

INVESTIGATING TRAFFIC ACCIDENTS: THE INTERACTION BETWEEN A MOTOR VEHICLE AND A PEDESTRIAN

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Abstract. The paper presents the methodology for expert investigation of traffic accidents involving running over pedestrians. This methodology is aimed at determining the availability of any technical possibility for a motor vehicle driver, driving at a particular speed, to avoid hitting the pedestrian in a particular situation. Furthermore, the paper presents the analysis of different investigation methods and the description of investigation procedures. Various patterns of the path of the motor vehicle and the pedestrian travel before the accident are described, providing a deeper insight into the peculiarities of investigation of each particular pattern. The description is supported by the case study, illustrating the investigation of a specific traffic accident, involving actual hitting of a pedestrian. The methodology presented may be successfully used for investigating traffic accidents by experts.

Keywords: motor vehicle; pedestrian; running over pedestrian; traffic accident; traffic safety; technical possibility to avoid an accident; expert investigation.

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Introduction

It is well known (Sivilevičius 2011) that traffic safety mainly depends on (Fig. 1):

- infrastructure;
- vehicles;
- humans.

Passive safety of a motor vehicle includes measures of external safety of a motor vehicle aimed at minimising the injuries inflicted on pedestrians, cyclists and motorcyclists in the running-down accidents (Černiauskas *et al.* 2010; Cristoforou *et al.* 2010; Prentkovskis *et al.* 2010; Dargužis *et al.* 2011; Keall, Newstead 2011; Keršys *et al.* 2011; Kopczyński *et al.* 2011; Rosén *et al.* 2011; Sapragnas, Makaras 2011; Zou *et al.* 2011; Ptak *et al.* 2012, etc.). The factors, determining the external safety of a motor vehicle, e.g. a car (Fig. 2), include (Zubakov, Shhurin 2010):

- the characteristics associated with deformability of the motor vehicle body;
- geometric characteristics of the motor vehicle body.

Active safety of a motor vehicle is achieved by rational design of suspension, steering wheel, braking system and by choosing optimal dynamic characteristics of a motor vehicle (Buzeman *et al.* 1998; Straky *et al.* 2003; Prentkovskis *et al.* 2010; Bera *et al.* 2011; Sapragnas, Dargužis 2011; Solomon, Padmanabhan 2011; Zou *et al.* 2011; Ptak *et al.* 2012; Tang *et al.* 2013).

Passive safety of the constituent parts of traffic infrastructure embraces the elements ensuring their external safety (e.g. guardrails, posts, road signs, etc.), intended for minimising the injuries of the motor vehicle drivers and passengers in the case of an accident (Sokolovskij *et al.* 2007; Antov *et al.* 2009;

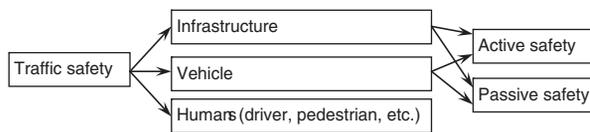


Fig. 1. The factors determining traffic safety

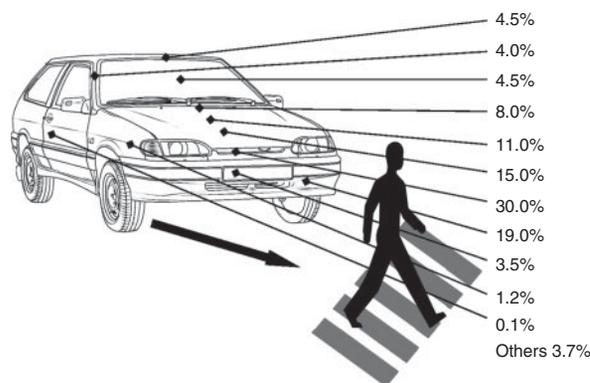


Fig. 2. The risk of pedestrian collision with various parts of a car

Dell’Acqua, Russo 2011; Keršys *et al.* 2011; Sapragonas, Makaras 2011; Hampton, Gabler 2012; Prentkovskis *et al.* 2012, etc.). The factors determining the external safety of the elements of traffic infrastructure include:

- the characteristics associated with deformability of metal elements (e.g. posts, supporting structures, guardrails, etc.);
- geometric characteristics of metal, concrete, reinforced concrete, wooden and other elements (e.g. posts, supporting structures, guardrails, curbs, speed reduction bumps, etc.);
- the characteristics of automobile and other roads.

The analysis of the dynamics of the pedestrian thrown onto the bonnet of the car during the frontal impact shows that, at the same speed of running over a pedestrian and the same configuration of the car front, the throw distance for tall people is longer. It may be accounted for by the fact that the taller the person, the higher his/her centre of gravity and, therefore, the higher the angular momentum, because the impact force acting on the pedestrian body is stronger in this case. One should not think that the deformations caused only by striking the pedestrian head against the car roof can be detected on it. It has been shown that, in practice, these mechanical injuries can also appear, when a pedestrian strikes his back, arm, etc. against the car body.

