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The variety of the behaviour of drivers at risk accident situations

Rafał S. Jurecki, Marek Jaśkiewicz, Andrzej Zuska

Kielce University of Technology, Faculty of Mechatronics and Machine Building
Department Vehicles and Transport
25-314 Kielce, ul. Tysiąclecia Państwa Polskiego 7, e-mail: {rjurecki; m.jaskiewicz; a.zuska}@tu.kielce.pl

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Abstract

The following article presents a brief overview of research regarding driver behaviour in simulated situations of accident risk. The research carried out within a research work N N509 549 040 included an accident situation involving the sudden intrusion of a pedestrian into the road area from behind a curtain either from the left or right side.

This paper presents and analyses a variety of registered driver behaviours to simulated risk accident situations and drivers' reaction parameters.

Introduction

Road situations involving a sudden intrusion of a pedestrian in front of an incoming vehicle can be found quite often. This situation is quite common on our roads, when the pedestrian steps out from behind parked vehicles, from a side street or a group of people standing at the edge on the road. In such situations drivers have little time to react. Despite a significant decrease in the number of people killed in road accidents in 2012 (to about 3.5 thousand), what worries is the number of fatal accidents involving pedestrians that is vulnerable road users. Pedestrians – killed in road accidents in 2012 accounted for over 30 percent of all road fatalities in Poland. Similar ratios are also listed in previous years.

The consequence of such accidents are proceedings carried out by the police and prosecutors designed to determine the causes of an accident and determine the fault of persons involved. There is a need for reconstruction and analysis of traffic accidents, which is carried out with the use of sophisticated computer systems that are used to simulate the movement of vehicles. The vast majority of them generate a computer animation of a reconstructed accident situation, so that it can be presented it in the form of a video visualization. Such a presentation of the reconstruction has advantages because the result is not presented in the form of complex calculations, but as a film, scenes, in which the background can be the surrounding of the actual scene of the accident. It also has disadvantages. A major problem, however, is that the situation in the form of simulation can be very suggestive and, therefore, influences the feelings of recipients (in the court), and suggest a possible guilt. This can happen despite committed gross errors.

Therefore, it is very important to use such a tool (software) with full knowledge and deliberation. Properly conducted accident reconstruction determines final outcome of judicial proceedings concerning the case, including the definition of the scope of guilt and penalty amount of individual participants of the analysed road accident. The credibility of the reconstruction carried out by an expert depends on many factors. One of the most important, in addition to the expertise of the person carrying out the simulation, is the correct choice of input parameters which an expert uses and introducing them to the simulation software. Some of necessary parameters can be found in the documentation prepared by the police, many (e.g. vehicle parameters) can be relatively easy to input. Unfortunately, many others (not less important ones) the expert must take alone. Some of them are estimated based on expert's own experiences, but many are chosen based on recommendations from professional literature. These parameters include, for example: coefficient of friction surfaces, driver's reaction time, or the coefficient of restitution.

Applied computational models used in the simulation programs have strong sensitivity to the change in the value of parameters used for calculations.

Therefore, the most accurate action seems the necessity to define the range of possible actions of a driver. During the analysis of a road accident, variant analysis is often performed in order to be able to answer the question of whether the use of "border ranges" of different parameters in the simulation and the driver's behaviour was correct, whether the driver could have avoided the collision, etc.? Unfortunately, in the case of many parameters, they can be taken arbitrarily.

One of the parameters whose assumed value may significantly affect the result of the executed simulation is "driver's reaction time". This is the time that elapses from the time of the accident risk occurrence, to the start of driver's influence on vehicle control mechanisms i.e. the steering wheel, the pedals and levers. Many textbooks and handbooks for experts present one value of drivers' reaction times. However, the expert often does not have any additional information regarding e.g. research methodology. The data frequently refers to some "average" driver. Frequently only gender and possible age of a driver are distinguished. Such a given value very often does not depend on any parameters. However, a question may be asked. Do drivers of similar age, in an emergency situation, behave in the same way?

