

## THE POSSIBILITIES OF USING AN OUTLINE CRASH SKETCH IN MODELING AND SIMULATION OF ACCIDENTS

**Abstract:** The paper underpins the reconstruction and analysis of a vehicle - motorcycle-biker-assembly collision type by means of a graphical method. The virtual modeling of the traffic accident reconstruction was achieved by complying the traces and the distances identified; hence it was imported and developed the accident scene sketch. Following the numerical processing of the simulation, the vehicles speed during the pre-collision, collision and post-collision phases was determined in graphical form, generating speed and space variation diagrams.

**Key words:** crash, sketch, automotive, simulation, motorcycle, reconstruction, graphics

### 1. INTRODUCTION

Contemporary civilization increased transportation demands and the constant need to transfer both people and goods has led to transport networks congestion, and subsequently to a considerably higher number of serious road accidents [6].

Under the circumstances, two-wheeled vehicles have been featured as rather efficient means of transport, both environmentally friendly and less massive considering roads occupancy degree.

However, due to the lack of special infrastructure and the heavy traffic, most developing countries have reported an increasing number of road accidents with serious injuries.

In the European Union, motorcyclists account for 15% of all deaths, as shown in Figure 1. For every 100,000 registered motorcycles, 11 deaths among motorcyclists are generally reported, compared to 5 deaths for every 100,000 vehicles registered [7], [8], which proves that motorcyclists are more exposed in the event of an accident.

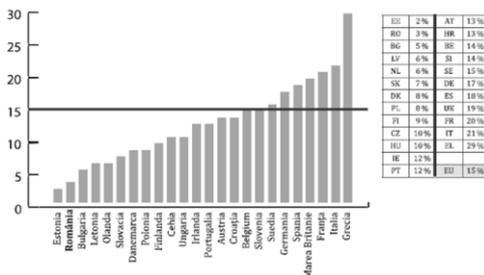


Fig.1 The death rate among motorcyclists.

Most victims (56%), lose their lives on interurban roads. At the other end of the scale, Estonia, Romania and Bulgaria have registered the lowest number of deaths, motorcyclists accounting for less than 5% of all deaths. However, it is necessary to consider that the total number of motorcyclists in these countries is considerably lower than the number of vehicle driver.

The most vulnerable categories of road users are pedestrians, cyclists and motorcyclists. A comparative

study on the assessment of injuries suffered by pedestrians and cyclists following collisions was carried out in [4]. Also, Serre et al., in [1], put forward in-depth investigations regarding the vulnerable users of road traffic, namely pedestrians and cyclists. The study includes both numerical simulations and experimental tests on PMHS (post mortem human surrogate).

As highlighted by mainstream literature, various research studies focused on the reconstruction and the dynamics of traffic accidents with vulnerable users. Still, only a few studies envisage the collision between a motorcycle and a motorcycle - motorcyclist assembly.

In what follows, the research study was set out to extend further developments on the investigation procedure of road accidents, especially the collision between a vehicle and a motorcycle.

The investigation method puts forward underpins the use of a software package to graphically illustrate both the production mode, and to graphically visualize the values of the parameters of interest.

### 2. APPLICATION FIELD

The reconstruction and the analysis of traffic accidents is nowadays more accessible and cost-effective via specialized software platforms.

Such software platforms provide a user-friendly interface. The tools, the predefined library elements and the editing option assist users to reconstruct a traffic accident, in compliance with the actual conditions of the accident under consideration.

The main goal of the paper is the virtual modeling of a traffic accident by reconstructing its dynamic stages. In this respect, it is important to observe the traces and distances, based on the accident scene scheme. Following the numerical simulation processing, the speed in the pre-collision, collision and post-collision phases was determined for the two vehicles involved in the road accident, hence speed and space velocity diagrams were generated.

To model and analyze the impact between a vehicle and a motorcycle-motorcyclist assembly, the Virtual Crash software platform was used.