Pedestrians sustain the most severe injuries during the dynamic contact with the car front.

The analysis of the real cases of running over pedestrians and simulations of car collisions with dummies has shown that, in most cases, fatal head injuries of pedestrians are caused both by their contact with a car and the subsequent falling on

the road and striking their heads against the asphalt pavement. The contact location depends on the pedestrian height and the configuration of the car front (e.g. the bonnet or the bonnet front windcreens for a motor car). *Group 1* of the most severe injuries includes the cases involving the contact of a passenger with the windscreen aperture or windscreen pillars. Since modern triplex windcreens (consisting of two curved sheets of safety glass and a thin plastic layer laminated between them) are much more pliable than the metal parts, pedestrians most often sustain fatal injuries by striking their heads against the upper or lower edge of the windscreen aperture, the wipers’ levers, etc. However, the glass of the windcreens near the edges of the aperture is almost as hard as metal. *Group 2*, embracing the most common injuries of pedestrians, includes shin bone fractures and knee-joint and fibula injuries. Generally, the injuries of legs are not fatal, but can often lead to disability. The pedestrians can sustain these injuries by striking themselves against the bumper or the front edge of the bonnet. Therefore, it is clear that the car front should be made more pliable. However, this can be achieved only partially, because hard units and assemblies will still be found under a thin sheet of the car’s bonnet and the plastic covering of its bumper.

The above considerations refer to the problem of increasing the safety of the motor vehicle’s structures, which, in turn, is closely connected with the outcomes of traffic accidents, because the seriousness of their consequences for passengers and other participants of road traffic depends on how effectively safety problems are being solved. This applies to accidents such as running over pedestrians, a collision between two (or more) motor vehicles, etc. Therefore, traffic accidents should be thoroughly investigated and simulated.

A high accident rate on the roads of Lithuania (and other countries) may be accounted for by factors such as irresponsible behaviour of drivers and pedestrians on the road, poor traffic control and the road condition, etc. Besides, traffic culture, mutual respect and mutual aid of people on the road are still rather low (Kong, Yang 2010; De Carvalho Ponce *et al.* 2011; Keall, Newstead 2011; Lazda, Smirnovs 2011; Rosén *et al.* 2011; Girasek 2012; Prentkovskis *et al.* 2012; Vardaki, Yannis 2012; Abay 2013; Al Naser *et al.* 2013; Gjerde *et al.* 2013; Zhang *et al.* 2013, etc.).

Every year, the Traffic Police of Lithuania register traffic accidents (Accident Rate Information 2012). The dynamics of the traffic accidents registered in 2000–2012 is shown in Fig. 3. In 2012, 3173 traffic accidents were registered. Their distribution (in percent) is given in Fig. 4. In Fig. 5, the percent distribution of traffic accident guilty parties in 2012 is shown. In 2012, 1120 traffic accidents, involving *Running over pedestrians*, were registered. The dy-

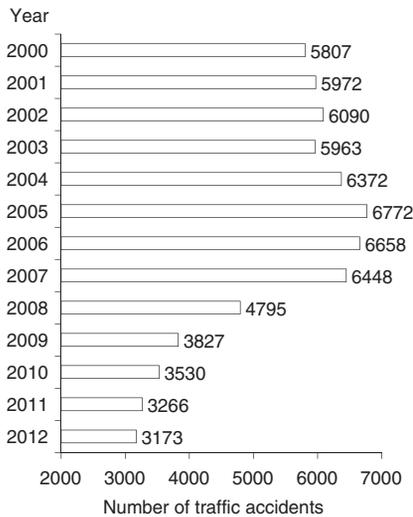


Fig. 3. The dynamics of traffic accidents registered by the Traffic Police of Lithuania in 2000–2012

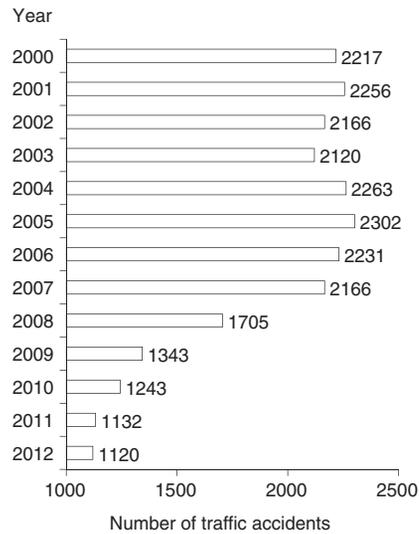


Fig. 6. The dynamics of traffic accidents, involving *Running over pedestrians*, registered by the Traffic Police of Lithuania in 2000–2012

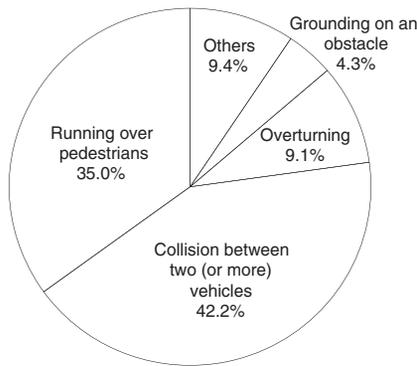


Fig. 4. The percent distribution of traffic accidents in Lithuania in 2012 (the total number of the registered accidents was 3173)

