A METHOD OF VEHICLE-PEDESTRIAN ACCIDENT RECONSTRUCTION

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Abstract: *This paper presents a method of vehicle-pedestrian accident reconstruction in case of vehicle low beam illumination and transverse movement of the pedestrian. This method allows to determine the pedestrian visibility time and pedestrian visibility distance in the case of nighttime accidents. The analysis of this type of accident is only possible if a certain shape and size of the illuminated area. This method can be very useful in the pedestrian accident reconstruction expert practice.*

Keywords: ACCIDENT RECONSTRUCTION, VEHICLE–PEDESTRIAN ACCIDENT

1. INTRODUCTION

In the Bulgaria alone approximately 130 pedestrians are killed as a result of motor vehicle crashes every year, and approximately 2000 are injured. In urban areas about half of vehicle accidents with killed people are pedestrian accidents. Pedestrian injuries from vehicle collisions arise from both the vehicle and the ground contact. Above 7 m/s collision speed, the vehicle impact is responsible for higher severity injuries [5]. The injury outcome in elderly pedestrians was more severe and the head severe injury proportion in children was more than that of an adult. Multiple injuries were common in pedestrians. The pedestrian injury outcome was relative to the impact speed [7].

Assessing the ability of a driver to see objects, pedestrians, or other vehicles at night is a necessary precursor to determining if that driver could have avoided a nighttime crash. The visibility of an object at night is largely due to the luminance contrast between the object and its background [6]. This difference depends on many factors, one of which is the amount of illumination produced by a vehicle's headlamps.

Vehicle-pedestrian accidents reconstruction is becoming critical in the field of traffic accident reconstruction [4]. Pedestrian accident reconstruction at nighttime differs from typical pedestrian accident reconstruction. Little attention has been paid to the investigation of such accidents in Bulgaria. The aim of this work is to be present a method of vehicle-pedestrian accident reconstruction in case of low beam illumination and transverse movement of the pedestrian.

2. METHOD AND DISCUSSION

Pedestrian visibility distance at night is limited in space, which is illuminated by the vehicle headlight beams (high or low). When the driver uses the vehicle's high beams, they illuminate the road over a distance of 100 meters and the driver can see and identify objects in this area. In this case the driver have enough time to react in case of hazard, provided that moves permitted by law speed. Furthermore, the pedestrian visible at a distance greater than the stopping distance for a car [3].

When the driver uses the vehicle's low beams the form of illuminated space in front of the car is asymmetric. In this case at transverse movement of the pedestrian the driver has a different time to see pedestrian and react. This time depends on the location at which the pedestrian crossing and enters the illuminated area in front of the car.

The main difficulty in this type of accident reconstruction is to determine the moment at which the pedestrian enters in the illuminated area where it is possible to be seen by the driver and pedestrian visibility time. Theoretically, this is the moment when the pedestrian crosses the 2,0 lx border luminance by a vehicle's low headlamps. The determination of this moment allows to determine the time at which the driver of the car has to perform action to prevent an accident.

The analysis of this type of accident is only possible if a certain shape and size of the illuminated area. Another prerequisite is known character of the movement of the car since the illumination of the pedestrian until the moment of impact - constant speed or deceleration.

Fig. 1 shows the low beams illuminated area in front of the car. The same figure shows and pedestrian that enters in the illuminated space.

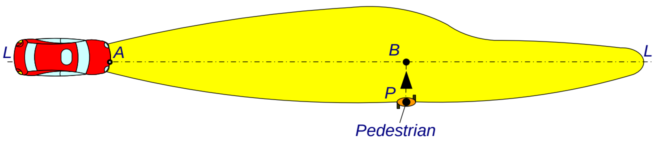

Fig. 1. *Low beams illuminated area and pedestrian*

With point ***A*** indicated the place of the vehicle, which hit the pedestrian. This point moves on the line ***LL***, provided that the vehicle moves rectilinearly.