Is the simulation carried out for such an "average" driver appropriate for all drivers? Certainly not. Many publications present only average value of the reaction time of a driver. Carrying out a simulation within some tolerance range (in terms of reaction time) is then impossible. Other publications, which use statistical analysis for intended values of reaction time, obtain additional information such as standard deviation, percentiles, etc. Then, the variant analysis of the situation is possible. The best solution would be to determine, during specialist research, the reaction time for a specific driver – accident culprit and to know his or her reaction. You have to realize, however, that it would be difficult in such a situation to reproduce perfectly the traffic situation, because in a structured situation driver's reaction may be yet determined at the time by a number of circumstances, for example [1]. Sole reproduction (simulation) of a similar situation at the site of the accident, may seem difficult and unethical, as it would be very expensive and would make people taking part in it re-live the nightmare of the accident.

The professional literature shows many studies of drivers' behaviours in case of emergency situations, including their reaction time. It also presents factors that may have an impact on drivers' behaviour. The following paper presents the results of the studies of drivers and diversity of their behaviour in such situations.

Overview of the factors affecting the behaviour of drivers and test methods

The behaviour of a vehicle driver in road traffic is dependent on his or her psycho-physiological properties such as reaction time, hand-eye coordination, perceptual abilities, specific personality traits, temper, ability to anticipate changes in emergency situations, etc. An important influence on the behaviour of a driver while driving is the surrounding environment.

Driving efficiency may be affected by:

– fitness determined in clinical tests;
– verified for example as a result of psychological tests, fitness to drive motor vehicles and its mental fitness;
– driving skills, knowledge and experience of a driver;
– various factors causing scattering his attention for example talking on a mobile phone, talking to a passenger, etc.

Fatigue caused by long riding, the monotony of driving and other external factors such as the state of the road surface, the noise emitted by other vehicles, the degree of "density" of traffic can also determine the behaviour of a driver. As a result of the wide variety of factors that may affect the behaviour of a driver, in the literature there are examples of the various drivers' tests in various driving situations and on different devices by different methodology, because the behaviour of a driver is still not fully understood.

Research methodology largely depends on the environment of research in which they are implemented and the goals pursued by this type of research. Such studies can be carried out on separate research stands (e.g. stands for psychological research) in driving simulators or on test tracks [2, 3, 4].

Reaction times values are determined in drivers' clinical behaviour tests to a variety of stimuli that interact with a driver. During studies to the so-called simple stimulus, the task of a driver is the reaction to an item of car control, for instance, the brake pedal, acceleration or steering wheel. An example of such research are studies conducted by Burckhardt and Burg [5], which involved two vehicles, and a driver driving a car reacted to brake lights illuminated in a car in front. In other studies, a driver reacted to the light pulse from the lights unit stuck on the windscreen [6], or the ring tone [7].

The reaction of drivers (including the value of reaction time) can be affected by many of the above-mentioned factors related both to the environment, driver and vehicle. These include, for example, the state of the environment, weather, driver's age, driver's emotional state, psycho-motor performance of a driver, the presence of alcohol, drugs, and other similar substances in driver's body [8, 9, 10, 11, 12, 13].

Among many studies of drivers we can cite research to assess driver's distraction or loss of concentration caused by the phone call on a mobile phone (with or without a hands-free set), listening to the radio in the car, talking with a passenger during his or her reaction [14, 15] etc. In order to avoid an accident the driver performs various manoeuvres: braking and bypassing, and the amount of information that reaches the driver is significant. Paper [16] describes the study of the complex stimulus which uses light stimulator stuck to the windscreen. The driver during the study was designed to react to both, the colour of lit lamps, and their layout (colours of the lights and their arrangement in fact corresponded to a specific manoeuvre).