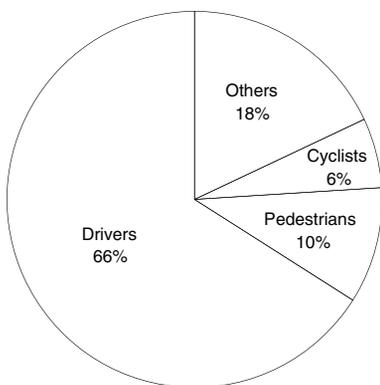


Fig. 5. The percent distribution of traffic accident guilty parties in Lithuania in 2012 (the total number of the registered accidents was 3173)

namics of the traffic accidents, associated with *Running over pedestrians*, which were registered in 2000–2012, is shown in Fig. 6.

The dependences graphically presented in Figs 3–6 show that:

- in recent years, the number of the registered traffic accidents in Lithuania has been decreasing;
- a large number of traffic accidents are associated with *Running over pedestrians*, 35.0%;
- most of the traffic accidents are caused by *Drivers + Pedestrians*, 66% + 10% = 76%.

The transport system of any country has three constituent parts: road (route), passengers (goods) and vehicles. All of them, taken individually or in interaction, strongly affect road traffic safety. The researchers all over the world investigate the problem of traffic safety. In particular, some of them focus on the study of pavement quality (Čygas *et al.* 2011; Ožbolt *et al.* 2012; Zhong *et al.* 2012, etc.), while others concentrate on the investigation of active and passive measures, ensuring vehicle safety (Keršys *et al.* 2011; Kopczyński *et al.* 2011; Ptak *et al.* 2012; Prentkovskis *et al.* 2012, 2010; Tang *et al.* 2013, etc.). There are also works, dealing with the problems of passengers and freight safety in transportation (Bazaras *et al.* 2013; Kelley *et al.* 2013, etc.) and the interaction between various elements of transport systems (Buzeman *et al.* 1998; Sokolovskij *et al.* 2007; Černiauskas *et al.* 2010; Weng *et al.* 2010; Dargužis *et al.* 2011; Keršys *et al.* 2011; Kopczyński *et al.* 2011; Sivilevičius 2011; Prentkovskis *et al.* 2012, 2010; Hampton, Gabler 2012, etc.).

The problems, associated with the investigation of traffic safety (particularly, the interaction between a motor vehicle and pedestrians) and its increase, have been in the focus of the researchers in various countries for many years. In particular, some of them focus on the studies of alcohol- or drug-related traffic accidents (Holmgren *et al.* 2005; Assum 2010; Dunlop, Romer 2010, De Carvalho Ponce *et al.* 2011; Gjerde *et al.* 2013, etc.). Other researchers concentrate on the analysis of the collision risk

and other risk factors (Kong, Yang 2010; Zhang *et al.* 2013, etc.) or focus on the interaction between pedestrians and other traffic participants and the influence of the behaviour of the former on traffic safety (Kong, Yang 2010; Kopczyński *et al.* 2011; Rosén *et al.* 2011; Zou *et al.* 2011; Ptak *et al.* 2012, etc.). Similar to the case of any other type of traffic accidents (Buzeman *et al.* 1998; Prentkovskis *et al.* 2012, 2010, etc.), the investigation of pedestrian-related accidents requires a very precise reconstruction of the traffic accident and determination of its major cause (Soni *et al.* 2009; Weng *et al.* 2010; Kopczyński *et al.* 2011; Zou *et al.* 2011; Ptak *et al.* 2012, etc.).

Usually, the expert investigation of the running-down accidents is carried out in accordance with the procedure involving the following steps:

- determining the hitting location, i.e. the exact location, where the pedestrian was run down on the road (normally, it is made based on physical evidence, e.g. the location of debris, fragments of broken glass, skid marks on the road surface, traces, etc., which are shown on the diagram of the accident scene);
- determining the motor vehicle speed before the traffic accident;
- determining whether the driver had any technical possibility to avoid the accident through a timely attempt to brake or swerve while running the motor vehicle at the speed as estimated by the expert or reported by the driver;
- determining if the driver had exceeded the maximum permissible speed limit on the particular road section, and if it could have been possible for the driver to avoid hitting the pedestrian through a timely attempt to brake or swerve if the maximum speed limit before the accident had not been exceeded;
- reconstructing the traffic accident;
- determining whether the actions of the motor vehicle driver and the pedestrian in a particular situation could be acceptable in terms of their compliance with the existing Road Traffic Rules (2002) and determination of the major cause of the accident.

The key question to be answered in such investigation is whether the motor vehicle driver had any technical possibility to avoid running down the pedestrian through a timely attempt to brake or swerve. In most cases, the answer to this question will give the clue as to whose actions in a given traffic situation, i.e. those of the driver or the pedestrian, have actually caused the traffic accident.