### 3. VEHICLE - MOTORCYCLE COLLISION ANALYSIS

#### 3.1 Typical situations of vehicle - motorcycle collision

The consequences of a collision between a motorcycle and a vehicle depend on a number of factors; among the most important are the type and mass of the vehicle, the road-type, road coordinates and the impact direction, as well as the characteristics of the road and the environment

Among motorcycle accidents, the motorcycle-vehicle type are reported as most frequent and severe collisions (Figure 2). To frame the large number of data registered from real-life situations, six types of collisions were defined [2]:

- Type 1 collision ( $90^\circ \pm 20^\circ$ ): front vehicle - lateral motorcycle;
- Type 2 collision ( $180^\circ \pm 70^\circ$ ): front vehicle - front motorcycle;
- Type 3 collision ( $90^\circ \pm 20^\circ$ ): lateral vehicle - front motorcycle;
- Type 4 collision: corner vehicle - front motorcycle;
- Type 5 collision: rear vehicle - front motorcycle;
- Type 6 collision: front vehicle - rear motorcycle.

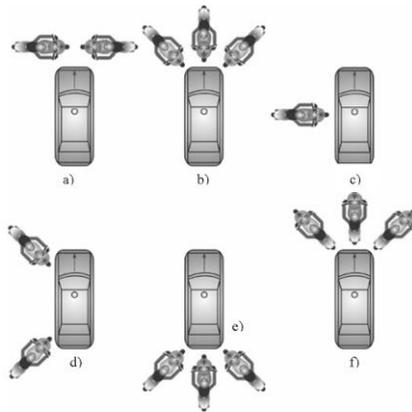


Fig. 2 Motorcycle-vehicle types of collision.

#### 3.2 Parameters used in the reconstruction of motorcycle - vehicle collisions

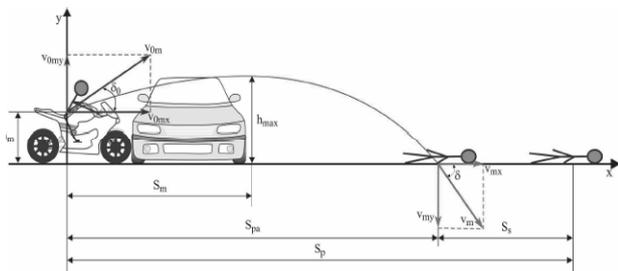


Fig.3 Scheme of a motorcycle-vehicle collision.

Where:

$S_m$  – the distance traveled by the motorcyclist until the center of mass reaches the maximum height

$S_{pa}$  – the distance traveled by the motorcyclist until the impact with the road

$S_s$  – the distance traveled by the motorcyclist on the road, until he reaches the final position

The vertical displacement of the motorcyclist, as presented in Figure 3, is characterized by the equation [3]:

$$y = h_m + v_{omy} \cdot t - \frac{g \cdot t^2}{2} = h_m + (v_{om} \cdot \sin \delta_0) \cdot t - \frac{g \cdot t^2}{2} \quad (1)$$

Where:  $t$  – is the random time

$h_m$  – mass center of the motorcyclist

The motorcyclist travels parallel to the road with a uniform motion according to the equation [3]:

$$x = v_{omx} \cdot t = (v_{om} \cdot \cos \delta_0) \cdot t \quad (2)$$

After solving the equation (2), in relation to the resultant  $x$  [3]:

$$x = \frac{v_{om}^2 \cdot \sin \delta_0 \cdot \cos \delta_0}{g} + \sqrt{\frac{v_{om}^4 \cdot \sin^2 \delta_0 \cdot \cos^2 \delta_0}{g^2} - (y - h_m) \cdot \frac{2 \cdot v_{om}^2 \cdot \cos^2 \delta_0}{g}} \quad (3)$$

If the land on which the motorcyclist is projected is at the same level as the road, then  $y = 0$  and  $x = S_{pa}$ , [3]:

$$S_{pa} = \frac{v_{om}^2 \cdot \sin \delta_0 \cdot \cos \delta_0}{g} + \sqrt{\frac{v_{om}^4 \cdot \sin^2 \delta_0 \cdot \cos^2 \delta_0}{g^2} + \frac{2 \cdot h_m \cdot v_{om}^2 \cdot \cos^2 \delta_0}{g}} \quad (4)$$

Where:

- the angle between the original trajectory of the motorcyclist and the road  $\delta_0$  [degree]
- gravitational acceleration  $g$  [m/s<sup>2</sup>]
- the motorcyclist initial speed  $v_{om}$  [m/s]
- the component in the horizontal direction of the motorcyclist initial speed  $v_{omx}$  [m/s]
- the component in the vertical direction of the motorcyclist initial speed  $v_{omy}$  [m/s]

### 4. METHOD USED

The working method proposed is based on the graphical representation of the accident scheme that has been imported in the platform used, for the configuration of the accident scene. The graphical representation of the intersection geometry is the starting point for the collision simulation.

