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Identification of Driver Model Parameters

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The paper presents a driver model, which can be used in a computer simulation of a curved ride of a car. The identification of the driver parameters consisted in a comparison of the results of computer calculations obtained for the driver-vehicle-environment model with different driver data sets with test results of the double lane-change manoeuvre (Standard No. ISO/TR 3888:1975, International Organization for Standardization [ISO], 1975) and the wind gust manoeuvre. The optimisation method allows to choose for each real driver a set of driver model parameters for which the differences between test and calculation results are smallest. The presented driver model can be used in investigating the driver-vehicle control system, which allows to adapt the car construction to the psychophysical characteristics of a driver.

driver vehicle active safety driver-vehicle-environment system computer simulation

1. INTRODUCTION

Road traffic is one of the most dangerous areas of human activities. From among the three components of the driver-vehicle-environment system, the driver is the most unsafe part of this system: 70–80% of accidents are caused by the driver's mistakes. In this case a better understanding of the driver-vehicle control system, which makes it possible to adapt the car construction to psychophysical characteristics of the driver, is a method to improve the active safety of the car.

The active safety problem is part of the study of vehicle dynamics. A computer simulation of the curved ride and directional control of the car

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plays a significant role in this area as the cheapest and safest investigation method. An analysis based on an advanced dynamic vehicle model only is not satisfactory in many cases. A control response of the driver model, co-ordinated with visual stimuli and related to the dynamic vehicle control model can potentially make a correct simulation of the car motion possible. Traffic safety problems involving the interaction between the driver and the vehicle should also regard the highway environment. Therefore a system of these three elements and the vehicle-driver-environment model should be taken into consideration.

2. CONCEPTS OF THE VEHICLE-DRIVER-ENVIRONMENT SYSTEM

Various schemes for vehicle-driver systems have been considered and the driver-vehicle model structure has been developed and improved over the last years in several papers (cf. a more extensive list of publications in Guo & Guan, 1993). Many of these systems consist of three components: The first one represents the vehicle (road-vehicle kinematics and vehicle dynamics), the second one—the driver (his or her perception and response), and the third—the environment and the impact of different disturbances. A mathematical description of the vehicle is relatively easy. In this case for a description of the curved ride of the car a simple bicycle vehicle model can be used, although there is no restriction for using more complicated non-linear models, for example, Lozia (1998).

Much more complicated is the development of the driver model. His or her behaviour as a human controller can be changed in a very wide range. Psychological aspects should also be taken into account (Wicher, 1995). In order to describe the function of the driver mathematically, the driver model should be reduced to several conceptually simple parameters for closed loop compensatory vehicle control. One of the most important driver functions is directional control of the car. It was assumed that for directional control most important is the visual signal (the driver obtains more than 80% of all information in this way). Taking into consideration problems with identification of driver parameters, it was assumed that the driver model should be described by a possibly small number of parameters.

Thus the driver's steering control law, used in the model (Reński, 1998) is limited to a visual feed back loop and is defined as follows (see Figure 1): A driver observes an aim point A, which is situated on the desired path at a distance L_a down the road—aim point distance. The driver sees this point at an angle ε to the longitudinal axle of the car. This angle is equal to

$$\varepsilon(t) = \frac{y_d(x_{0S} + L_a) - y_{0S}(x_{0S})}{L_a} - \Psi(x_{0S}) \quad (1)$$

where,

$x_{0S} = v\ t$ — longitudinal position, the way covered by the car down the road;

v — constant speed of the car;

y_{0S} — lateral position of the car;

y_d — desired path deviation from x_0 axis;

Ψ — heading angle.