1. Methodology for investigating the accidents associated with running over pedestrians

Most often, pedestrians suffer hitting when attempting to cross the roadway, whereas the cases when they

are run down by a motor vehicle while walking along the roadway can be observed much less frequently. Therefore, our further case study will be focussed on the accident involving the pedestrian's crossing the roadway. It should be noted, however, that manoeuvring actions normally resorted to with the aim of avoiding a potential traffic accident are not acceptable in this particular case, because the driver is not able to foresee further behaviour of the pedestrian in the given situation.

Generally, the following two methods are available for determining whether the driver had any technical possibility to avoid the traffic accident involving auto-pedestrian collision (Fig. 7):

- *The first method* is based on the comparison of distance S_a (the distance of the motor vehicle from the location where the pedestrian was hit at the moment, when he became an obstacle to the moving motor vehicle (or posed a threat to traffic safety)) with distance S_0 (braking distance, i.e. the distance the motor vehicle travels in the braking mode before it brakes to a halt);
- *The second method* involves the reconstruction and analysis of the traffic situation at the moment, when the motor vehicle was away from the location of the pedestrian hitting at distance S_0 , and the driver did not make any attempts to swerve, which subsequently excludes the availability of any technical possibility for the driver to avoid the collision with the pedestrian.

Normally, given the availability of the sufficient data for the necessary estimations, the first method is applied.

The second method is preferred in situations, when an expert is faced with the uncertainty in determining the exact moment, when a threat was posed to traffic safety by the pedestrian and when the distance, at which the pedestrian was at the moment of posing a threat to traffic safety (while being within the range of visibility for the driver), is unknown. In such cases, the expert estimates the critical distance of the pedestrian travel (the distance travelled by the pedestrian over the time span necessary to bring the motor vehicle to a full stop), within the range of which the technical possibility for the driver to avoid a traffic accident still existed. Then, the expert determines whether the driver could already identify the traffic situation as dangerous and take an appropriate action for avoiding the accident at the moment, when the pedestrian was at some particular distance from the hitting location. Normally, the expert's conclusions drawn based on the above estimations are of provisory nature, whereas the final conclusion is made by the respective officers or the court.

When applying the first method, the distance S_a , marking the position of the motor vehicle with respect to the hitting location at the moment, when the pedestrian became the obstacle to the motor

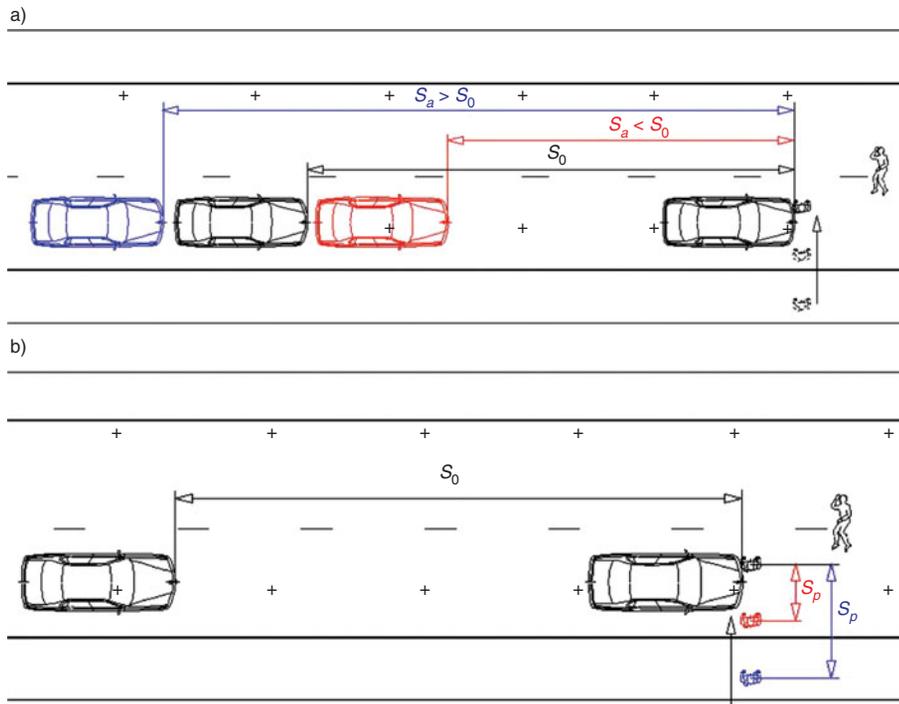


Fig. 7. The methods for determining the availability of technical possibility for the driver to avoid the pedestrian accident: a – through the comparison of distance S_a (the distance between the motor vehicle and the location of the pedestrian hitting at the moment, when a threat to traffic safety occurred) with distance S_0 (the braking distance); b – through the reconstruction and assessment of the traffic situation at the moment when the motor vehicle was away from the hitting location at distance S_0

vehicle (or posed a threat to traffic safety), should be estimated first. If the driver hit the pedestrian prior to starting braking, this distance should be computed using the equation:

$$S_a = S_p \cdot \frac{V_a}{V_p}, \quad (1)$$

where: S_p is the distance covered by the pedestrian, when he was obstructing the movement of the motor vehicle or posing a threat to traffic safety (and was in the range of visibility of the driver before he reached the location of hitting) [m]; V_a is the speed of the motor vehicle before the accident [km/h]; V_p is the speed of the pedestrian travel before the accident [km/h].

