ACTUAL ACCELERATION, VELOCITY AND TRAVELED DISTANCE PROFILES OF VEHICLES IN URBAN ENVIRONMENT AS DOMINANT MICROSCOPIC TRAFFIC FLOW PARAMETERS

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Abstract: *In this paper we have presented a methodology used to determine actual acceleration, velocity and traveled distance profiles of vehicles of different categories in urban environment, as dominant microscopic traffic flow parameters. The tests have been done on representative arterial road in the city of Skopje. Within a period of one month, we have been observing the traffic on the subject arterial road and have determined the average traffic flow during different day periods. The structure of the traffic flow has also been analyzed. In the experiment we have used a probe vehicle equipped with adequate measuring system to follow more than 130 vehicles of different categories on the observed arterial road, imitating i.e. reproducing their behavior as much as possible. The final goal to determine the domains of these microscopic traffic flow parameters in specific velocity intervals, regarding different vehicle categories was reached. These results have shown to be very useful as input parameters in the single lane urban traffic flow simulator that we have developed.*

Keywords: TRAFFIC FLOW, MICROSCOPIC TRAFFIC FLOW PARAMETERS, ACCELERATION PROFILES, VELOCITY PROFILES, TRAVELED DISTANCE PROFILES.

1. Introduction

The propulsive idea of the performed research was to obtain knowledge about the real traffic conditions in urban environment through relevant traffic flow parameters [5, 7]. The reason for that is the need to parameterize actual daily traffic as a start for analysis of its weaknesses in an effort to improve it by engineering methods as introduction of components of Intelligent Transportation Systems. Afterwards the results could be used as input parameters in microscopic traffic flow simulators [3, 4]. Having in mind the complexity of the task, there is an obvious need to perform experimental research under appropriate methodology, with a goal to determine the structure of the traffic and dynamical behavior of representative vehicles of each category. This should be done without interaction of experimental procedure with the real traffic, and therefore no direct measurement of vehicles in traffic is acceptable. First off all we have selected a representative arterial road in the city of Skopje for observation, based on several factors like traffic flow, density, position in the city, etc. Then, within a period of one month, we have been observing the traffic on the subject arterial road and have determined the average traffic flow during the pick hours. Furthermore we have analyzed and defined the structure of the traffic flow regarding the presence rates of different vehicle categories, vehicle brands and models [2]. Based on these information we have selected those vehicle brands and models with the highest presence rates in the traffic flow to be used as measuring objects in the experimental research. In the experiment we have used a probe vehicle equipped with adequate measuring system. With the probe vehicle we have followed more than 130 vehicles of different categories on the observed arterial road, imitating i.e. reproducing their behavior as much as possible. Each measurement has started at the beginning of the observed arterial road and has ended when the vehicle has left the road. As a result we have obtained actual acceleration, velocity and traveled distance profiles of the observed vehicles. The final goal was to determine the domains of these microscopic traffic flow parameters in specific velocity intervals, regarding different vehicle categories [1].

2. Description of the measuring system used in the conducted experimental research

The dominant microscopic traffic flow parameters, i.e. vehicles actual acceleration, velocity and traveled distance, are obtained with a probe vehicle equipped with adequate measuring system. The system contains sensors, measuring amplifier and data registration and acquisition device. The schematic layout of the measuring system is shown on Fig.1.

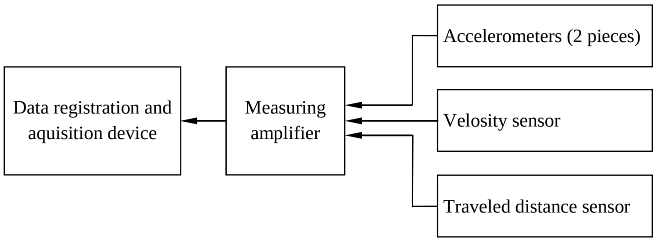

Fig. 1 *Schematic layout of the measuring system*

The acceleration is measured with two inductive HBM accelerometers, type B12/200. They have a measuring range of ± 200 m/s^2, linnear error below 2% and an output signal within the measuring range of ± 80 mV/V. These accelerometers are mounted in the probe vehicle in a lateral direction on the lowest possible point that corresponds to the vertical projection of the vehicle's center of gravity (Fig.2). In this way, the influence of the vertical and lateral acceleration components on the signal is minimized. The accelerometers are oriented in opposite directions in order to obtain a possibility to control their functionality and to evaluate the influence of other acceleration components.

