged to apply the legal requirements regarding the safety of the braking system. Requirements braking system of vehicles can differ depending on the period of validity of the regulations. Thus, the Regulation of dimensions, total masses and axle loads of vehicles and the basic conditions that must be fulfil by devices and equipment on vehicles in traffic (herein after referred to as 'the old Regulations'), which was abolished by the 22.09.2010, the minimum value prescribed braking coefficient for passenger cars is 0.55. Applying the

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applicable Regulation of the division of motor vehicles and trailers, and technical requirements for vehicles in traffic (hereinafter 'the new Ordinance'), the minimum value prescribed braking coefficient for passenger cars is 0.50.

Another significant difference between the old and the new Regulations is that the difference braking force on the wheels of the same axle does not exceed 30%, under the new Regulations, or 20% under the old Regulation. The third significant difference in the brake system of passenger cars between old and new Regulations is related to the ratio of braking force the each axle and the braking coefficient. Under the old Regulations the value of brake force at each axle is at least 30% of the braking coefficient, and under the new Regulations such restrictions does not exist. To calculate the braking coefficient or percentile differences as a basis always use higher braking force. Differences in values of minimum correct braking systems old and new Regulations also exist for other categories of vehicles.

For correct brake system of a vehicle, the expert must verify the correctness of the operating brake and check the correctness of auxiliary brake. Condition to meet the auxiliary brake is that the braking coefficient auxiliary brake must not be less than 20%.

## DETERMINATION OF DECELERATION

Deceleration of the vehicle in the particular case at this particular place can achieve depends on two main factors, namely the deceleration provided by roadway (bk) and deceleration can achieve vehicle (ba). Deceleration of the vehicle (b) in a particular case is determined by the 'law of the minimum' b = min (bk, ba) or deceleration of the vehicle (b) is the minimum of deceleration that can provide vehicle and roadway.

Deceleration braking system of the vehicle can achieve (ba) can be determined by calculating the braking coefficient if available, of a diagram of brake force, or assessment, taking into account all the important elements. Regardless, did the deceleration of the braking system of vehicle could achieve calculated or estimated, an expert to determine the deceleration of the vehicle is able to achieve (b), must take into account several factors that influence the definition and assessment of deceleration, which are: road condition (new, worn, smooth, rough, dark, bright, ....), road surface material (asphalt, concrete, cube, earth, dirt road, ...), the road surface (dry, moist, wet snow, frozen, ...), weather conditions (at the time of the accident was raining, just started raining, snowing, windy, ...), or as exist marks of braking and possibly some indirect indication of the correctness of the brake system of the vehicle.

The first and certainly the easiest way of determining the deceleration to the vehicle after a traffic accident sent for emergency inspection, where the measured braking force, and then based on measured brake force calculation of the theoretical (maximum) value of deceleration that the vehicle could achieve. Then it checks to see if the vehicle is in the specific conditions at a given site could achieve the calculated deceleration and check the condition of the carriageway, pavement materials, road surface, weather conditions, the existence of exist marks and the like. And determines the deceleration of the vehicle is able to achieve. If the deceleration of the vehicle is able to achieve less than the deceleration provided by road, or if you are not leaving traces of braking, then the expert to analyze accidents using calculated deceleration. Please note that this is a theoretical value that is rarely achieved in real terms. In real driving conditions, the value of the deceleration is generally lower. Namely, the technical review, when measuring the brake force on the device with rollers, and due to the characteristics of these devices, there is no lock braking, in real driving conditions, if any exist marks, the wheels were blocked. Also, the coefficient of adhesion of road is often less than the coefficient of grip the rollers on a technical review.

If braking forces are not measured, i.e. if the expert does not have the possibility of calculating the braking coefficient and deceleration, an expert will assess vehicle deceleration is able to achieve, also bearing in mind that the slowing vehicles (b) define the basis deceleration realise the vehicle and the deceleration provided by roadway.