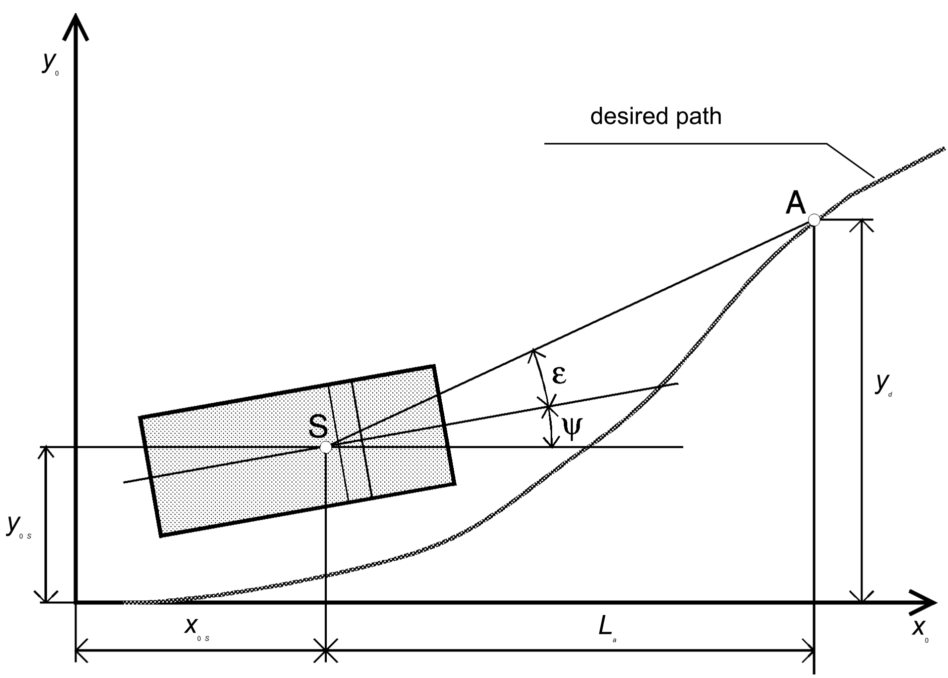

Figure 1. Driver's steering control law used in the driver model.

Steering angle δ_1 controlled by the driver is proportional to the ε angle (steering angle gain W). The driver response delay between position perception and steering response is T_k. Then

$$\delta_1(t) = W\ \varepsilon(t - T_k). \quad (2)$$

Finally,

$$\delta_1(t) = \frac{W}{L_a} y_d\left(t + \frac{L_a}{v} - T_k\right) - \frac{W}{L_a} y_{0S}(t - T_k) - W\,\Psi(t - T_k). \tag{3}$$

The block diagram of the model is shown in Figure 2. The desired path deviation from x_0 axis y_d, side force F_y (e.g., side wind), and torque M_z are external influences. The car lateral position y_{0S} and the heading angle Ψ are feedback signals. Thus the driver model is characterised by three parameters: aim point distance L_a, response delay T_k, and steering angle gain W.

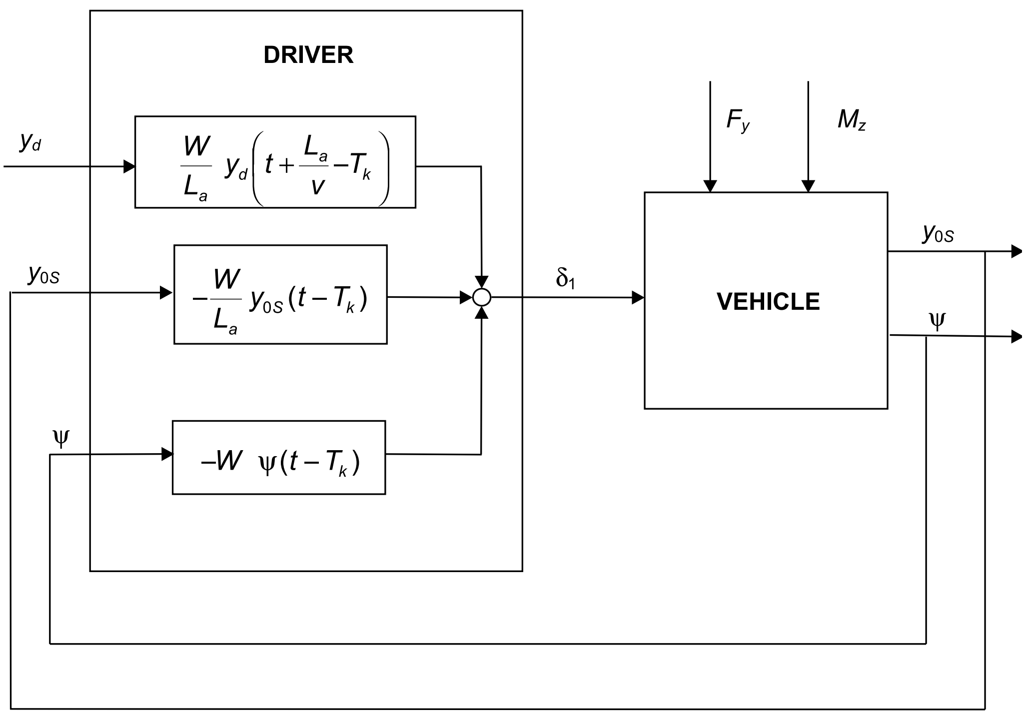

Figure 2. Block diagram of the vehicle-driver model.

The task of identification of these parameters can be set in two ways:

1. To find driver parameters that enable car's lateral deviation from its desired path to be possibly small;
2. To find driver parameters that enable the path realised by the driver-vehicle model to be possibly similar to the path realised by a real driver.

In both cases the optimisation method can be used.