The braking distance under the specific conditions of the road should be calculated based on the following equation by Kristi (1971), Ilarionov (1989) and Danner and Halm (1994):

$$S_0 = (t_1 + t_2 + 0.5 \cdot t_3) \cdot \frac{V_a}{3.6} + \frac{V_a^2}{26 \cdot j}, \quad (2)$$

where: t_1 is the response time of the driver [sec]; t_2 is the time of the brake system's activation [sec]; t_3 is the time of the motor vehicle deceleration increase [sec]; V_a is the speed of the motor vehicle travel before the accident [km/h]; j is the maximum motor vehicle deceleration rate, while braking on the road with a particular surface [m/sec²].

If prior to the accident, the motor vehicle had been travelling at the speed exceeding the permissible maximum speed limit on the particular road section, the same equation (2) may be applied to determine the motor vehicle braking distance at the permissible speed.

$S_a \geq S_0$ means that, when the motor vehicle was running at the speed deemed permissible, the technical possibility to avoid the collision with the pedestrian through timely attempts to brake or swerve really existed for the driver, whereas $S_a < S_0$ implies that such possibility was not available for the driver (Fig. 7). In some cases, when distance S_a is only slightly shorter than distance S_0 and the pedestrian was walking fast and therefore had very little time to withdraw (e.g. walk or run away) from the risk zone, the expert should determine whether the driver, who started to brake in due time, would have avoided hitting the pedestrian if the latter had succeeded to withdraw (walk or run away) from the risk zone.

If the driver started to brake prior to hitting the pedestrian and the impact occurred while the motor vehicle was running in the braking mode, the distance S_a , marking the position of the motor vehicle with respect to the hitting location at the moment, when the pedestrian became an obstacle to the motor vehicle (or posed a threat to traffic safety), should be calculated according to the equation by

Kristi (1971), Ilarionov (1989) and Danner and Halm (1994):

$$S_a = S_p \cdot \frac{V_a}{V_p} - \left(\sqrt{\frac{V_a^2}{26 \cdot j}} - \sqrt{S_T''} \right)^2, \quad (3)$$

where: S_T'' is the distance, which the motor vehicle has travelled after the impact in the mode of braking before stopping [m].

For computing the motor vehicle braking distance in the case, when during the traffic accident the driver started braking, leaving the skid marks on the road surface, equation (2) should be replaced with another one, which, according to Kristi (1971), Ilarionov (1989) and Danner and Halm (1994) reads as follows:

$$S_0 = (t_1 + t_2 + t_3) \cdot \frac{V_a}{3.6} + S_{sk}, \quad (4)$$

where: S_{sk} is the skid mark length [m].

The distance S_p , travelled by the pedestrian, when he was in the way of the motor vehicle or posed a threat to traffic safety, while being in the driver's visibility range before reaching the hitting location, is usually determined as the distance covered by the pedestrian from the moment of entering the roadway to the moment of reaching the hitting location, identified based on the findings of the investigation. However, there are other cases, when, for some reasons, the driver is not able to notice the pedestrian, entering the roadway or the latter poses no threat to traffic safety at that particular moment. In such cases, distance S_p is assumed to be starting only from the point, where the pedestrian appears within

the driver's visibility range, i.e. when the driver, based on the objective judgement, is already able to notice the pedestrian and the latter poses a threat to traffic safety. A case study, demonstrating the methods used in the present investigation, is given below.

2. A case study of the traffic accident, involving running over a pedestrian

The case study is based on the particular traffic accident, when the truck-tractor with a semi-trailer hit the pedestrian, who was moving from the right side of the truck-tractor with a semi-trailer leftwards and appeared behind the minibus on the fast lane of the road. The scene of the traffic accident recorded after the accident is given in Fig. 8.

According to equation (5), the presence of 15.6-m-long skid mark on the road surface made it possible to determine that the considered motor vehicle had been running at the speed of 46.8 km/h before the driver attempted to brake at the pedestrian hitting location:

$$V_a = 1.8 \cdot t_3 \cdot j + \sqrt{26 \cdot S_{sk} \cdot j}, \quad (5)$$

where: t_3 is the time of the motor vehicle deceleration increase (in this case, 0.9 sec); j is the motor vehicle's deceleration rate while braking on the sloppy asphalt road (in this case, 4 m/sec²); S_{sk} is the recorded skid mark length (in this case, 15.6 m).