The expert will assess the benefits braking coefficient corresponding to the minimum of the correct braking system for a given category of vehicle, or to evaluate the braking coefficient depending on the brand and type of car, the age and condition of the braking system, etc. Regardless of the method estimates the deceleration of the braking system of the vehicle could have been achieved, an expert to determine the deceleration of the vehicle is able to achieve (b), must take into account these factors influence the definition and assessment of deceleration, as follows: the road condition, road materials, road surface, weather conditions, the existence of skid marks and the like.

If the expert estimate that at the time of a traffic accident braking system was at least technically correct, it will be an expert to use the value of the coefficient of brake service brakes which corresponds to a minimum of proper brake system for a given vehicle category (see table 1). If the expert assessment of the vehicle braking coefficient varies from a minimum of proper braking system for a given category of vehicle, adopt a lower or higher value of the braking coefficient values corresponding to the minimum of the correct braking system for a given category of vehicle. After considering the circumstances of overall expert will assess the deceleration taking into account all the circumstances are fulfilled or evaluate slowing based on several factors, but will be in the form of so-called again. law of the minimum. This method of deceleration in some cases it may be accurate enough, whereas the expert must take into account whether the slight differences in the assessed value of the deceleration affects the output of the analysis of traffic accidents, and the definition of failure of participants of a traffic accident.

*Table 1The minimum prescribed braking coefficients operating brake*

| | *Operating brakes* | *Auxiliary brakes* |
|---|---|---|
| *Motorcycle* | *40* | *20* |
| *Passenger vehicle* | *50* | *20* |
| *Buses* | *50* | *20* |
| *Trucks* | *45* | *20* |
| *Trailers* | *40* | - |
| *Other vehicles (tractors, machinery, ...)* | *25* | - |

We emphasize that in practice it can happen that the roadway does not occur skidmarks brake, where the vehicle is forced braked. This situation occurs when the deceleration roadway provides greater brake than that achieved deceleration braking system of the vehicle and the vehicle brake 'only' a deceleration of the vehicle can achieve and will not be skidmarks brake on the roadway. If the vehicle deceleration greater than the

deceleration provided by roadway, then the vehicle in that place brake provided the roadway and a rule will 'stay' skid marks brake on the roadway.

It is important to emphasize the frequent situation encountered in real driving conditions, and the forced braking, when a decline in performance achieved braking or retarding a decline in the vehicle, which must be taken into account under the right conditions. Namely, if the length of the skid marks brake 20 m to 30 m and if the vehicle speed at the beginning of skid marks greater than 60 km/h, a decline decelerating from 10%. If the skid marks brake longer than 30 m and if the vehicle speed at the beginning of the skid marks braking in excess of 60 km/h there is a decline deceleration of 15%. Example: If the vehicle deceleration is 5.4 $m/s^2$, and there by the speed of the vehicle at the beginning of the skid marks brake 80 km/h and the length of skid marks brake is 25 m, the further calculation leads to a deceleration of $5.4 \cdot 0.9 = 4.86$ $m/s^2$.

## EXAMPLE OF DETERMINING ACCIDENT

This paper presents three examples of analysis of traffic accidents, with special emphasis on the definition of deceleration and impact deceleration to determine the failure of the participants of an accident.

The first example shows how the lack of data on the weight of the vehicle (which is a person who performs inspection was required to state, as is obtained by reading from the vehicle registration card or by measuring the vehicle), the exercise of extraordinary technical inspection and measurement of brake force leaves open the question of the failure participants in traffic accidents. Namely, with respect to the mass of the same brand and type of the vehicle may vary, and more than 500 kg, depending on the types of vehicles and engines, and that the maximum value of the coefficient of the brake, and therefore the maximum speed of the vehicle to brake the traces may vary, and more than 30 km/h. Depending on the use of the vehicle weight, will depend on the value of the calculated velocity to skid marks braking, and therefore the possible gaps participant accident, because failures of participants depends on the calculated speed at which the vehicle was on the scene of an accident.

The second example shows how the speed of the vehicle at the time of impact varies depending on whether at the time of the accident was located in the trunk of the vehicle load. Available documentation contained a diagram of brake force, but not the fact that you are in the trunk of the vehicle was located burden and whether the vehicle is on a technical review measured the potential burden that was in the trunk, and given the state of drivers that are located in the trunk load mass 300 kg. Depending on the vehicle's weight, varies the speed of vehicles at the time of the collision. On the other hand, given that the used vehicle weight of the vehicle registration to be, depending on whether the measurement of brake force in vehicle located burden or not, differentiate and deceleration of the vehicle. Using different deceleration and speed at the time of the collision, leads to different vehicle speed at the beginning of the skid marks brake.