3. DRIVER PARAMETERS THAT MINIMISE LATERAL DEVIATION FROM THE DESIRED PATH

In this case the “best driver” is searched. To identify the driver parameters, computer simulations of two manoeuvres are used: the double lane-change manoeuvre and the reaction to wind gust.

3.1. Double Lane-Change Manoeuvre

The track of the double lane-change manoeuvre according to Standard No. ISO/TR 3888:1975 (International Organization for Standardization [ISO], 1975) is shown in Figure 3. The track axis is assumed as a leading line, also the desired path of the car (compare Figure 1). Data of a medium-size car is used for calculations.

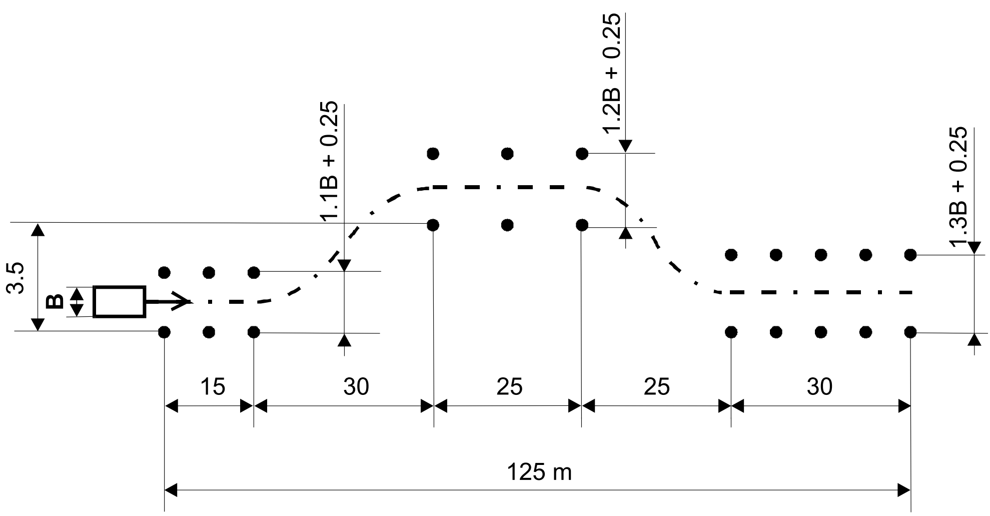

Figure 3. The track of the double lane-change manoeuvre according to Standard No. ISO 3888:1975 (International Organization for Standardization [ISO], 1975); B—car width.

In order to find the parameters of a driver model that can correctly pass the test, a number of car movement simulations for different driver parameter sets were carried out. The constant longitudinal car speed was 40 km/hr. Driver parameters were changed in the following intervals:

- aim point distance $L_a = 6 \dots 40$ m,
- response delay $T_k = 0.2 \dots 0.6$ s,
- steering angle gain $W = 0.2 \dots 1.2$.

As an optimisation criterion the average value of position errors in relation to track borders is assumed. The average value of position errors $<\Delta y>$ was calculated as follows:

$$\begin{aligned} & \Delta y = 0 && \text{for } y_{min} \le y_{0S} \le y_{max}, \\ \text{or} \quad & \Delta y = y_{0S} - y_{max} && \text{for } y_{0S} > y_{max}, \\ \text{or} \quad & \Delta y = y_{min} - y_{0S} && \text{for } y_{0S} < y_{min}, \end{aligned} \tag{4}$$

where y_{min}, y_{max} are a lower and upper border of the desired track. The error average value is

$$<\Delta y> = \frac{\sum_n \Delta y}{n}. \tag{5}$$

In Figure 4 the dependence of the error average value from aim point distance L_a and steering angle gain W for response delay $T_k = 0.4$ s is shown. An error equal to zero means a correct pass of the double lane-change manoeuvre. As it is evident from Figure 4, for a particular value of the response delay T_k the errorless manoeuvre can be realised for a number of sets of the other two parameters. The three-dimensional diagram in Figure 5 shows an interdependence between these three parameters. Each point situated under the shown surface represents driver parameter sets that make it possible to pass the test correctly.

