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).

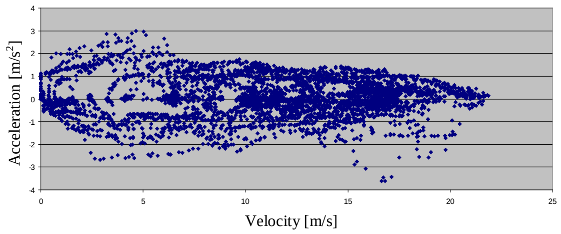

Fig. 9 *Phase diagram of followed vehicle (Astra-G)*

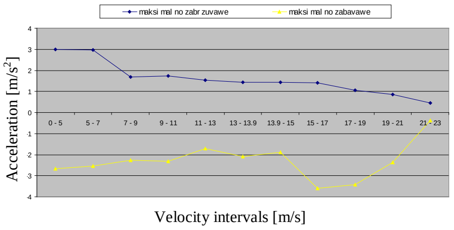

Fig. 10 *Maximum values of acceleration and deceleration of followed vehicle (Astra-G) in different velocity intervals*

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.

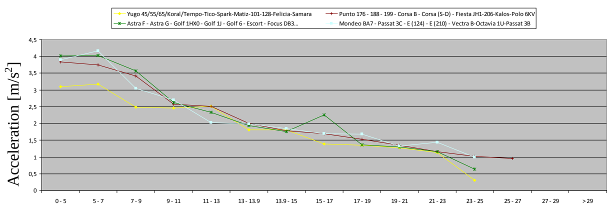

Fig. 11 *Maximum accelerations of the vehicles of M1 category systematized in groups*

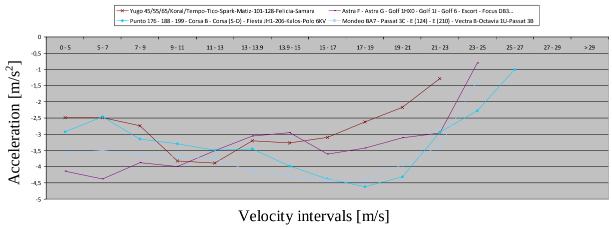

Fig. 12 *Maximum decelerations of the vehicles of M1 category systematized in groups*

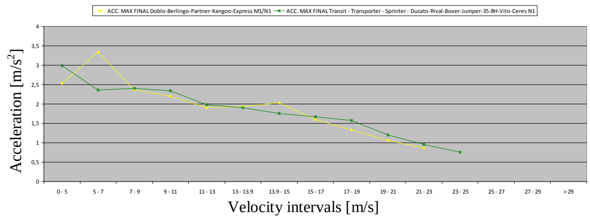

Fig. 13 *Figure 13 Maximum accelerations of the vehicles of N1 category systematized in groups*

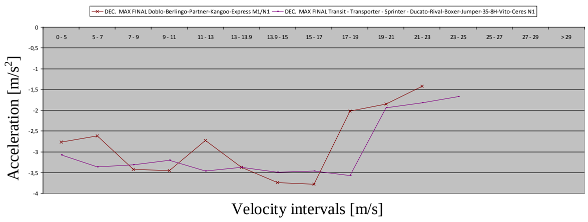

Fig. 14 *Maximum decelerations of the vehicles of N1 category systematized in groups*

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.

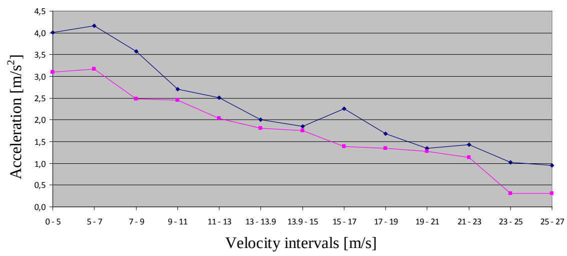

Fig. 15 *Range of the maximum acceleration of the vehicles of the category M1 related to the interval of the speed*