#### 4.1 Image import in the working window

To accurately design the road, a geometric representation of the accident scene was imported in the main working window.

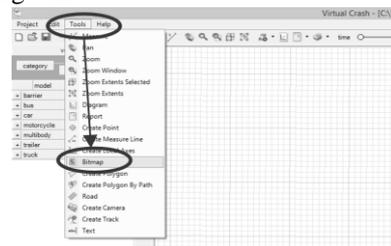


Fig.4 Image import in the working window.

To import the image click on the *Tools Menu* on the *Menu Bar* and select the *Bitmap option*, or click the *Bitmap icon* (Figure 4) on the *Icon Bar*.

After clicking the *Help Network*, the desired file will be selected in the window that appears, and then with the *Open* option the image will be imported. For the analyzed case, the image called *Intersection*, previously saved in the working folder, is imported. After uploading the image, the scale and the opacity degree was set. The value of these parameters is illustrated in figure 5: length: 100 m, opacity: 70%.

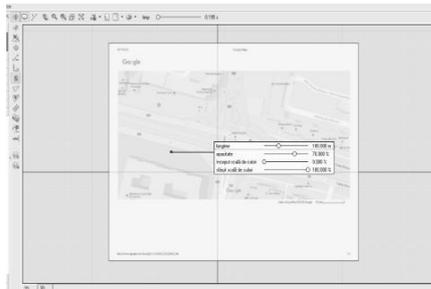


Fig.5 Parameters setting to import images.

#### 4.2 Virtual road design

The first step in the virtual reconstruction of the traffic accident is to model of infrastructure, namely the road section and the markings on the road. In this respect, it is necessary to design the road section considered, the road markings and the traffic signs so that the virtual simulation of the accident faithfully reflects the real accident scene. This stage is completed by using the *Tools Menu*, select the *Road option* (Figure 6) or just click the *Road icon* on the toolbar.

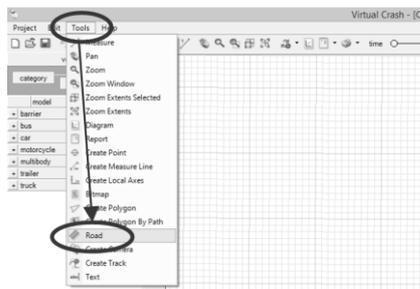


Fig.6 Virtual road design.

Once the road-network image is uploaded, the road section is designed observing the dimensions of the road section on this image, as presented in Figure 7.

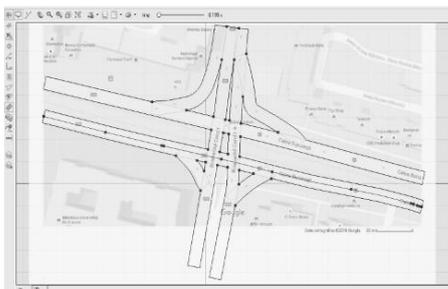


Fig.7 Virtual road section design.

#### 4.3 Road markings design

To import road markings click the *Polyline icon*, once this option is enabled, move in the working window and position the cursor above the road section to create road marking. In this case study, it was designed a longitudinal mark consisting of (Figure 8): interrupted line -> length 1 = 1.3 m, length 2 = 1.5 m.

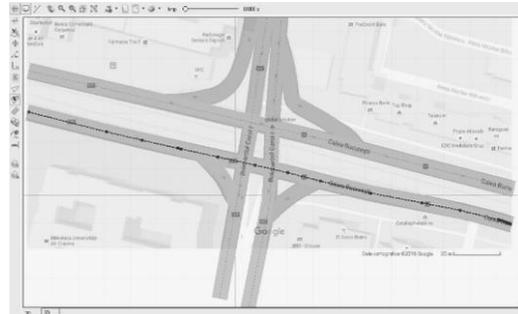


Fig. 8 Road markings design.