The third example shows an analysis of traffic accident which was not known whether the cargo that is transported on the roof of the vehicle affected by the weight of the vehicle at the time of occurrence is greater than the maximum allowable weight of the vehicle. Specifically, the file was a fact that the braking system of the vehicle is technically correct, in which there were no data on measured forces on a technical review, nor in evidence existed diagram of brake force. The analysis is further complicated if one takes into account that the vehicle transporting cargo on the roof, where it is not known whether the vehicle is on a technical review was burdened with the same load as the time of the accident, nor is it known weight load. Since the weight load is not known, it is the mass of

the vehicle at the time of an accident could be greater than the maximum allowable weight of the vehicle.

***Example analysis of a traffic accident with the attached diagram of brake force which is not fixed vehicle weight***

In a traffic accident in April 2008, there was a collision RENAULT KANGOO with pedestrian. In the scriptures were not given information on the type of engine, associated equipment and possible cargo in the hold and on the basis of an analysis of the investigating documents could not get to the data on the mass RENAULT. Consequences of traffic accidents were such that the pedestrian sustained injuries resulting in death.

Based on the attached diagram of brake force with extraordinary technical inspection performed on XXX, in the "XXX" in the vote, it has been found that the sum of the braking force RENAULT was 776 daN, as the braking force RENAULT were.

| | | | |
|---|---|---|---|
| At front right wheel | 246 daN | At front left wheel | 248 daN |
| At back right wheel | 144daN | At back left wheel | 138 daN |

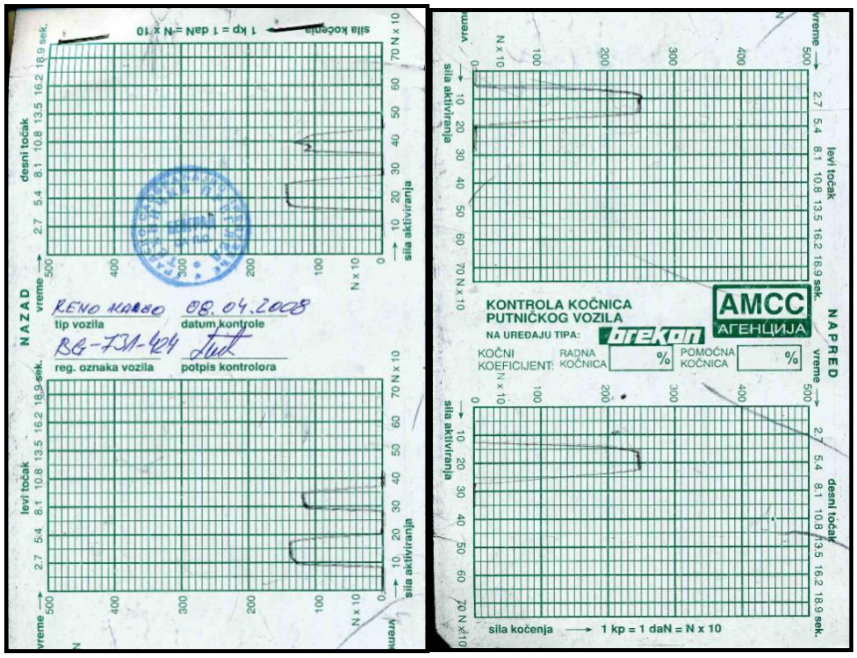


*Figure 1 The diagram of braking force*

However, the Commission of the Institute of Traffic Engineering in Belgrade, the file is not found information on weight RENAULT in the time of the extraordinary technical inspection. In fact, during the inspection, did not state that the mass-RENAULT, as well as whether RENAULT during the time of the accident and emergency technical inspection was loaded and how much.