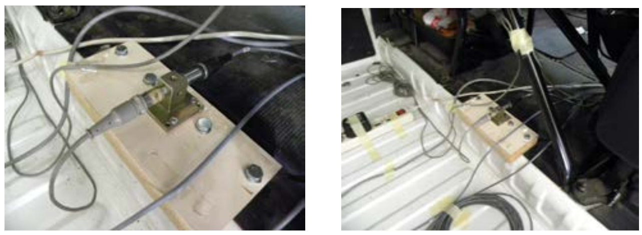

Fig. 2 *Accelerometers and their position in the probe vehicle*

For the velocity measurement, we have used a fifth wheel with an inductive sensor BALLUFF, type BES M12MI-NSC40B-BV03. The sensor has an operating frequency of 300Hz, working distance of 4mm and a guaranteed working distance between 0 and 3.2mm. The error is less than 5%. The fifth wheel with the sensor, within the designed measuring system, is shown on Fig. 3.

Fig. 3 *Fifth wheel and a sensor for velocity measurement*

Besides the velocity measurement, the signal from the sensor is also used to measure the travelled distance. With an appropriate adaptation of the electric scheme of the velocity sensor we have split (doubled) its output signal. In this way, one signal was used for velocity measurement and the other was used for travelled distance measurement.

The calibration process of the measuring system is performed with known physical properties which are applied on the sensors in the system. The accelerometers are calibrated according the ±g method, regarding their orientation in vertical direction. The velocity sensor is calibrated according to the frequency that corresponds to fifth wheel's angular velocity of 2π rad/s, and its rolling radius.

The above described sensors are passive sensors. Therefore, we have used a HBM measuring amplifier, type SPIDER-8, for their power supply and amplification of their output signals (Fig. 4). For data registration and acquisition we have used a PC and the data acquisition software HMB CATMAN 4.0.

Fig. 4 *Measuring amplifier HBM - SPIDER-8*

3. Program of the experimental research

In the conducted experimental research we have followed 131 vehicles of different categories along the selected arterial road. During the following process with the probe vehicle, we have measured their acceleration, velocity and travelled distance. Of the total number of vehicles that were followed, 93 were M1 category, 15 were M3 category, 17 were N1 category, 2 were M2 category, 2 were N2 category, and 2 were N3 category [6]. The selection of a vehicle as a measuring object was done primarily according to the presence rate of the vehicle's model in the inlet traffic flow on the observed arterial road. The following process of each vehicle (measuring object) has started at the beginning of the observed arterial road and has ended when the vehicle has left the road. In order to measure the subject properties of the followed vehicle, the process was performed with imitation i.e. reproduction of its behavior. The results of the measurement become relevant at the moment when the imitation of the measuring object begins.

4. Presentation and analysis of the experimental testing results

Fig. 5, Fig. 6 and Fig. 7 show the acceleration, velocity, and distance travelled by one vehicle from M1 category which has been followed within the frames of the experimental research.

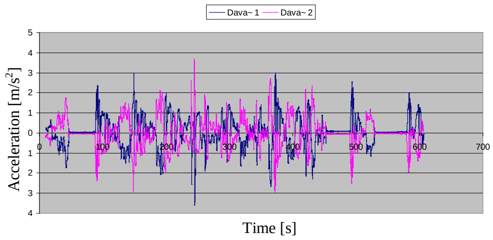

Fig. 5 *Acceleration of followed vehicle (Astra-G)*

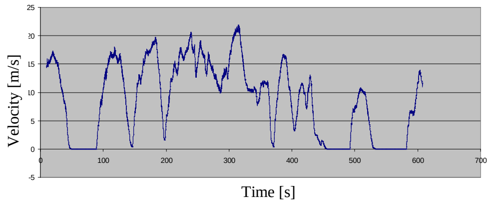

Fig. 6 *Velocity of followed vehicle (Astra-G)*

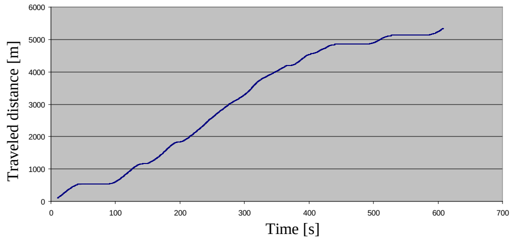

Fig. 7 *Distance travelled of followed vehicle (Astra-G)*

The acceleration profile is expected and normal during driving of vehicle in urban environment. Its characteristics are frequent accelerations and decelerations as a result of starting and stopping, or due to adopting the speed to the other traffic participants. It is obvious that acceleration and deceleration make pairs. Fig. 8(a) shows acceleration profile which is characteristic for starting and stopping. Fig. 8(b) shows the acceleration profile in the phase of adopting of the speed.