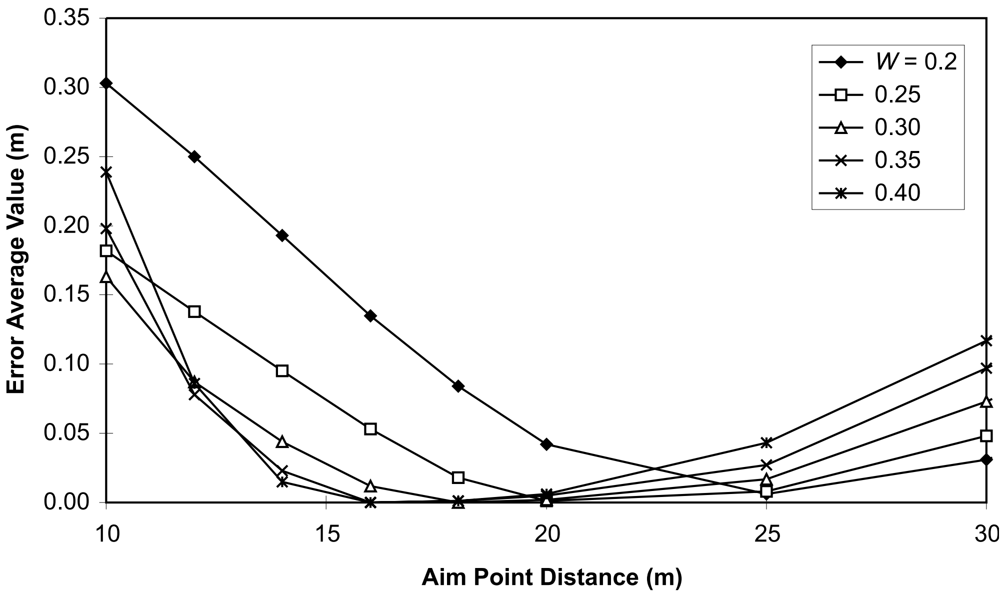

Figure 4. The average values of the car trajectory error as a function of aim point distance L_a and steering angle gain W for response delay $T_k = 0.4$ s.

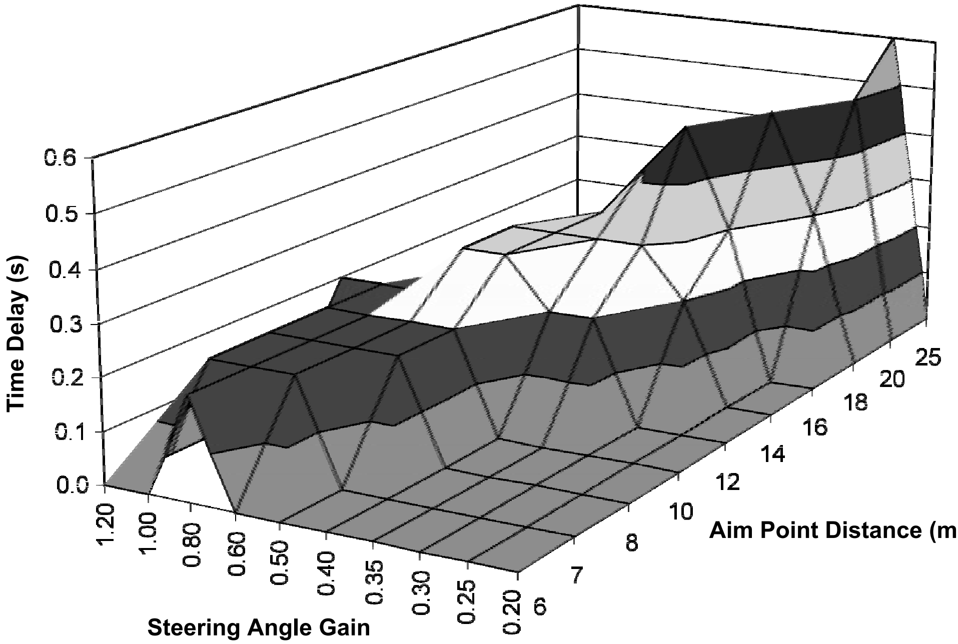

Figure 5. Interdependence between three driver parameters. The points situated under the shown surface represent the parameter sets that make it possible to pass the test correctly.

If the calculated car trajectory is compared not with the ISO test tolerance borders, but with the desired path (track axis), it is possible to find a combination of driver parameters for which car deviation from the desired path is smallest. In this case the average deviation from the desired path $<\Delta y>$ is calculated as follows:

$$\Delta y = \left| y_{0S} - y_d \right|, \tag{6}$$

$$<\Delta y> = \frac{\sum_n \Delta y}{n}. \tag{7}$$

It is self-evident, but not realistic, that the best results are obtained for the driver response delay T_k equal to zero. Therefore it is interesting how the other two parameters depend on the response delay. As an example, Figure 6 shows the dependence of the car average deviation from the desired path as a function of aim point distance L_a and steering angle gain W for chosen response delay $T_k = 0.4$ s. For this value of the response delay the minimum average deviation is obtained for aim point distance