Tests of drivers' behaviour conducted on special measuring stands may refer to reaction time which is determined for disabled drivers or drivers after diseases or surgeries. They may be carried out, among others, to determine the degree of disability, rehabilitation progress of drivers after orthopaedic surgeries such as total replacement of the knee [17], hip [18] etc., or the impact of various diseases such as Parkinson's on driver's psycho-motor performance [19]. Among many important factors affecting the behaviour of a driver, which are analysed in various tests, we may find tiredness [20], somnolence [1], fatigue [21] and alcohol, for example [10, 13].

Test tracks include the realization of drivers' tests in a variety of specific accident situations. An example of such a study could be the one described in [22], in which on-track tests simulated a perpendicular vehicle intrusion to the crossroads, a small children's bike [23], ball [24] or a cardboard box thrown on the driving track [25].

The authors of this publication for many years have conducted research implemented in real-life conditions (on the track) of some specific accident situations.

The studies of the authors conducted in 2004–2005 used a Styrofoam model entering the area of the road at the moment a test vehicle reached the proper distance from an obstacle [26, 27, 28, 29]. The study was conducted at a simulated crossroads of two two-lane, two-way roads, with reduced visibility (through the use of double-sided curtains) on the right and left sides. The behaviour of a driver in this study was recorded using specialized equipment installed in the test vehicle. These studies were also conducted in a driving simulator, and the results were published in [28, 30].

The studies carried out by the authors beetween 2006–2010 included three different accident situations. The first one consisted in a car entering the crossroads perpendicularly from the right of the road whereas on the opposite left lane of the road, was another test vehicle moving in the opposite direction, which significantly limited space for bypassing manoeuvre [31]. Another simulated traffic situation included a pedestrian entering perpendicularly the road in front of an oncoming vehicle from the right side in the right lane, and the drivers could only bypass the pedestrian on the left side [32]. Research was also carried out for a situation in which a truck moved in front of an oncoming vehicle from a transverse road from the right side in such a way as it blocked both traffic lanes (it was impossible to bypass it) [33].

Methodology of on-track tests

The analysed new scenario included two models of pedestrians, which entered the road area from the side, both from the left and from the right side of the road (Fig. 1). During the studies drivers were not forced to behave in a particular way in a simulated accident situation. The drivers themselves decided what defensive manoeuvre to use at the moment (only braking, only avoiding obstacles, or both actions at the same time). Each of the 30 tested drivers aged 22–25 years (the group of biggest risk), performed 10 rides for both models emerging from the left and from the right sides, for each of the 10 values of TTC in the range between 0.6–3.0 s.

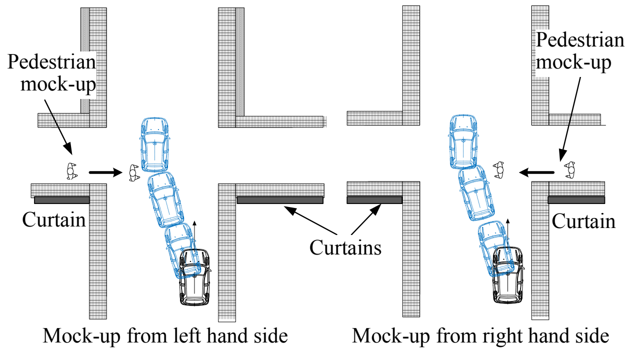

Fig. 1. Implementation scheme of an accident situation

TTC (Time To Collision) that characterizes an accident situation is the resultant parameter used in previous studies and publications by the authors [26, 27, 29] when determining the distance to the obstacle in time (in these works referred to as risk time). TTC is calculated as the quotient of a test vehicle distance from obstacle S to its speed V at the time of accident risk occurrence – equation (1):

$$\mathrm{TTC}=\frac{S}{V} \qquad (1)$$

where: S – distance to obstacle, V – vehicle speed to obstacle.

Tests conducted on the track used a specially prepared test vehicle (Fig. 2) which was equipped with specialized measurement apparatus used to determine the behaviour of a test driver and the parameters of the test vehicle.