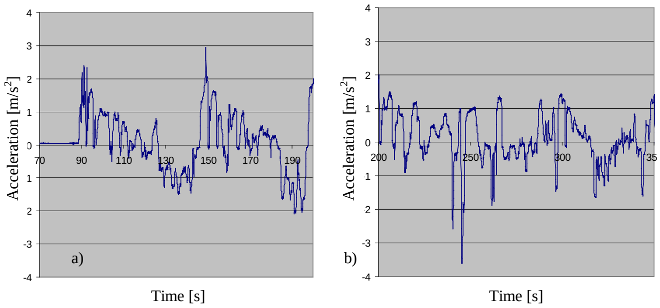

Fig. 8 *Characteristic profiles acceleration*

Characteristic acceleration profiles show that the vehicle after start reaches its maximum acceleration in a very short period of time. In this period the influence of vehicle inertia is noticeable. After reaching its maximum value, the acceleration decreases. The intensity of such decreasing depends of the driving style of the driver. During stopping phase three characteristic cases are noticeable: gradually increasing of the deceleration until the vehicle stops; gradually increasing of the deceleration to its maximum value and its maintaining until the vehicle stops, and fast increasing of the deceleration and then its relaxation untill the vehicle stops. The last case relates to the phase of adopting of the vehicle speed where main characteristic is frequent switching between acceleration and deceleration.

The velocity and distance traveled profiles of the vehicle are in line with the acceleration profile. Parallel analysis shows whether the acceleration happens in the phase of start, stop, or during adopting of the speed of the vehicle. This analysis shows also the actual location of the vehicle on the arterial road.

Fig. 9 shows phase diagram for the vehicle followed. It describes the correlation between the vehicle accleration and its velcity. This diagram is the basis to define maximum acceleration and deceleration of the vehicle in different intervals of its velocity (Fig. 10).

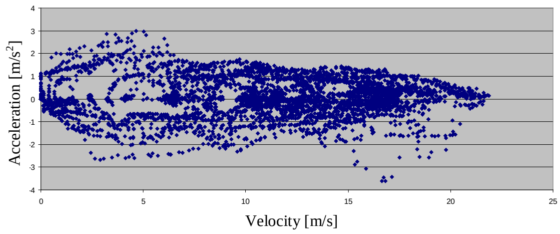

Fig. 9 *Phase diagram of followed vehicle (Astra-G)*

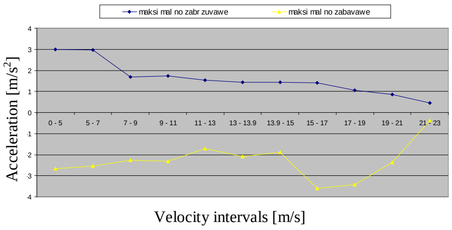

Fig. 10 *Maximum values of acceleration and deceleration of followed vehicle (Astra-G) in different velocity intervals*

This analysis has been done for each of 131 vehicles being tested. In order to draw generalized conclusions, the results received by described measurements are systematically processed in the categories the vehicles belong. In some categories this has been done in groups of vehicles. The category M1 has been divided in four groups depending of their dimensions and performances. First group is formed by vehicle models Yugo, Koral, Tempo, 101, 128, Tico, Spark, Matiz, Felicia and Samara. Second group is formed from vehicle models Punto, Corsa, Fiesta, Kalos, 206 and Polo. Third group includes vehicle models Astra, Golf, Escort, and Focus, and the fourth group takes the vehicle models Mondeo, Passat, Vectra, Ostavia and E class.

The maximum accelerations and decelerations of the vehicles of M1 category systematized in described groups are shown on Fig. 11 and Fig. 12.