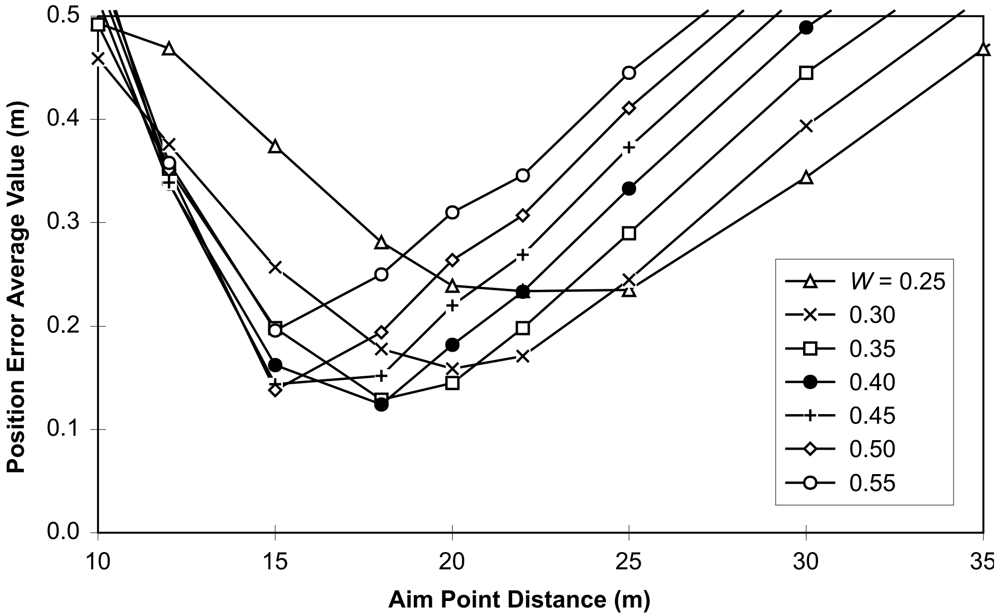

Figure 6. Optimisation procedure for the double lane-change manoeuvre: the average values of car lateral deviation from the desired path as a function of aim point distance L_a and steering angle gain W for response delay $T_k = 0.4$ s.

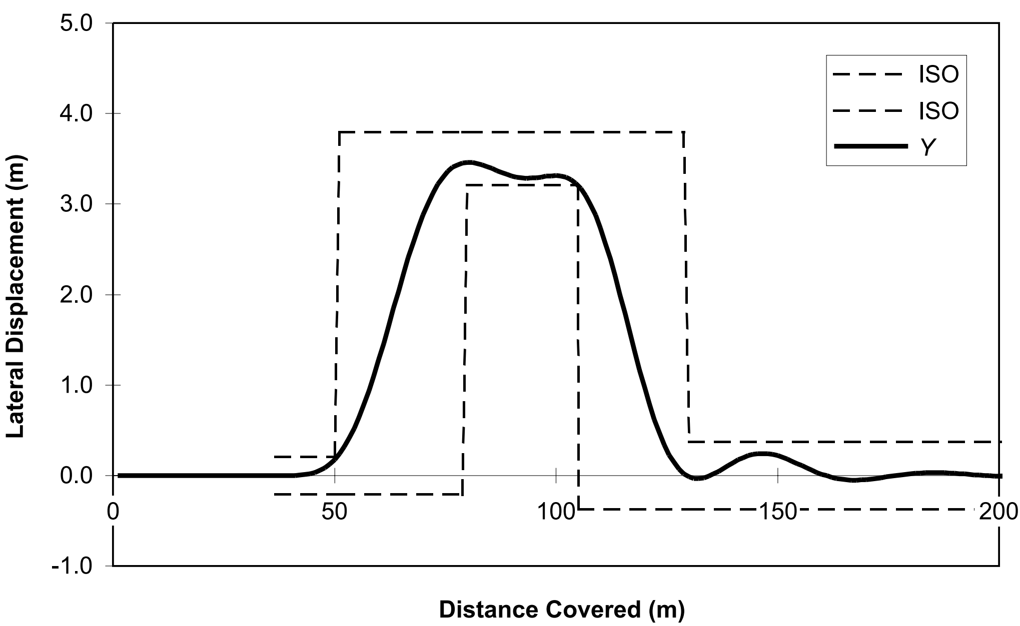

Figure 7. Calculated car trajectory Y for driver parameters: response delay $T_k = 0.4$ s, aim point distance $L_a = 18$ m, and steering angle gain $W = 0.4$.

L_a = 18 m and steering angle gain W = 0.4. An example of a diagram of lateral displacement versus the way covered by the car for this set of driver parameters, compared with the test tolerance borders (track width minus car width) according to Standard No. ISO 3888:1975 (ISO, 1975) is shown in Figure 7. Naturally, with other values of the response delay correspond different optimum combinations of the driver parameters.

Optimum values of driver parameters also depend on vehicle speed. In Table 1, the result of calculations, the optimum values of aim point distance L_a and steering angle gain W for response delay 0.4 and 0.6 s and vehicle speed 40 and 80 km/hr are compared.