Judging by the location of the stain produced by a liquid similar to blood, it appeared that, with respect to the length of the road in the original direction of the motor vehicle travel, the pedestrian was run down near the spot, marking the occurrence of the aforementioned stain. Based on the position of

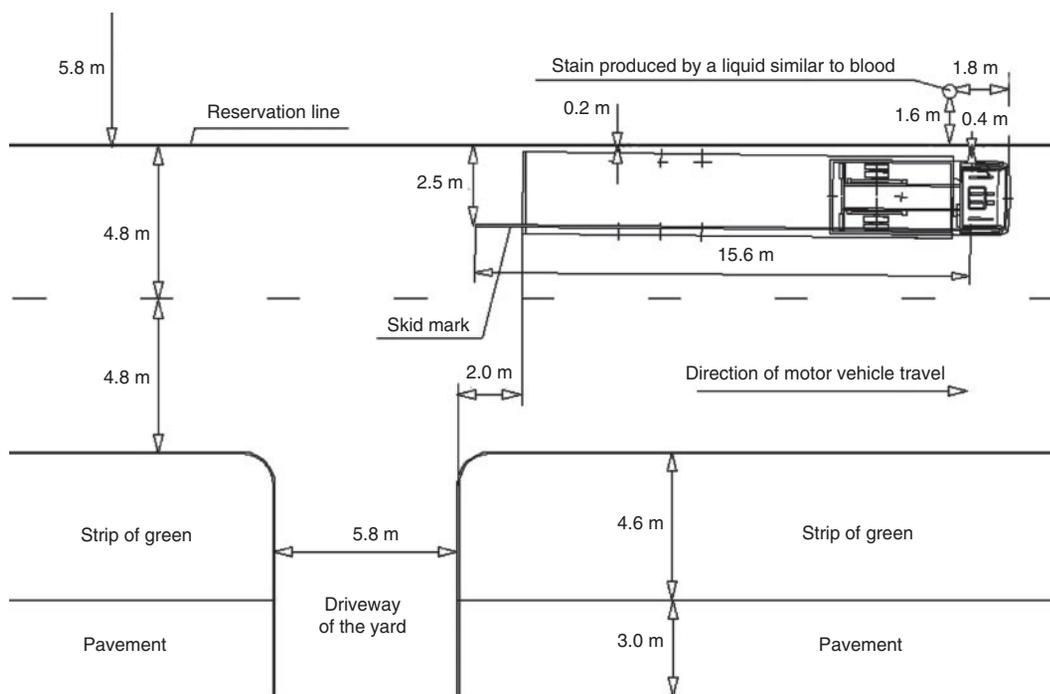


Fig. 8. The diagram of the traffic accident scene

the damage marks found on the truck-tractor with a semi-trailer, it was also determined that the impact was produced by the left side of the motor vehicle's frontal plane.

Then, based on the graph data, the distance, which the pedestrian could have covered while walking in the truck-tractor with a semi-trailer driver's visibility range before he reached the location of hitting, was estimated (Fig. 9). In the absence of more accurate data, it was assumed that the minibus, from behind of which the pedestrian started walking, was keeping to the central part of the first roadway lane. As shown in Fig. 9, before reaching the location of hitting, the pedestrian, who started moving from behind the minibus moving along the first lane of the roadway, could have travelled the distance of approximately 5 m (S_p) within the visibility range of the driver of the truck-tractor with a semi-trailer.

Fig. 9 shows the probable travel path of the pedestrian from the moment of his emerging within the range of visibility of the truck-tractor with a semi-trailer driver until the moment when he reached the hitting location. Therefore, the positions of the truck-tractor with a semi-trailer and the minibus on the first lane of the roadway are recorded (Fig. 9) at different moments of time: the position of the minibus is shown at the moment, when the pedestrian, walking from behind it, could occur within the visibility range of the driver of truck-tractor with a semi-trailer (at that instant, the truck-tractor with a semi-trailer had not yet reached the pedestrian hitting location); the possible position of the truck-tractor with a semi-trailer is shown at the moment of running over the pedestrian (by that time, the

position of the minibus could have changed, because, when the pedestrian was moving towards the hitting location, the minibus could have moved some distance ahead).

According to equation (3), at the instant, when the pedestrian started moving from behind the minibus, driving along the first lane of the roadway, and was within the range of visibility of the driver of the truck-tractor with a semi-trailer, the truck-tractor with a semi-trailer was about 33.6÷43.8 m away from the pedestrian hitting location (when $S_p = 5$ m is the distance within the visibility range of the driver of the truck-tractor with a semi-trailer, which the pedestrian could have covered before reaching the hitting location (Fig. 9); $V_p = 4.5 \div 5.6$ km/h is the speed of the pedestrian travel estimated based on the accident data available; $S_T'' = 3$ m is the distance assumed to be travelled by the truck-tractor with a semi-trailer in the mode of braking from the moment of hitting the pedestrian until stopping).

According to equation (4), the braking distance for the truck-tractor with a semi-trailer, running at the speed of 46.8 km/h under the particular road conditions, should extend over about 45.5 m (in this case, $t_1 = 1$ sec is the response time of the driver; $t_2 = 0.4$ sec is the time of activating the braking gear of the truck-tractor with a semi-trailer).