From the moment of illumination of the pedestrian until the collision, vehicle travels a distance $D_v = AB$. For the same time the pedestrian travels a distance $D_p = PB$. Consequently, the time for movement of pedestrians from point ***P***, which is on the border of the illuminated area to point ***B***, located on the line ***LL***, can be calculated by the equation 1:

$$t_p = PB / V_p \text{, s} \tag{1}$$

where ***PB*** is the pedestrian distance D_p, travelled from the moment of illumination of the pedestrian until the collision, *m*;

V_p - pedestrian speed, *m/s*;

Once known shape and size of the illuminated area can be calculated pedestrian movement time t_{pi} for each point P_i from the border of the illuminated area to the line ***LL*** and draw appropriate graphics. Practical for this purpose are required at least 8-10 points.

Fig. 2 shows a graph that displayed the pedestrian movement time t_{pi} from point P_i to point B_i in a certain interval ΔL along the illuminated area.

Along the X axis is applied the illuminated area, and on the Y axis – the pedestrian movement time.

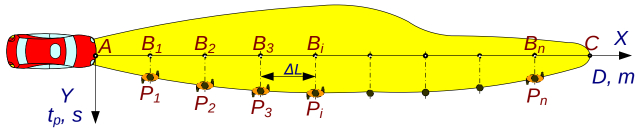

Fig. 2. *Pedestrian movement time in illuminated area*

The width of the vehicle B_v is given by the time for which pedestrians can travel that distance. It can be calculated by the equation 2:

$$t_{pv} = B_v / V_p \text{, s} \tag{2}$$

where $\boldsymbol{B_v}$ is the width of the vehicle, *m.*

If the vehicle is moving at a constant speed, it will go the distance $\boldsymbol{S_{vi} = AB_i}$ (Fig. 2) for the time $\boldsymbol{t_{vi}}$:

$$t_{vi} = S_{vi} / V_v \text{, s} \qquad (3)$$

where $\boldsymbol{V_v}$ is the vehicle speed, *m/s.*

The time $\boldsymbol{t_{vi}}$ is equals to the time $\boldsymbol{t_{pi}}$. These two times are equal to the pedestrian visibility time - $\boldsymbol{t_{pvt}}$ from the moment of illumination of the pedestrian until the collision.

Vehicle movements in the coordinate system "distance – time" at a constant vehicle speed is shown a straight diagonal line that passes through the coordinate system start.

2.1. Determination of the shape and size of the illuminated area on the road from vehicle's low beams.

The shape and size of the illuminated area on the road from vehicle's low beams is determined by measuring in 2,0 lx border luminance. Measurement data are filled in table 1.

Table 1. *Vehicle illuminated area*

№	*1*	*2*	*3*	*...*
D, m	5	10	15	...
$\boldsymbol{B_{r(l)}}$***, m***				...

The symbols in the table 1 have the following meaning: $\boldsymbol{D}$ is the distance ahead of the vehicle; $\boldsymbol{B_{r(l)}}$ - width of the right (left) half of the illuminated area in front of the vehicle.

2.2. Determination of the distance that the pedestrian travels in the illuminated area.

The distance $\boldsymbol{D_p}$, which the pedestrian travels in the illuminated area is determined by considering the position of the impact point on the width of the vehicle relative to its longitudinal axis by the equation 4:

$$D_p = B_v \pm \Delta \text{, m} \qquad (4)$$

where $\boldsymbol{\Delta}$ is the distance between the longitudinal axis of the vehicle and the impact point on the width of the vehicle $\boldsymbol{B_v}$, *m.*

Calculation data are filled in table 2.

Table 2. *Distance and time for the movement of pedestrians in the illuminated area*

№	*1*	*2*	*3*	*...*
D, m	5	10	15	...
$\boldsymbol{D_p}$***, m***				...
$\boldsymbol{t_p}$**, s**				

2.3. Determination of the time that the pedestrian travels in the illuminated area.

The time $\boldsymbol{t_p}$ that the pedestrian travels in the illuminated area can be calculated by the equation 5:

$$t_p = \frac{D_p}{V_p} \text{, s} \qquad (5)$$

Pedestrian speed $\boldsymbol{V_p}$ is determined by the rate of movement, age and sex of the pedestrian. The results of the calculations for the time $\boldsymbol{t_p}$, that the pedestrian travels in the illuminated area are filled in the last row in table 2.