At the database of vehicles Committee of the Institute of Transportation Faculty found that mass RENAULT KANGOO-may be 1050 kg to 1505 kg (see Figure 2), depending on the type of engine and ancillary equipment, and based on analysis of images could determine of the RENAULT mass.

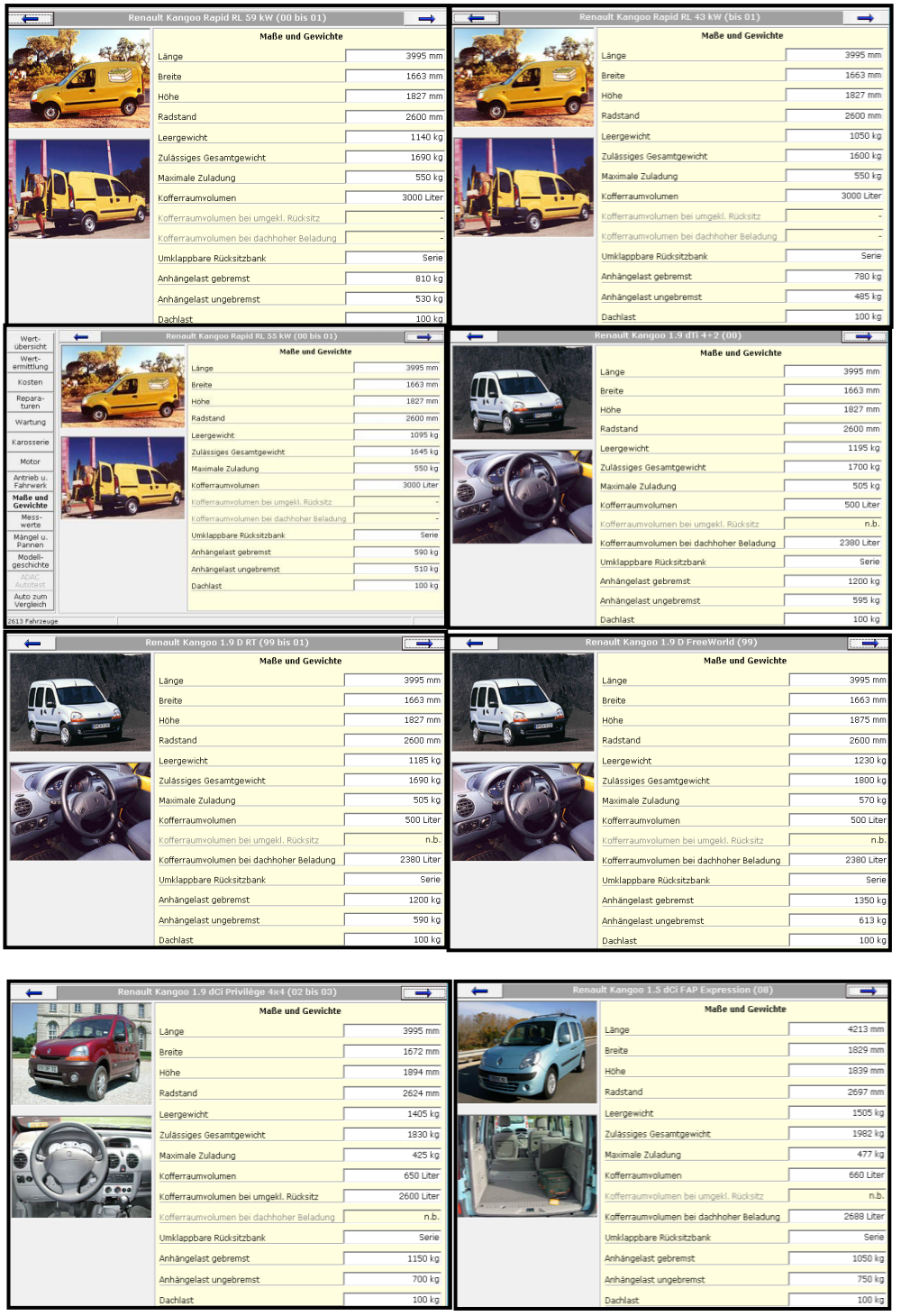


*Figure 2Mass RENAULT KANGOO-a depending of type energy and ancillary equipment*

If the mass of the RENAULT was 1055 kg and 1505 kg, then, with regard to the intensities of the brake force RENAULT, the braking ratio of RENAULT was:

$k = (776 \cdot 10)/((1055 + 75) \cdot 9{,}81$ , and $k = (776 \cdot 10)/((1505 + 75) \cdot 9{,}81$

$k = 0{,}7$, and $k = 0{,}5$

and the deceleration would RENAULT able to achieve in real terms would be up to:

$b = 0{,}7 \cdot 9{,}81$, and $b = 0{,}5 \cdot 9{,}81$

$b = 6{,}9\ {}^{m}/_{s^2}$, and $b = 4{,}9\ {}^{m}/_{s^2}$

Bearing in mind that in the long skid marks brake from 20 to 30 m and speeds greater than 60 km/h, a decline in braking performance achieved up to 10%, it would RENAULT able to achieve deceleration to:

$b_1 = 6{,}87 \cdot 0{,}9$, and $b_1 = 4{,}91 \cdot 0{,}9$

$b = 6{,}2\ {}^{m}/_{s^2}$, and $b = 4{,}4\ {}^{m}/_{s^2}$

The RENAULT speed at the moment of a collision with a pedestrian would be 46.5 km/h (mass RENAULT times of 1055 kg), or 41.8 km/h (mass RENAULT times of 1505 kg) until the speed RENAULT and, at the beginning of skid marks brake were up to:

$V = \sqrt{\left(\frac{46{,}5}{3{,}6}\right)^2 + 2 \cdot 6{,}18 \cdot 20{,}5}$, and $V = \sqrt{\left(\frac{41{,}8}{3{,}6}\right)^2 + 2 \cdot 4{,}42 \cdot 20{,}5}$

$V = 20{,}5\ {}^{m}/_{s}\ or\ V = 73{,}8\ {}^{km}/_{h}$, and $V = 17{,}78\ {}^{m}/_{s}\ or\ V = 64\ {}^{km}/_{h}$

The RENAULT speed, at the time of response driver of RENAULT would be up to:

$V = \frac{73{,}8}{3{,}6} + \frac{6{,}18 \cdot 0{,}15}{2}$, and $V = \frac{64}{3{,}6} + \frac{4{,}42 \cdot 0{,}15}{2}$

$V = 20{,}96\ {}^{m}/_{s}\ or\ V = 75{,}5\ {}^{km}/_{h}$, and $V = 18{,}1\ {}^{m}/_{s}\ or\ V = 65{,}2\ {}^{km}/_{h}$

The RENAULT that the response of the driver RENAULT's braked to a place of collision with a pedestrian, crossed the path length:

$d = 20{,}96 + 20{,}5$,

$d = 41{,}5\ m$,

If the mass of RENAULT's was 1055 kg, then the speed RENAULT in response time of drivers, in which the driver had the opportunity to reacting in the same manner and from the same place stop RENAULT ago of a collision was up to:

$V = \sqrt{(6{,}18 \cdot 0{,}925)^2 + 2 \cdot 6{,}18 \cdot 41{,}46} - 6{,}18 \cdot 0{,}925$,

$V = 17{,}63\ {}^{m}/_{s}\ \ or\ V = 63{,}4\ {}^{km}/_{h}$,

so the driver RENAULT's has a possibility of avoiding accidents when driving RENAULT times the speed limit to 60 km/h.

If the mass of RENAULT's was 1505 kg, then the speed RENAULT in response time of drivers, in which the driver had the opportunity to reacting in the same manner and from the same place stop RENAULT ago of a collision was up to:

$$V = \sqrt{(4{,}42 \cdot 0{,}925)^2 + 2 \cdot 4{,}42 \cdot 41{,}46} - 4{,}42 \cdot 0{,}925$$

$$V = 15{,}48\ {}^{m}/_{s} \quad or\ V = 55{,}8\ {}^{km}/_{h}$$

so the driver of RENAULT's would not have had the opportunity of avoiding accidents when driving RENAULT times the speed limit to 60 km/h.