The vehicles of N1 category are divided in two groups based on their total mass. First group includes vehicle models Doblo, Berlingo, Partner, Kangoo and Express. The second group is composed of the following vehicle models: Transit, Transporter, Sprinter, Ducato, Rival, Boxer, Jumper, 35-8H, Vito and Ceres.

The maximum accelerations and decelerations of the vehicles of N1 category systematized in described groups are shown on Fig. 13 and Fig. 14.

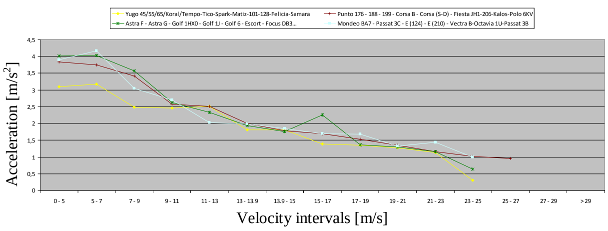

Fig. 11 *Maximum accelerations of the vehicles of M1 category systematized in groups*

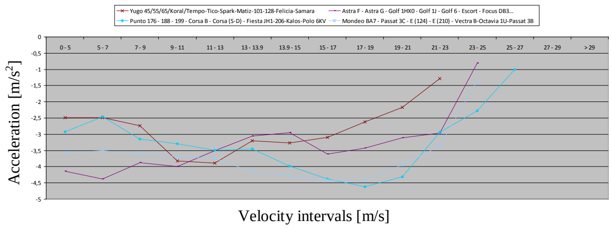

Fig. 12 *Maximum decelerations of the vehicles of M1 category systematized in groups*

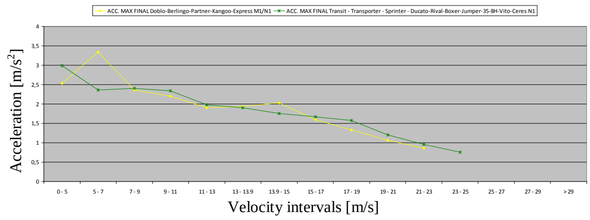

Fig. 13 *Figure 13 Maximum accelerations of the vehicles of N1 category systematized in groups*

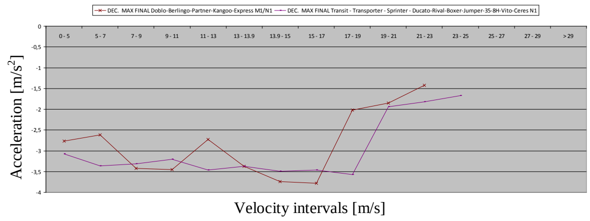

Fig. 14 *Maximum decelerations of the vehicles of N1 category systematized in groups*

Systematic processing of the results leaded to the range of the maximum accelerations and decelerations in different speed intervals. In order to make results more precise, the vehicle velocity is divided into intervals with relatively small size. First interval is between 0 and 5m/s. Other intervals are with a size of 2 m/s. The interval between 13 and 15 m/s has been additionally divided into two subintervals: from 13 to 13.9 m/s, and from 13.9 to 15m/s. This is done on the basis of the maximum functional speed of low speed following systems (13.9m/s), as defined in the standard ISO22178.

Fig. 15, Fig. 16, Fig. 17, Fig. 18, Fig. 19, Fig. 20, Fig. 21, Fig. 22, Fig. 23, Fig. 24, Fig. 25 and Fig. 26 show the range of maximum accelerations and decelerations related to the speed intervals measured on followed vehicles, representatives of the actual vehicle category.

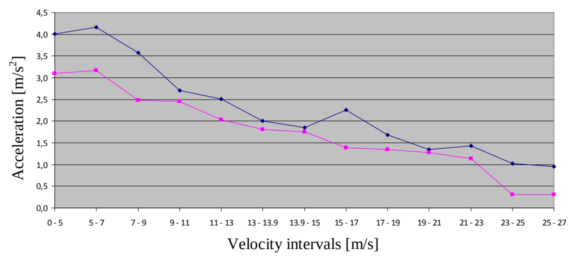

Fig. 15 *Range of the maximum acceleration of the vehicles of the category M1 related to the interval of the speed*