2.4. Drawing of chart for the pedestrian movement.

Based on data from table 2 drawing of chart for the movement of the pedestrian according to the distance ahead of the vehicle (Fig. 3). X-axis is applied to the distance ahead of the vehicle $\boldsymbol{D}$, and on the Y-axis - pedestrian movement time $\boldsymbol{t_p}$ in the illuminated area.

2.5. Drawing of chart for the vehicle movement.

By different vehicle accident reconstruction methods known in expert practice is determined the vehicle speed $\boldsymbol{V_v}$ [1]. Set value of time (for example, *t = 2,0 s* – Fig. 3) and calculate the distance that the vehicle trqveled for this time at constant speed by the equation 6:

$$D_v = tV_v \qquad (6)$$

Using the coordinates of the value of the time (used for the above example *t = 2,0 s*) and the calculated distance $\boldsymbol{D_v}$ determined point in the coordinate system (poin $\boldsymbol{A}$). Drawing a straight line through the coordinate system start and the point $\boldsymbol{A}$ (Figure 3). This straight line represents vehicle movement.

2.6. Determination of the pedestrian visibility time and distance.

The place, where are crossed the line 1 constructed in the order specified in paragraph 2.4 and the straight line 2 that describes the vehicle movement (paragraph 2.5), determine the pedestrian visibility time (Y axis) and the pedestrian visibility distance (X axis) – Fig. 3.

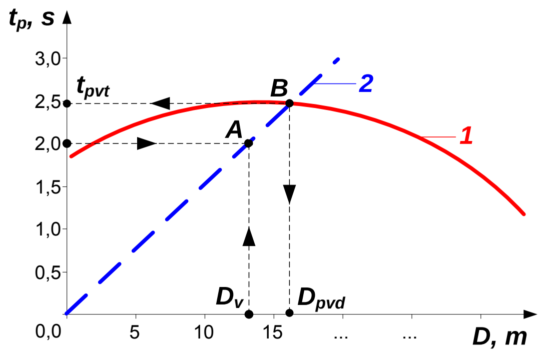

Fig. 3. *Determination of the pedestrian visibility time (*$\boldsymbol{t_{pvt}}$*) and distance (*$\boldsymbol{D_{pvd}}$*): 1- Pedestrian movement; 2 – Vehicle movement*

After determining the pedestrian visibility time and pedestrian visibility distance, analysis continues on known vehicle-pedestrian accident reconstruction methods [2].

2.7. Analytical determination of the pedestrian visibility time.

Based on data from table 2 to the time that the pedestrian travels in the illuminated area and the distance ahead of the vehicle can be obtained an equation by which discloses the graph that depicts the function of the time for the movement of the pedestrian according to the distance in front of the vehicle.

When a pedestrian has entered from the right side of the vehicle, equation which describes the movement of the pedestrian is equal to:

$$y = -ax^2 + bx + c \tag{7}$$

When the pedestrian has entered from the left side of the vehicle, for obtaining of the equation which describes the movement of the pedestrian are required from more points. It is a polynomial of the sixth degree:

$$y = -ax^6 + bx^5 - cx^4 + dx^3 - ex^2 + fx + g \tag{8}$$

Vehicle movement graphics is described by the equation of the first degree. This equation has the following form:

$$y = ax \tag{9}$$

By solving the equations 7 and 9 or 8 and 9 (depending on the direction of the pedestrian) was obtained value of the pedestrian visibility time.

Determination of the pedestrian visibility time by analytical method can be applied when is necessary determining at the visibility time for different variants of pedestrians movement.

3. CONCLUSION

In this paper, a new method for vehicle-pedestrian accident reconstruction in the case of nighttime accident was constructed.

The most important part of the paper is the possibility of determining the pedestrian visibility time and pedestrian visibility distance in case of vehicle low beam illumination and transverse movement of the pedestrian.

This method provides investigators a new possibility to reconstruct pedestrian–vehicle accident.

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