TABLE 1. Optimum Values of Aim Point Distance L_a, Steering Angle Gain W, and Minimum Average Deviation From Desired Path $<\Delta y>$ for Driver Response Delay 0.4 and 0.6 s and Vehicle Speed 40, 60, and 80 km/hr

			Vehicle Speed (km/hr)		
			40	**60**	**80**
Response Delay T_k (s)	**0.3**	**L_a (m)**	12	22	30
		W	0.55	0.45	0.45
		$<\Delta y>$ (m)	0.09	0.11	0.14
	0.4	**L_a (m)**	18	25	35
		W	0.4	0.4	0.4
		$<\Delta y>$ (m)	0.12	0.16	0.21

3.2. Reaction to Side Wind

If the car's reaction to side wind with feedback control realised by a driver is investigated, the optimum driver parameters can be obtained in a similar way. Figure 8 shows an example of car lateral displacement caused by a wind gust. In the simulation, car velocity was 80 km/hr, and a wind gust of 5 s was equal to 300 N. Driver parameters, aim point distance L_a = 15 m, steering angle gain W = 0.45 for response delay T_k = 0.3 s, were obtained in the optimisation procedure, which is shown in Figure 9.

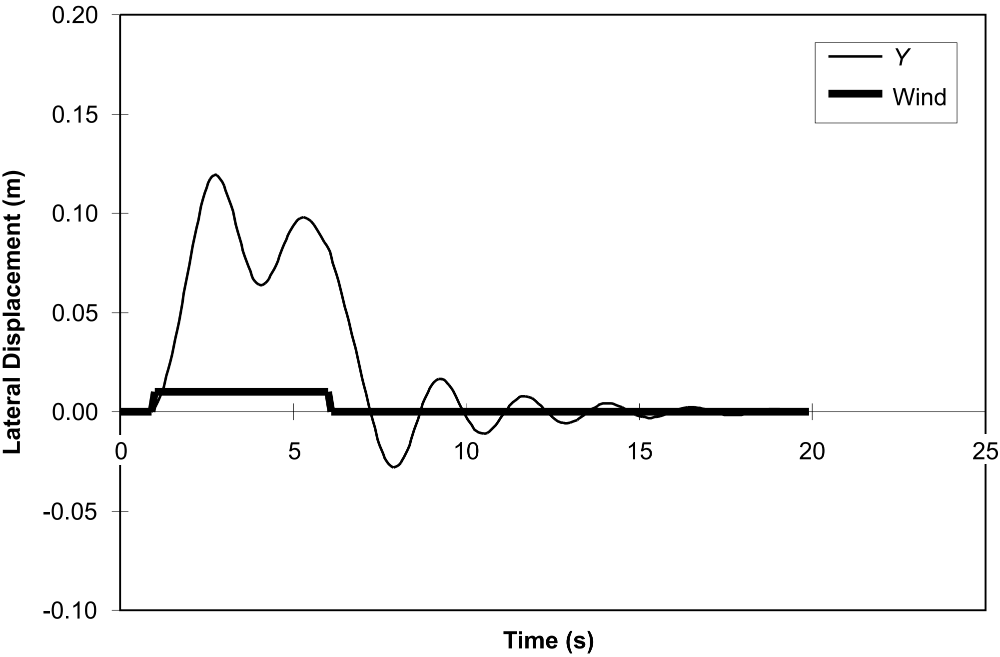

Figure 8. Car trajectory *Y* as a reaction to side wind.