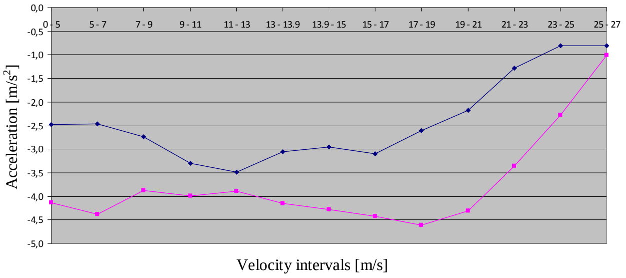

__Fig. 16__ Range of the maximum deceleration of the vehicles of the category M1 related to the interval of the speed

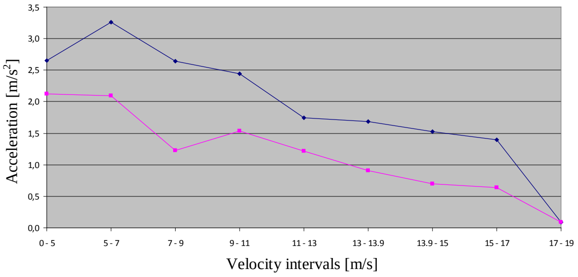

__Fig. 17__ Range of the maximum acceleration of the vehicles of the category M2 related to the interval of the speed

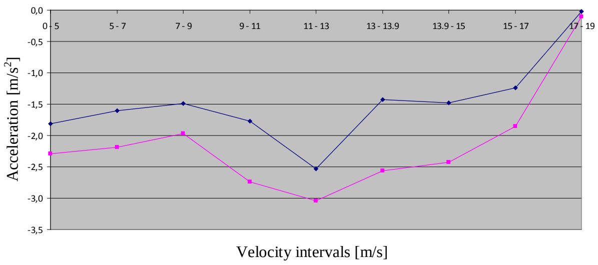

__Fig. 18__ Range of the maximum deceleration of the vehicles of the category M2 related to the interval of the speed

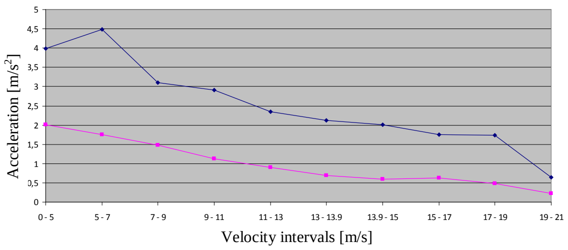

__Fig. 19__ Range of the maximum acceleration of the vehicles of the category M3 related to the interval of the speed

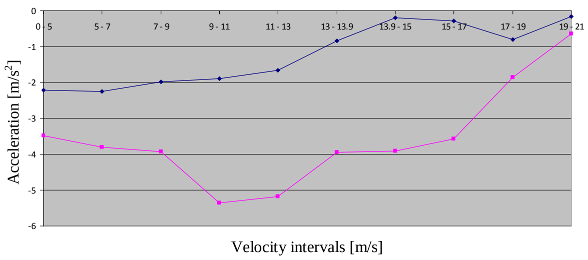

__Fig. 20__ Range of the maximum deceleration of the vehicles of the category M3 related to the interval of the speed

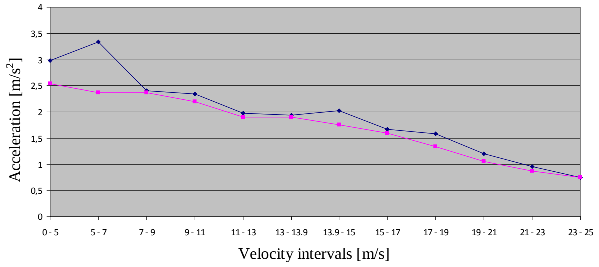

__Fig. 21__ Range of the maximum acceleration of the vehicles of the category N1 related to the interval of the speed

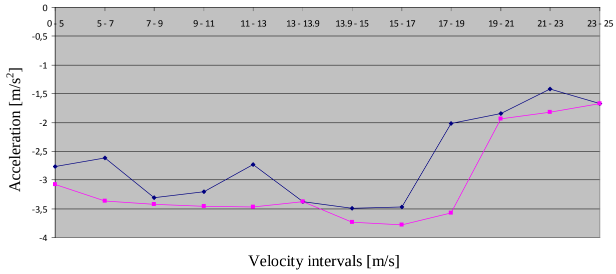

__Fig. 22__ Range of the maximum deceleration of the vehicles of the category N1 related to the interval of the speed

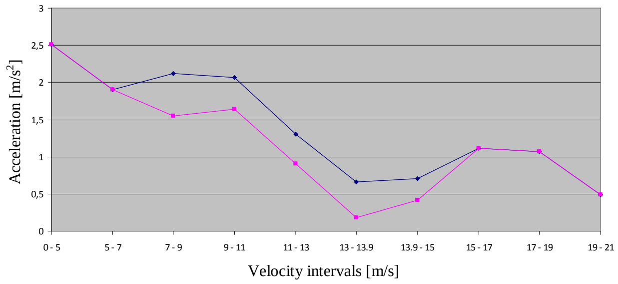

__Fig. 23__ Range of the maximum acceleration of the vehicles of the category N2 related to the interval of the speed

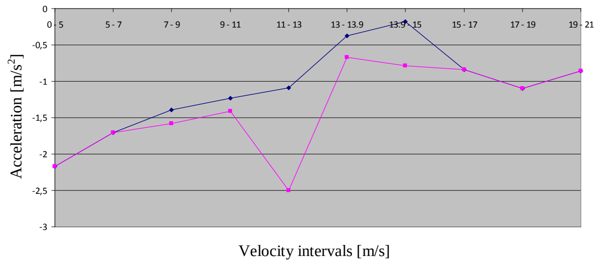

__Fig. 24__ Range of the maximum deceleration of the vehicles of the category N2 related to the interval of the speed

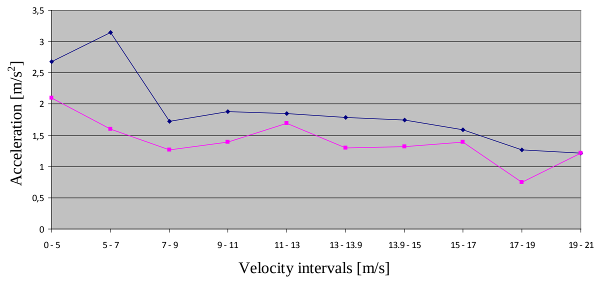

__Fig. 25__ Range of the maximum acceleration of the vehicles of the category N3 related to the interval of the speed

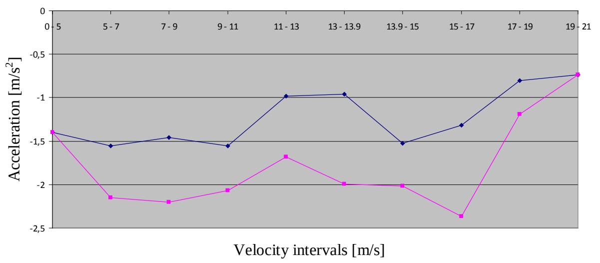

Fig. 26 *Range of the maximum deceleration of the vehicles of the category N2 related to the interval of the speed*