#### 4.4 Road user's identification and introduction

To access the predefined library elements:

- select the *Vehicle main menu*, choose the vehicle category and import it in the simulation; the manufacturer is considered, and, the desired model is selected from the list.
- access the *Vehicle main menu*, select the multibody - X category to import pedestrians in the simulation; and select data/multibody/pedestrian from the list.

To import items into the working window, select and hold the mouse left button (drag & drop). For the case under consideration, the following elements were imported:

- a Dacia Logan vehicle 1.4 – Figure 9
- a BMW K1 motorcycle – Figure 10
- a Multibody: pedestrian – Figure 11, 12



Fig.9 Vehicle identification and positioning.



Fig.10 Motorcycle identification and positioning.

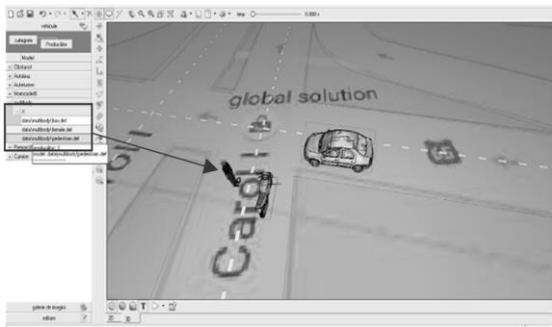


Fig.11 Multibody element import.

For the motorcyclist, a multibody-pedestrian element is selected and inserted. In the *Image Gallery*, it was selected the *d-pose* point and the *moto* image will be loaded onto the previously imported pedestrian, Figure 12.

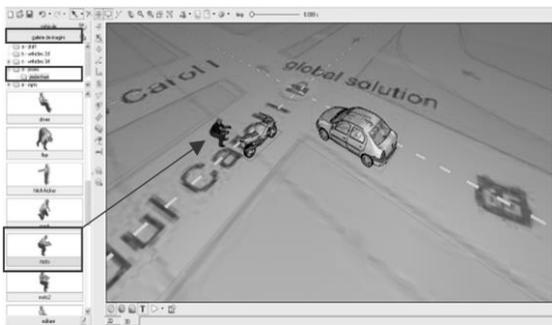


Fig.12 Selecting and placing the motorcyclist position.

The multibody element is positioned on the motorcycle via rotation and translation. Once properly positioned, it is assigned as a motorcycle link, see Figure 13.



Fig.13 Positioning the motorcyclist.

#### 4.5 Setting pre-collision data for road users

In the *Edit main menu* select the item (vehicle or pedestrian) whose data will be changed. At the bottom of the edit menu opens the window with the parameters that can be changed.

For the case under consideration, input the following initial data:

- Vehicle: initial speed = 40 km/h, Figure 14
- Multibody: initial speed = 60 km/h, Figure 15
- Motorcycle: initial speed = 60 km/h, Figure 15



Fig.14 Setting pre-collision vehicle data.



Fig.15 Setting pre-collision data for the motorcycle and its driver.

The following data for the vehicle is also known, Figure 16:

- the braking moment is simultaneous with the moment of impact
- a deceleration of  $4 \text{ m/s}^2$



Fig.16 The braking starting point and the vehicle deceleration.

After completing the presented steps, the integrated road accident scenario is illustrated in Figure 17.



Fig.17 Road accident scenario.

## 5. IDENTIFICATION OF COLLISION PHASES

In case of a vehicle-motorcycle impact, the following phases of the collision can be identified, Figure 18:

- Pre-collision phase: the moment before the two vehicles collides.
- Impact moment: the first contact between the vehicle and the motorcycle, as the cause of control loss of the driving direction by motorcyclist.
- The final position of the vehicles and the motorcyclist: after being projected on the road, from inertia, the motorcyclist is subjected to translation movements on the road until it reaches the final position.