The above estimates suggest that the driver of the truck-tractor with a semi-trailer, moving at the estimated speed of 46.8 km/h, had no technical possibilities to avoid hitting the pedestrian under the conditions, which were identified in the course of investigation. In particular, the distance $S_a = 33.6 \div 43.8$ m between the truck-tractor with a semi-trailer

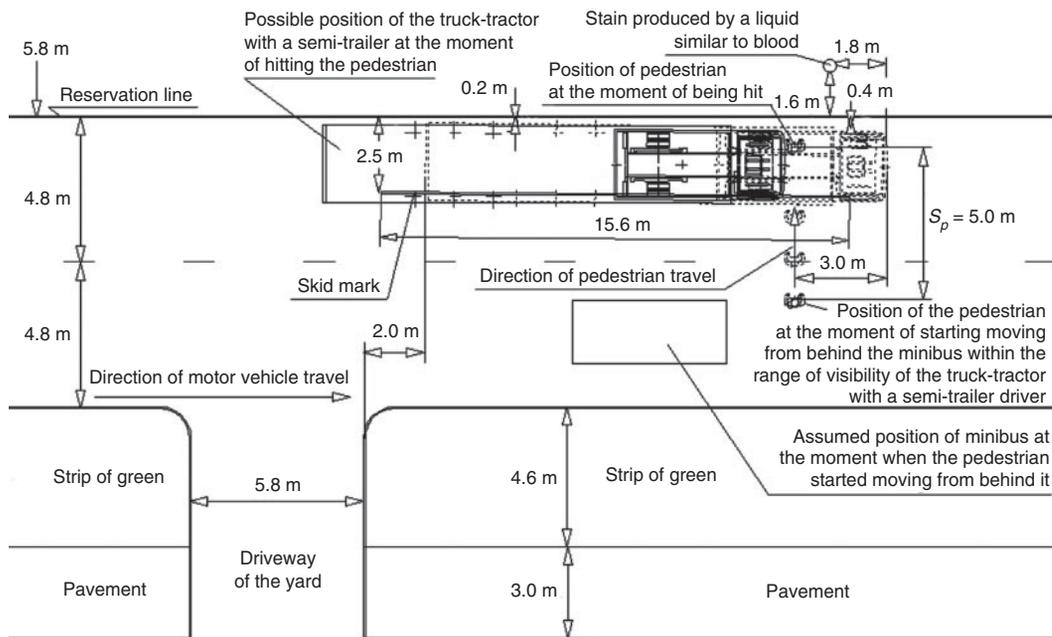


Fig. 9. The diagram of the traffic accident scene depicting the travel path of the pedestrian from the moment of appearing from behind the minibus, driving along the first lane of the road, until the moment the pedestrian has reached the hitting location, and the possible position of the truck-tractor with a semi-trailer at the moment of hitting the pedestrian

and the hitting location at the moment, when the pedestrian started moving within the visibility range of the truck-tractor with a semi-trailer driver from behind the minibus on the first lane of the roadway, was shorter than distance $S_0 = 45.5$ m required for braking the truck-tractor with a semi-trailer to a halt under the particular road conditions.

3. Other cases of investigating running-down accidents

If prior to the moment of being hit, the pedestrian was moving along the roadway, the accident should be investigated, using the procedure similar to that applied in the case, when the pedestrian is crossing the roadway. However, in this case, the expert should also take into account the actual distance covered by the pedestrian before he reached the hitting location and when he was obstructing the movement of the motor vehicle or posing a threat to traffic safety.

As mentioned above, the cases involving the movement of the pedestrian along the roadway are relatively rare. Under such circumstances, the pedestrian, before being hit, keeps moving in the same or opposite direction to the direction of the motor vehicle travel. Therefore, the occurrence of the traffic accident depends on whether the pedestrian is within the motor vehicle driver's visibility range, because, in these cases, pedestrians are usually hit due to limited visibility, preventing the driver from noticing the obstacle in due time or making a timely attempt to avoid the collision with it, rather than due to the movement of the pedestrian. Furthermore, when the pedestrian moves along the roadway, which is wide enough to provide free passage, both braking and swerving are deemed acceptable as the techniques, helping to avoid an accident.

The distance required for the driver to shift the motor vehicle over a certain distance y across the roadway (either leftwards or rightwards) may be estimated by applying the equation suggested by Ilarionov (1989):

$$S_m = (t_1 + t_v) \cdot \frac{V_a}{3.6} + \frac{V_a}{3.6} \cdot \sqrt{\frac{6 \cdot y}{g \cdot \varphi'}}, \quad (6)$$

where: t_v is the time needed for activating the steering system gear [sec]; y is the distance, over which the motor vehicle has to move leftwards or rightwards on the roadway in order to avoid the accident [m]; g is the gravitational acceleration [m/sec²]; φ' is the coefficient of adhesion for crosswise sliding of the wheels on the particular road surface.