Presented diagrams show high consistency of results achieved in different vehicle categories. At the same time the differences between such categories are noticeable. In addition, a number of analytical checks have been done in order to compare the experimental results with theoretical maximum performances of tested vehicles. The results confirmed validity of experimental results. These analyses are not presented here due to room issue.

5. Conclusion

Having on mind that vehicles in the real traffic are driven by drivers with diverse (different) driving styles, and at the same time the vehicles could also have significant differences in performances, the research that is performed relies on a methodology which comprises wide experimental testing and appropriate processing of the results. It provides a possibility for systematic presentation of the results for groups of vehicles and categories according to the international categorization in power of ECE-EC systems.

The analyses of the obtained results showed that the developed experimental testing methodology has capacity to cope with the research goals and to be used as a method for measuring dynamical behavior of different vehicles in real traffic without a burden of their equipping with measuring instruments and deterioration of their normal rhythm of driving in the traffic.

Actual acceleration, velocity and traveled distance profiles that we have measured reflect a vehicle behavior in urban environment.

The obtained domains of the maximum accelerations and decelerations of vehicles of different categories, in relation to the velocity intervals, are consistent within a vehicle category and note the differences between vehicle categories.

Large number of the achieved results is useful in different purposes. They could be used as input parameters for development of urban traffic flow simulators. At the same time, they could serve as a basis for analysis and modeling of the behavior of different driver profiles (males, females, ordinary drivers, professionals, etc.)

6. References

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