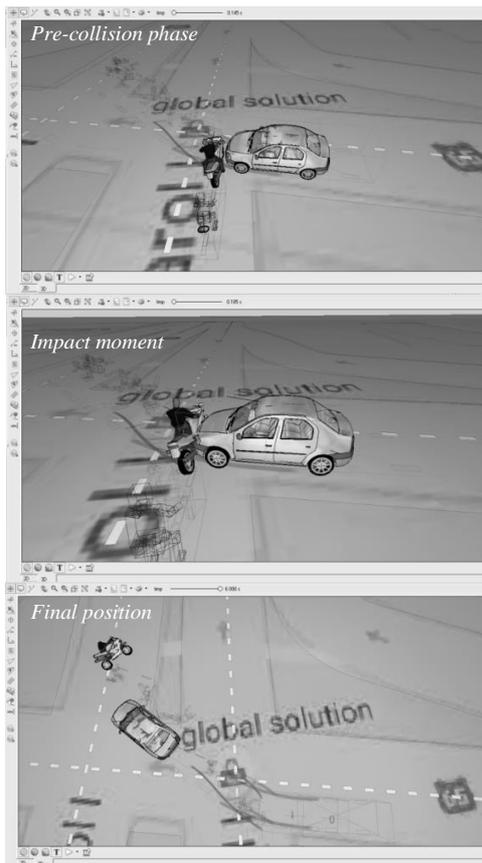


Fig.18 Collision phases identification.

## 6. RESULTS

The software processes a preliminary computation, the input parameter is the speed of the vehicle before the

collision, and hence compute the speed variations at the time of separation.

The software uses the Kudlich-Slibar [5] collision model that enables users to compute post-impact parameters using pre-impact data from the defined input data (mass, position). This model is based, on the one hand, on the fact that the collision takes place within a very short time-span and takes into account the vehicles displacements during the collision, and on the other hand, the transmission of force takes place in a single point.

The collision computation is based on the fact that the forces impacting on the vehicle are negligible, except the actual collision force [5].

The method uses pre-collision speeds as input parameter. It is necessary to consider the common displacement of impact points and to compute their speeds.

The diagrams generated by the Virtual Crash software enable users to graphically illustrate time and space simulation.

On the horizontal axis of the diagram are represented the time and/or space outputs and on the vertical the outputs compared to the display of the unit of measure.

In the Virtual Crash environment, the pedestrian is designed as a multibody, with 14 components. In order to generate a clearer and easier diagram, it was considered only the speed at the head of the dummy, see Figure 19.

The colors of the illustrated functions correspond to the colors of the matching vehicle. User interventions in motion parameters are signaled by the vertical lines in the chart.

### 6.1 Generating the speed diagram according to time

To generate the speed diagram according to time, open the diagram window after selecting the *Diagram icon* on the toolbar. From the time section, select the speed and then the items of interest, namely the vehicle, the motorcycle and the motorcyclist head.

The diagram in Figure 19 indicates the colors of the illustrated functions in compliance with the colors of the matching vehicles, respectively green for the vehicle, black for the motorcycle and blue for the motorcyclist.



Fig.19 The speed of the vehicle, the motorcycle and the motorcyclist - in the head area, depending on time.

Based on the diagram, the following parameters can be extracted:

- the impact moment: 0.2 s

- the pre-collision speeds are the initial parameters used for the simulation, namely: 40 km/h for vehicle, 60 km/h for motorcycle and also 60 km/h for the dummy
- the vehicle impact speed: 40 km/h
- the motorcycle impact speed: 60 km/h
- the vehicle post-impact speed: 32 km/h
- the motorcycle post-impact speed: 48 km/h
- the dummy speed before the impact: 60 km/h
- the dummy speed after the impact: 67 km/h

## 6.2 Generating the speed diagram according to space

To generate the space-based speed diagram, was applied the same procedure as previously, while speed will be selected under the space section. Based on the diagram from Figure 20, the following parameters can be extracted:

- the vehicle distance traveled before impact: 1.90 m
- the motorcycle distance traveled before impact: 2.40 m
- the vehicle distance traveled after the impact: 10 m
- the motorcycle distance traveled after impact: 14.30 m
- the motorcyclist distance traveled before impact: 2.40 m
- the motorcyclist distance traveled after impact: 17.40 m

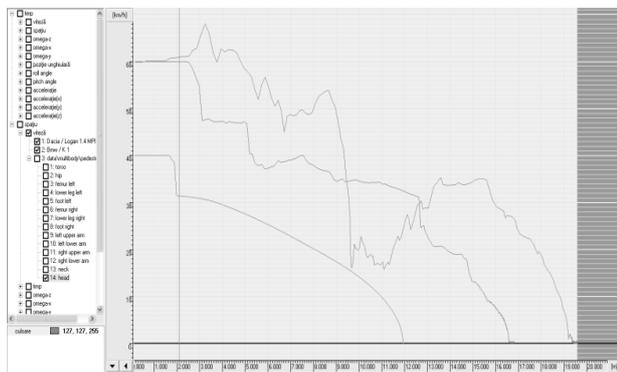


Fig.20 The speed of the vehicle, the motorcycle and the motorcyclist - in the head area, depending on space.