Fig. 2. Test vehicle at a measuring section

Analysis of the diversity of drivers' behaviours

The reactions of drivers to the simulated emergency situations in the analysed studies varied. Although the study group of drivers were in similar age 22–25 years, they reacted differently to an identical accident risk situation.

Figure 3 shows the reaction on the brake pedal (expressed as a percentage stroke) for all test drivers for the selected situation of 1.44 s TTC, when the obstacle emerged from the left side. As it can be seen, these reactions differ not only in average reaction time, which is from 0.6 to 1.9 s, but also in the intensity of the reaction.

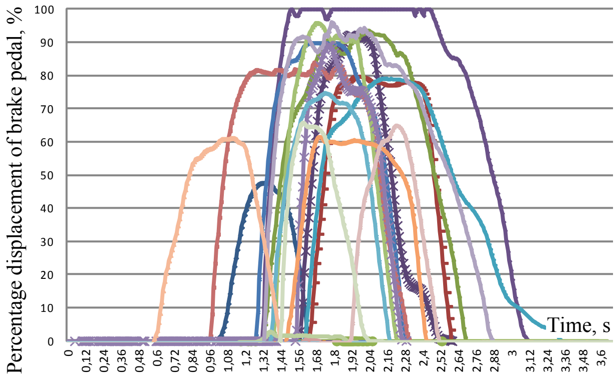

Fig. 3. The reactions of different drivers with a brake pedal to the situation of TTC equal to 1.44 s for the obstacles entering from the left side

The reaction on the brake pedal of many drivers was "muted", while others braked much more intensively using "maximum" brake pedal stroke. The study also noted, although very few, drivers who did not react with a brake pedal to simulated threat or reacted only after bypassing an obstacle after a collision with it.

Figure 4 shows the comparison of drivers' brake pedal reactions for a test of the same TTC, whereas an obstacle of a pedestrian emerged from the right side of the road. As it may easily be seen, the characteristics of brake pedal displacements is in this case also vary. Average reaction time of most drivers is contained in a smaller range of 0.3÷1.3 s. It may be noticed that slightly larger number of drivers decided to "stronger" press the brake pedal, as evidenced by increased number of characteristics in which the stroke of the brake pedal exceeds 80–90%.

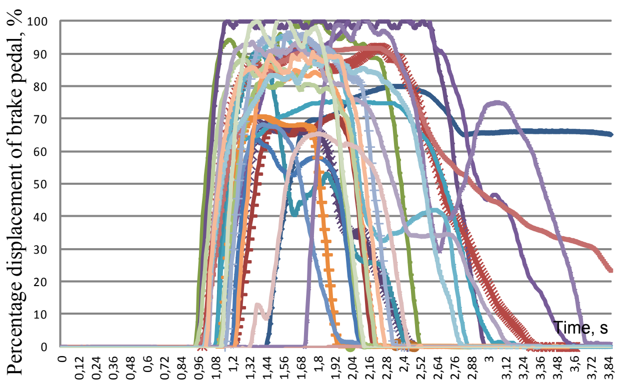

Fig. 4. The reactions of different drivers with a brake pedal to the situation of TTC equal to 1.44 s for the obstacles entering from the right side

Figure 5 illustrates the variety of behaviours of a selected driver for different simulated situations (with different TTC) with reference to the brake pedal reaction. Driver's reactions have been presented for both versions of the scenario, when an obstacle entered from the left and right side of the road. Driver's reactions on the brake pedal differ. The driver reacts more rarely to an obstacle entering from the left side, performing such a manoeuvre especially in situations with less TTC.

Figure 6 shows driver's reactions on a steering wheel (identified as a turning manoeuvre) in all ongoing tests in this scenario. Driver's reactions also differ in terms of both quantity and quality. As in the case of the reaction on the brake pedal, they differ not only with the time of its initiation (driver's reaction time), but also its intensity and maximum values, including the values of the steering angle. What is important, in both implemented versions of the accident situation the significant difference in the behaviour of the driver is visible.