If the mass of RENAULT's was 1055 kg, then the maximum speed RENAULT times could be up to 75.5 km/h, while the speed at which the driver RENAULT's a possibility of avoiding accidents, reacting to the same place and the same was up to 63.4 km/h. Given that the speed limit at the site of the accident is limited to 60 km/h, the driver would RENAULT's a possibility of avoiding accidents when driving RENAULT was up to the speed limit. Under these circumstances, the driver RENAULT times would stand deficiencies relating to the possibility of avoiding accidents.

If the mass of RENAULT's was 1505 kg, then the maximum speed RENAULT times could be up to 65.2 km/h, while the speed at which the driver RENAULT's a possibility of avoiding accidents, reacting to the same place and the same was up to 55.8 km/h. As to the speed of the scene of an accident is limited to 60 km/h, it RENAULT driver would not have had the opportunity of avoiding an accident or driving RENAULT's speed limits. Under these circumstances, the driver RENAULT would not have any failures related to the possibility of avoiding accidents and failures related to the contribution of an accident, but would eventually standing deficiencies relating to the weight of the consequences of this traffic accident.

***Example analysis of a traffic accident for which there is attached a diagram of brake force participants vehicle accident***

In a traffic accident in May 1998, there was a collision FIAT and OPEL, where the place of collision was located in the left lane, looking in the direction of FIAT-a. In the scriptures there were no data on the mass FIAT, while there were various statements about the cargo that was allegedly transported in the FIAT-in.

If it was located in the trunk FIAT's load weight of 300 kg, and as mentioned driver FIAT, then, using the program PC Crash, speed FIAT`s the time of the collision with the OPEL was 61 km/h, and a speed OPEL would be 51 km/h.

If the trunk FIAT's not located burden, and as mentioned witness, then, using the program PC Crash, speed FIAT's the time of the collision with the OPEL was 64 km/h, and a speeds OPEL was 44.9 km/h.

As in the case file did not find information on whether the Mercedes was located burden and whether the brake force measured with or without cargo in the luggage compartment FIAT, given that the used mass FIAT of commercial licenses, it will be slowing FIAT vary. In fact, depending on whether, at the time of measurement of brake force in the FIAT was located a load of 300 kg or not, the braking coefficient FIAT would be:

$k = (720 \cdot 10)/((1230 + 75 + 300) \cdot 9{,}81)$, and $k = (720 \cdot 10)/((1230 + 75) \cdot 9{,}81)$

$k = 0{,}45$ , and $k = 0{,}56$

the deceleration would FIAT able to achieve in real terms would be up to:

$b = 0{,}46 \cdot 9{,}91$ , and $b = 0{,}56 \cdot 0{,}9$

$b = 4{,}5\ {}^{m}/_{s^2}$, and $b = 5{,}5\ {}^{m}/_{s^2}$

If you are located in a FIAT cargo weight of 300 kg, and as mentioned driver FIAT or if FIAT would not have located a burden, and as stated by the witness, then the speed FIAT at the beginning of skid marks brake were:

$V = \sqrt{\left(\frac{61}{3{,}6}\right)^2 + 2 \cdot 4{,}15 \cdot 15{,}8}$, and $V = \sqrt{\left(\frac{64}{3{,}6}\right)^2 + 2 \cdot 5{,}5 \cdot 15{,}8}$

$V = 20{,}72\ {}^{m}/_{s}\ or\ V = 74{,}6\ {}^{km}/_{h}$, and $V = 22{,}13\ {}^{m}/_{s}\ or\ V = 79{,}7\ {}^{km}/_{h}$

while the speed of the Mercedes in the time of the driver braking response was:

$V = 20{,}72 + \frac{4{,}5 \cdot 2}{2}$, and $V = 22{,}13 + \frac{5{,}5 \cdot 0{,}2}{2}$

$V = 21{,}17\ {}^{m}/_{s}\ or\ V = 76{,}2\ {}^{km}/_{h}$, and $V = 22{,}68\ {}^{m}/_{s}\ or\ V = 81{,}6\ {}^{km}/_{h}$

This example shows how incomplete data on the weight of cargo can affect the operation of the braking system, the vehicle speed at the time of the collision, but the definition of failure of participants of a traffic accident. Namely, if the FIAT during the technical inspection located the burden of a weight of 300 kg and used mass FIAT of vehicle licenses, then with respect to the measured braking force, braking system FIAT was inoperative of law, because the braking coefficient FIAT was 0.45, and the minimum value of the braking coefficient is 0.5. With the value of the braking coefficient of 0.45 FIAT by the time response of drivers FIAT braking had a speed of 76.2 km/h, and with regard to the place of accident speed was limited to 80 km/h, the driver's FIAT would any failures related to the occurrence of accidents and the severity of consequences.