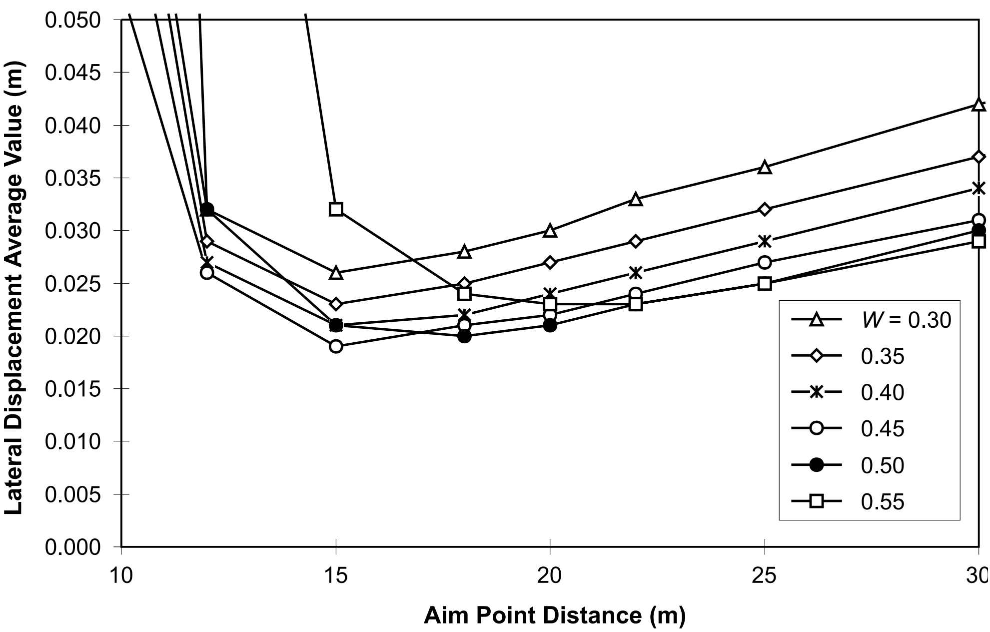

Figure 9. Optimisation procedure for the wind gust manoeuvre: average values of car lateral displacement calculated for time delay $T_k = 0.3$ s as a function of aim point distance L_a, and steering angle gain *W*.

4. DRIVER PARAMETERS THAT REPRODUCE THE PATH REALISED BY A REAL DRIVER

The optimisation method can be used for identifying real driver parameters. Figure 10 shows trajectories obtained by three drivers in a double lane-change manoeuvre simulated on a test stand (Reński, 1998; Reński, Pokorski, Lozia, & Stegienka, 1995). An example of the optimisation procedure for one of the examined drivers is shown in Figure 11. In Figure 12 the car trajectory resulting from a computer simulation for the driver model characterised by the parameters obtained in the optimisation procedure from Figure 11 is compared with the trajectory realised by a real driver (Driver 3 in Figure 10).

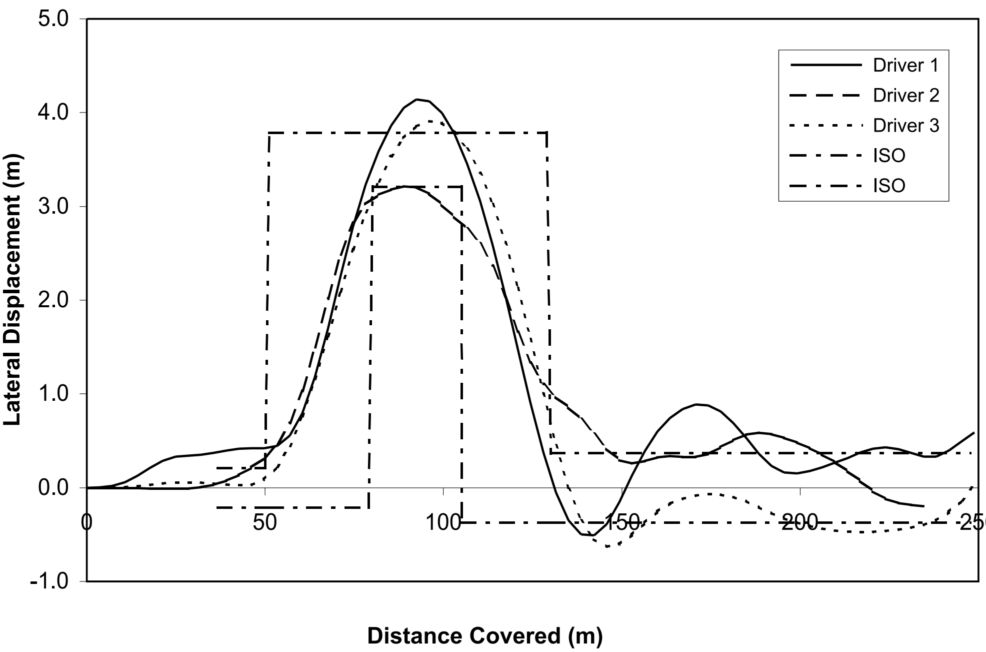

Figure 10. Diagram of the trajectories obtained on the test stand by three drivers.

The same method can be used in order to find the parameters of other drivers if the car trajectories realised by them have been recorded. As an example, the parameters of driver models that correspond with the car trajectories shown in Figure 10 are compared in Table 2. It can be stated that each real driver can be characterised by a different set of parameters.