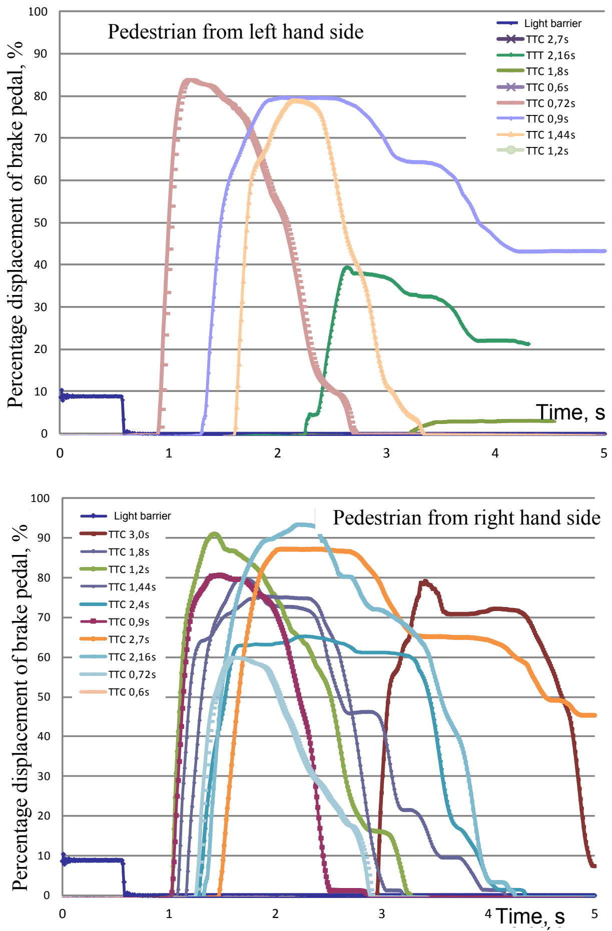

Fig. 5. The variety of reactions of a selected driver to a brake pedal

The question may therefore be asked. Whether in the case of such large discrepancies of drivers' reactions, when analysing such a large discrepancy of recorded rides, it can be assumed that the results of averaging the reaction time, the adoption for example of such a single arbitrary value, can be used in the analysis of road accidents?

Reactions of a driver on the wheel steering – Figure 6 – to an obstacle in the form of pedestrian's silhouette entering from the left side are calmer. It can be said that, in these tests, in principle, the driver only tries to correct the path of the vehicle, while in the case of an obstacle which appears from the right side road, these reactions are more spontaneous.

The authors in their publications for many years have requested that drivers' reaction times were not accepted as single arbitrary value, but to use reaction times that vary in the function of TTC (various test parameters of the sample – vehicle's speed and distance to an obstacle). Since the reactions vary greatly, the reaction time used in the reconstruction should be determined for a similar situation accident, because as it can be seen, even change of the direction of obstacles entering the road may affect the parameters that characterize the behaviour of a driver.

Figure 7 shows the areas of obtained reaction times for 30 tested drivers and for tests of various TTC, limited at the top with 75 percentile value, while the bottom with 25 percentiles for both versions of the scenario. The area between the percentile values assigned to the accelerator pedal reaction time to an obstacle emerging from the left is larger, which also confirms greater dispersion of values of reaction time obtained by drivers. It is worth noting that percentile lines 25 and 75 in the case of the acceleration pedal are almost parallel to each other.

Figure 8 shows the values of reaction time on the brake pedal. Similarly to the reaction on the accelerator pedal, the average reaction time to an obstacle appearing from the left side of the road is also greater. The difference is slight for small values of TTC but increases with the increase of TTC. For tests with higher values of TTC, the difference of average values reaches 0.3–0.4s. Figure 8 additionally shows areas of reaction time on the brake pedal limited by percentiles 25 and 75.