## 7. CONCLUSION

The graphical method applied within the present paper indicates the stages carried out to complete the virtual modeling of a traffic accident, namely an accident between a vehicle and a motorcycle-motorcyclist assembly via Virtual Crash software.

Following the undertaken steps, the kinematic and dynamic parameters of both the vehicle and the motorcycle, as well as for the motorcyclist were determined, by virtually modeling a vehicle-motorcycle collision type. Also, the graphical method enabled to identify and interpret the collision phases, generating at the same time the velocity variation diagrams depending on time and space.

After extracting the parameters, it can be observed a speed increased for the dummy, from 60 km/h to 67 km/h, and a decrease for the vehicle speed from 40 km/h to 32 km/h.

## REFERENCES

- [1]Serre T., Masson C., Perrin C., Chalandon S., Llari M., Py M., Cavallero C., Cesari D. (2007). *Real accidents involving vulnerable road users: in-depth investigation, numerical simulation and experimental reconstitution with PMHS*, International Journal of Crashworthiness, 12:3, 227-234 Volume 12, Issue 3, Publisher: Taylor & Francis, ISSN: 1358-8265.
- [2]Todorut, A., Barabás, I., Branzas, P., Gavrilas, C.A. (2010). *Reconstructia Accidentelor Rutiere Motocicleta - Automobil*, A X-a Conferinta Nationala multidisciplinara – cu participare internationala, “Profesorul Dorin PAVEL - fondatorul hidroenergeticii romanesti”, Sebes.
- [3]Todorut, A., Cordos, N., Barabas, I., Balcau, M. (2016). *Aspects Regarding the Numerical Modeling of Traffic Incidents between Motorcycles and Passenger Cars*, Technical University of Cluj-Napoca, Acta Technica Napocensis, Series: Applied Mathematics, Mechanics, and Engineering, Vol. 59, Issue II.
- [4]Tolea B., Tarulescu S., Trusca D.D., Toganel G., Radu A.I. (2017). *The Assessment of the Head Injury of a Pedestrian in Comparison with a Cyclist*. In: Chiru A., Ispas N. (eds) CONAT 2016 International Congress of Automotive and Transport Engineering. CONAT 2016. Springer, Cham
- [5]\*\*Virtual Crash – User’s Manual
- [6]\*\*Strategia Nationala de Siguranta Rutiera pentru Perioada 2016 – 2020 – Anexa I
- [7]\*\*European Road Safety Observatory – Brandstaetter, C., et al. (2012) *Annual Statistical Report, Deliverable D3.9 of the EC, FP7 project DaCoTA*
- [8]\*\*European Road Safety Observatory (2012). *Traffic Safety Basic Facts Main Figures*, project DaCoTA

## Authors:

**Assistant professor. Oana OTAT**, University of Craiova, Faculty of Mechanical Engineering, Department of Automotive and Transportation, otatoana@yahoo.com

**Assistant professor. Lucian MATEI**, University of Craiova, Faculty of Mechanical Engineering, Department of Automotive and Transportation, mateiclucian@gmail.com

**Professor. Victor OTAT**, University of Craiova, Faculty of Mechanical Engineering, Department of Automotive and Transportation, otatvictor@yahoo.com

**Professor. Ilie DUMITRU**, University of Craiova, Faculty of Mechanical Engineering, Department of Automotive and Transportation, dumitru\_ilie@yahoo.com

**Assistant professor Magdalena DRAGOVIC**, Faculty of Civil Engineering, University of Belgrade, Serbia, dim@grf.bg.ac.rs

© 2019. This work is published under NOCC (the “License”). Notwithstanding the ProQuest Terms and Conditions, you may use this content in accordance with the terms of the License.