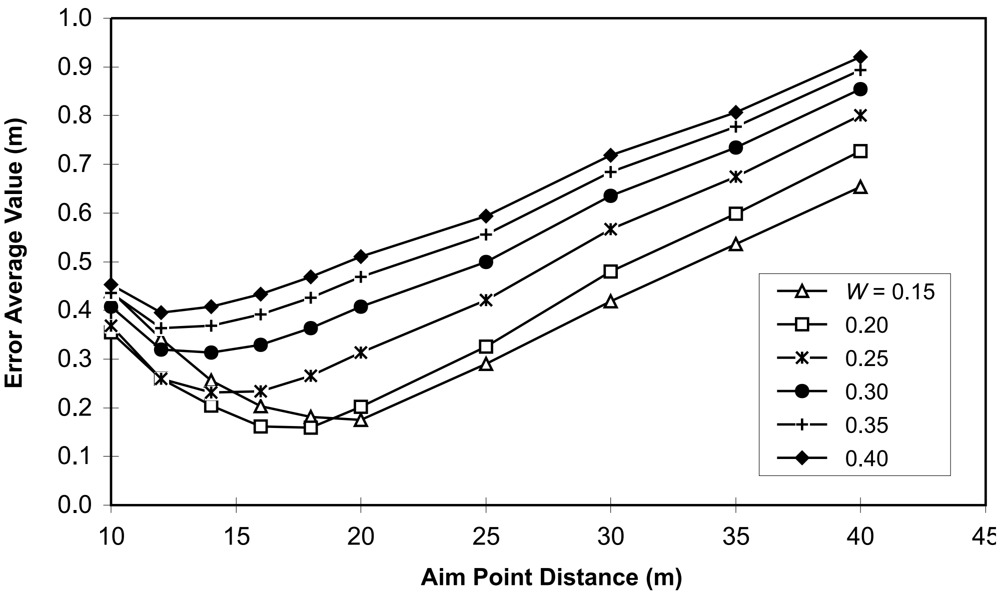

Figure 11. Optimisation procedure for the double lane-change manoeuvre: average values of the difference between the trajectory calculated for time delay $T_k = 0.2$ s and the trajectory realised by a real driver (Driver 3 in Figure 10) as a function of aim point distance L_a, and steering angle gain *W*.

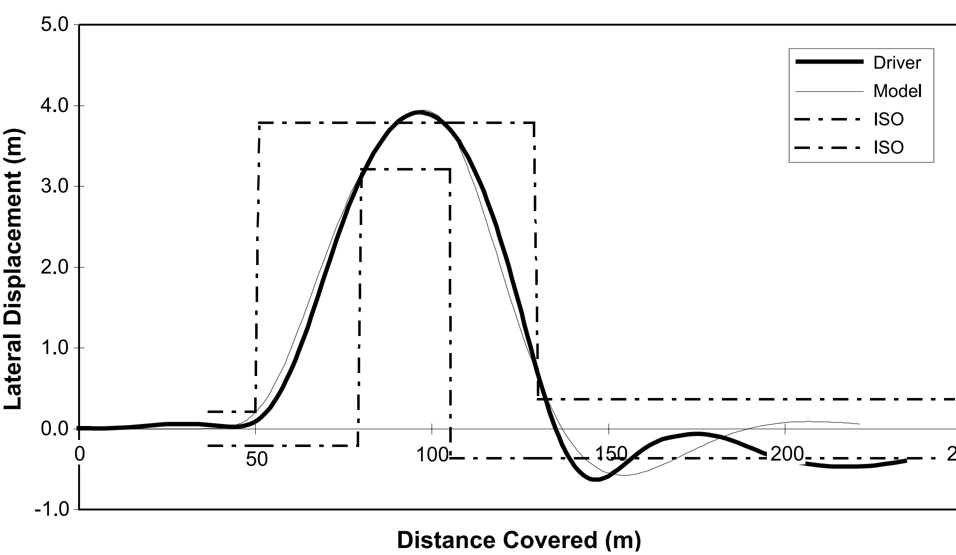

Figure 12. Comparison of the trajectories obtained on the stand (Driver) and as a result of a computer simulation for the driver model (Model).

TABLE 2. Driver Model Parameters for Real Drivers From Figure 10

	Model Parameters		
Driver	T_k (s)	L_a (m)	W
1	0.3	16	0.20
2	0.5	35	0.15
3	0.5	20	0.20

Notes. T_k—response delay, L_a—aim point distance, W—steering angle gain.

5. CONCLUSIONS

- The presented optimisation method allows to automatise the identification of driver model parameters.
- The optimisation procedure makes it possible to find for each driver a model characterised by a set of parameters, which in a computer simulation would be the best representation of his or her activity.
- As it is evident from Figure 12, the shapes of trajectories obtained in the computer simulation and on the test stand are very similar, therefore the presented driver model, though relatively simple, can be used in computer simulations.
- On the basis of many calculations it can be concluded that for a simulation of different manoeuvres (comparing differences in driver parameters for the double lane-change manoeuvre and reaction to wind gust) different driver parameters should be used.

The developed driver model can be used in studies of vehicle handling and stability when closed loop procedures are needed. The model can also be used for studies of the influence of different car parameters on the stability of the driver-vehicle system and in this way for a better adaptation of car dynamic properties to driver characteristics.

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