The area between the percentiles for the designated reaction time to an obstacle emerging from the left is slightly greater for tests with low TTC. With the increase of TTC, the spread between percentiles 25 and 75 for both versions of the scenario is similar.

Figure 9 shows average values of reaction time and percentiles 25 and 75. In the case of reaction on the steering wheel, drivers' reaction time span defined by the percentile value is the highest compared to the previous types of drivers' reaction and it is in the range 0.3÷2.1 s, and what needs to be emphasized, it also increases with TTC.

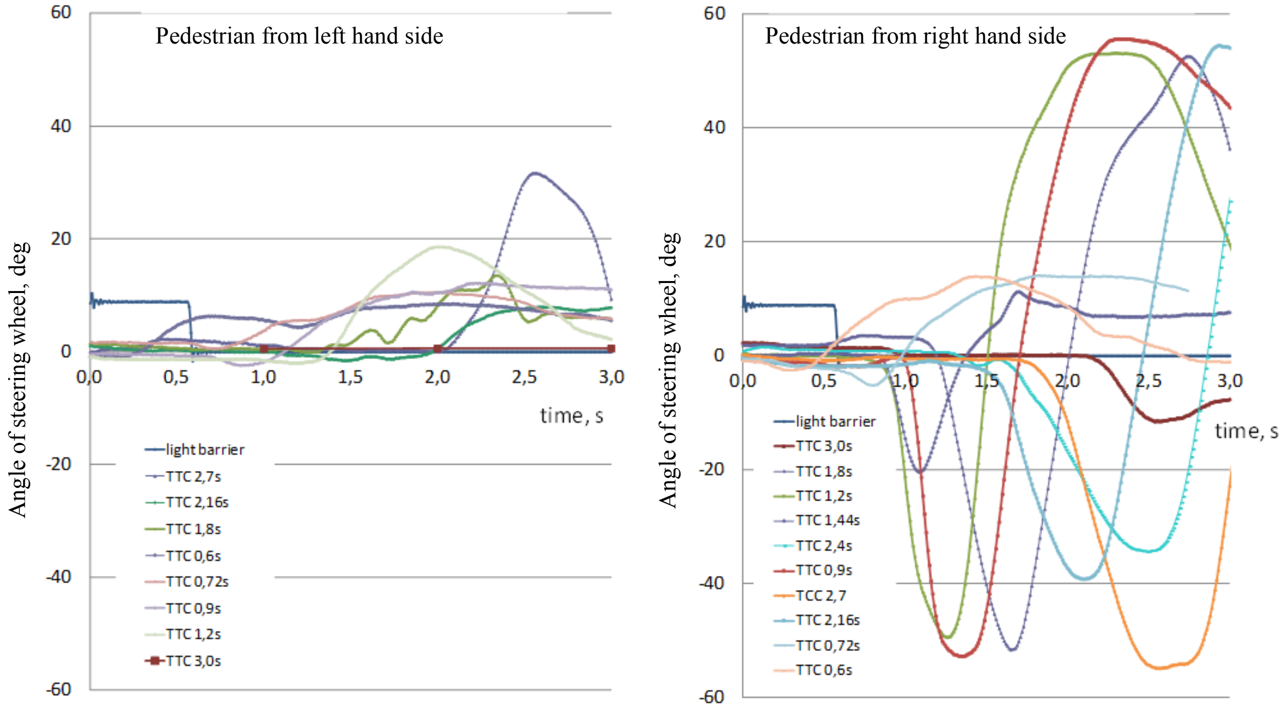

Fig. 6. Reaction to a steering wheel for a selected driver (tests of different TTC)