Thus, when determining the availability of a technical possibility for the driver to avoid hitting the pedestrian in the considered cases, the distance S_a between the motor vehicle and the location of the pedestrian hitting at the moment, when a threat to traffic safety occurred, may be compared both to the distance S_0 (the motor vehicle's braking distance) and

distance S_m (the distance, which the motor vehicle has to travel in order to bypass the pedestrian).

In some cases, the available data is very inaccurate and, therefore, cannot be used for obtaining the unambiguous answer to the question about the availability of a technical possibility for the driver to avoid hitting the pedestrian. Under these conditions, an alternative method, involving the critical value of a certain parameter based on which the conclusion about the availability of any technical possibility for the driver to avoid the accident can be made, should be applied. Hence, the obtained answer is only of provisory nature; however, based on it, the officers, having specified the value of the aforementioned parameter, may already come to certain conclusions. For example, if the exact speed of the pedestrian travel before the collision is unknown, the expert, having estimated the critical value of the pedestrian travel speed, may make the following conclusion: if the speed, at which the pedestrian was actually moving prior to being hit, does not exceed the estimated critical value, it means that the driver really had a technical possibility to avoid the collision with the pedestrian, and vice versa.

4. Computer simulation of motor vehicle–pedestrian accidents

It is possible to simulate a running-down accident by using a special computer program, e.g. *PC-Crash* (Fig. 10). The pedestrian is modelled in the software *PC-Crash* (version 8.1) as a multibody system. Various parameters of this system can be changed (Fig. 11) (*PC-Crash: A Simulation Program for Vehicle Accidents 2007*). However, the model of a pedestrian is not sufficiently perfect to precisely

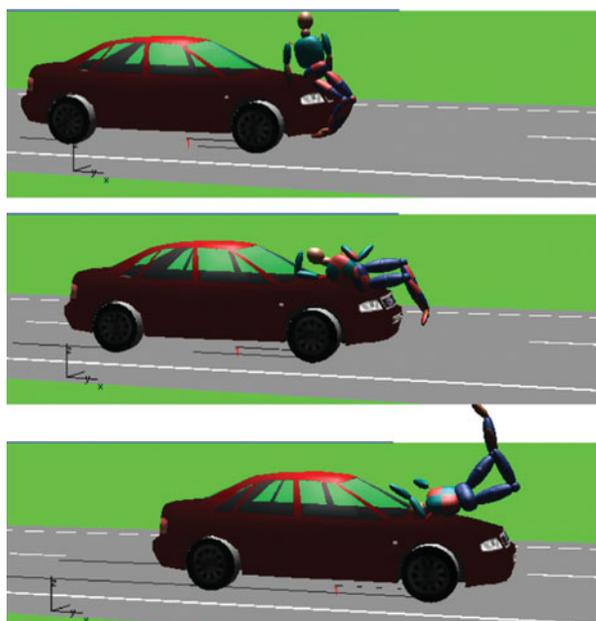


Fig. 10. Computer modelling of running over pedestrian (*PC-Crash* software)

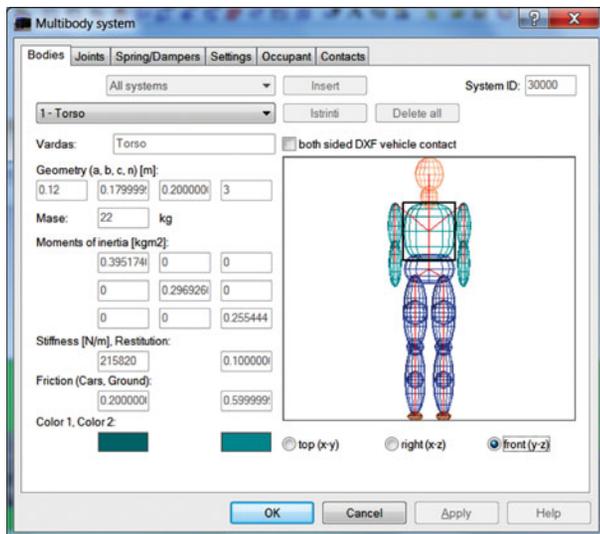


Fig. 11. The parameters of pedestrian (PC-Crash software)

simulate a traffic accident with a pedestrian. Such traffic accidents are complicated, and many parameters required for computer simulation of pedestrian accidents are usually unknown.

Conclusions

- 1) The methodology for expert investigation of the accidents, associated with running over pedestrians, which may be applied to identify the circumstances of traffic accidents and to perform the respective expert investigation, is presented.
- 2) The developed methodology enables us to determine, whether the driver had any technical possibility to avoid hitting the pedestrian in the situation, when the motor vehicle was travelling at a particular speed. The calculation methods used for different cases have been discussed for the situations:
 - a) when prior to hitting the pedestrian, the motor vehicle was travelling without braking;
 - b) when the driver used braking, depending on a particular pattern of the pedestrian travel.
- 3) A case study, illustrating practical application of the suggested methodology, is presented.

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