On the other hand if the FIAT during the technical review would not be located burden if used mass FIAT of vehicle licenses, then with respect to the measured braking force, braking system FIAT was correct, because the braking coefficient FIAT was 0.56, a minimum value of the braking coefficient is 0.5. However, the value of the braking coefficient of 0.56 FIAT by the time response of drivers FIAT braking had a speed of 81.6 km/h, and with regard to the place of accident speed was limited to 80 km/h, it would be on the driver's FIAT stay failures relate to the weight of the consequences of traffic accidents.

***Example analysis of a traffic accident for which there is not attached a diagram of brake force vehicles where the vehicle transporting cargo on the roof***

In May 2007, a traffic accident that involved a passenger car, LADA and a pedestrian has occurred. On the roof LADA is transported cargo unknown mass, because on the basis of available data from the file, the mass load from the roof LADA could not be reliably determined. The accident occurred when pedestrian collision and the front left part of LADA and pedestrian head impact and load from the roof of LADA. At the scene of an accident fixed skid marks brake of LADA are found.

The question was whether the weight of the vehicle with a load higher than the maximum permissible weight of the vehicle, as in the writings there were no precise data on

the weight of cargo that is transported LADA, as well as data on measuring the brake force LADA or deceleration that could achieve braking LADA system, and it is not possible to determine during the investigation of a traffic accident. But the fact that they are on the road the other skid marks brake was sufficient to establish that the weight of the vehicle at the time of an accident, including the weight load on the roof, was not greater than the maximum allowable weight of the vehicle.

In fact, bearing in mind that as a result of reaction LADA driver braked wheels LADA were blocked in the process of braking (with cargo on the roof), we find that the braking system LADA at the time of occurrence of traffic accidents could achieve deceleration to achieve locked wheels on asphalt. If the LADA was overloaded, then the brake system could cause wheels to brake LADA in the process of block on asphalt, because it would force the scope point was greater than the braking force at the wheels from locking, so that in these circumstances the possibility that the braking system LADA not realize deceleration provided by roadway in the area of traffic accidents.

An example presented shows that on the basis of a limited of data and the very specific circumstances of traffic accidents, possible to determine a fact which is of great importance for the elucidation of all the circumstances of the car accident.

## CONCLUSION

Presented paper has emphasized the importance of precise calculation of deceleration and precise data collection in investigations. Paper presented as examples of deceleration depends on the budget of the other parameters, which are important for the analysis of accidents, such as speed, the characteristic position of the participant accidents in certain stages of the collision and determine the possibility of avoiding accidents, but also situations where precise identification speed is essential for accurate determination of the collision. It is extremely important that traffic expert know the rules of proper calculation of deceleration of the vehicle, as well as rules regarding the minimum legal requirements of proper braking system of the vehicle.

Traffic experts must take into account the conditions of the brake system, which prescribes the rules at the time of occurrence of traffic accidents. In addition, it can be concluded that no matter what the expert has the possibility of calculating the deceleration must take into account all the other circumstances of the accident, in order to accurately and precisely determine the deceleration of the vehicle in this case. Was presented and the way they are based on a limited number of data in the file in some cases, can determine the elements of importance for the analysis of traffic accidents. Deceleration of the vehicle can be determined without knowing the braking force, but again must take into account all the circumstances of the car accident.

If the expert does not have the necessary data, deceleration, as a rule, is defined by the so-called. 'law of the minimum', according to which the vehicle deceleration to achieve the minimum of the defined deceleration according to all the circumstances (braking force, road conditions, weather conditions, the existence of skid marks and the like.).

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