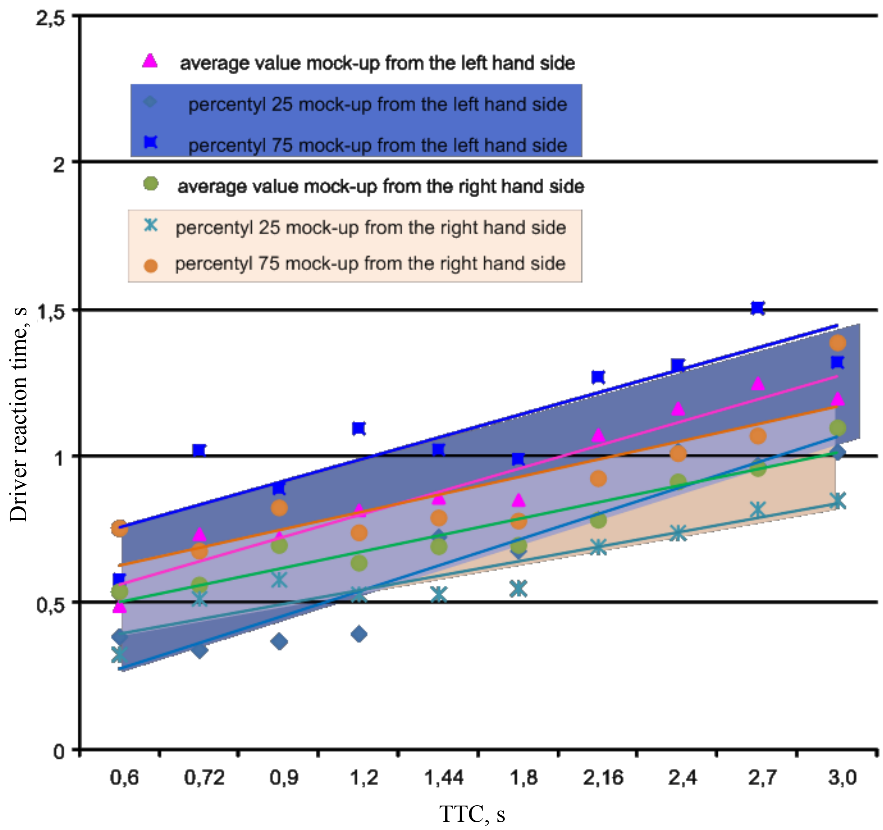

Fig. 7. Percentiles of driver reaction time to an acceleration pedal

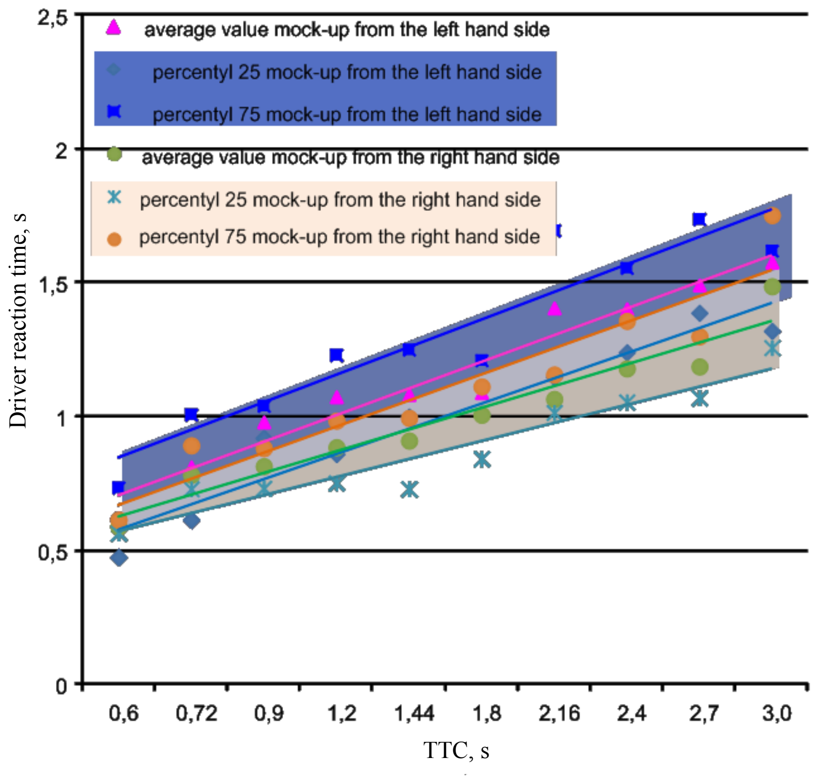

Fig. 8. Values of percentile reaction time to a service brake pedal

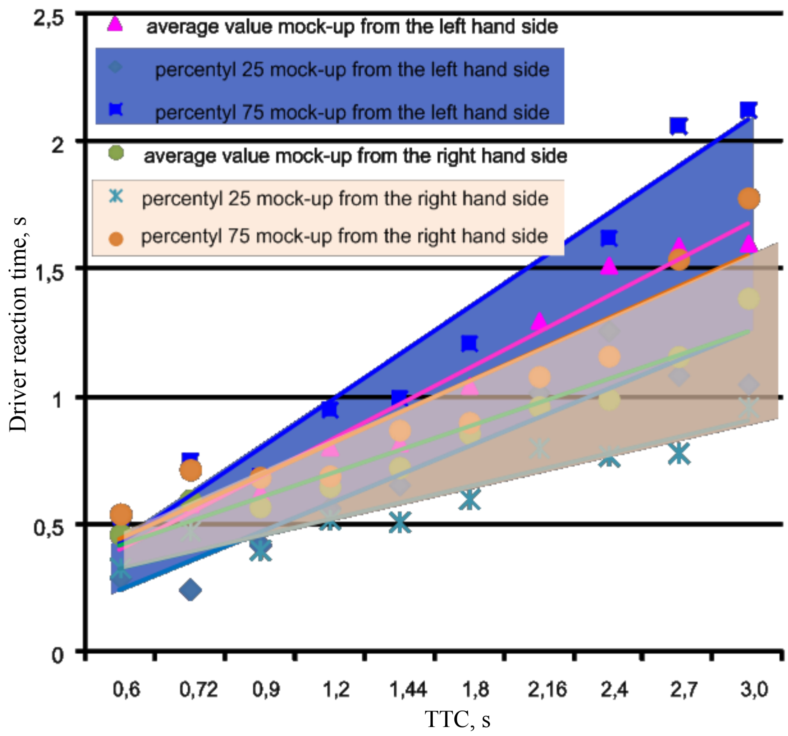

Fig. 9. Percentiles of reaction time to a steering wheel

Conclusions

Since the reaction of the same driver on a variety of simulated situations is different and in addition the differences of actions of various drivers on the situations with different values of TTC, in accident reconstruction one should use not only frequently presented only average values of reaction time, but TTC-dependent reaction times (which characterizes accident situations) along with ranges of "tolerance", for example, the values of the reaction time specified by the percentiles such as 25 and 75 or by the time average value ± standard deviation.

As you can see, in a relatively simple scenario that is discussed in this article, its even seemingly small alteration (pedestrian from the left or right side), can significantly affect the reactions of drivers, both in terms of quantity and quality. Therefore, the conclusion arises that the reconstruction of the behaviour of drivers, including consideration of reaction time, should be analysed with available results of studies with simulations similar to those that occurred in road situations.

The average value of reaction time to an obstacle emerging from the left is larger which means that driver's reactions are slower. By contrast, the scattering of reaction time results of a pedestrian to an obstacle appearing from the right side is smaller, which suggests that a variety of drivers' reactions to an obstacle emerging from the left side is also smaller. How can this be explained? It may result from their experience and habits of drivers, since moving on the right side of the road, they are frequently confronted with emergencies when obstacles emerge from that side. Obstacles entering from the right side can be treated by a driver as much higher risk (for example, there is less room for defence manoeuvre), hence the reactions of drivers can be much more intense.

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