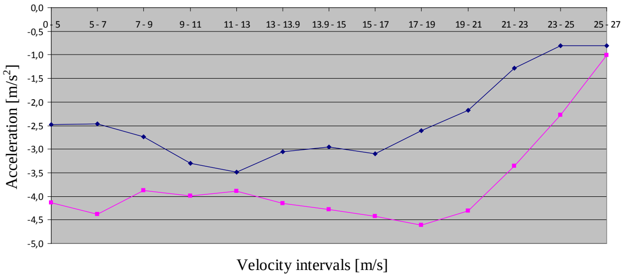

Fig. 16 *Range of the maximum deceleration of the vehicles of the category M1 related to the interval of the speed*

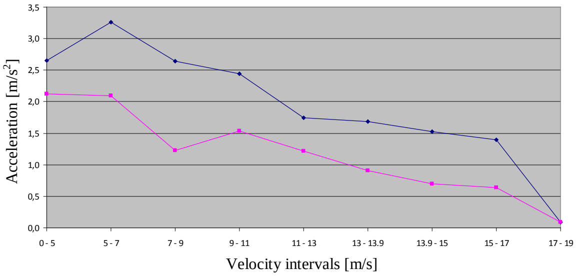

Fig. 17 *Range of the maximum acceleration of the vehicles of the category M2 related to the interval of the speed*

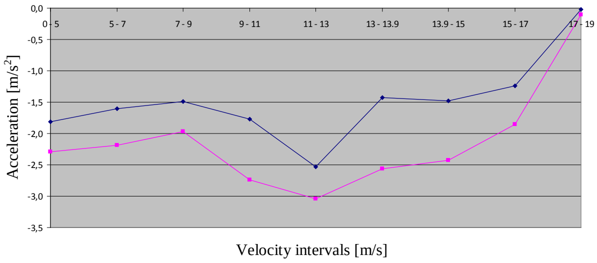

Fig. 18 *Range of the maximum deceleration of the vehicles of the category M2 related to the interval of the speed*

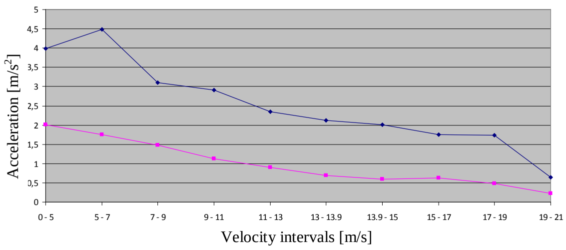

Fig. 19 *Range of the maximum acceleration of the vehicles of the category M3 related to the interval of the speed*

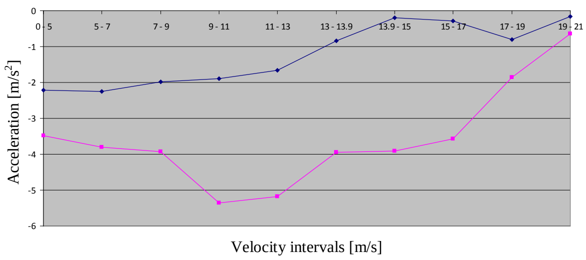

Fig. 20 *Range of the maximum deceleration of the vehicles of the category M3 related to the interval of the speed*

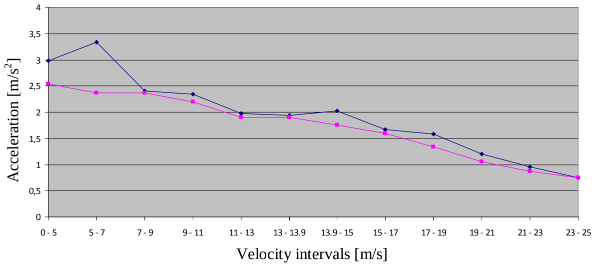

Fig. 21 *Range of the maximum acceleration of the vehicles of the category N1 related to the interval of the speed*

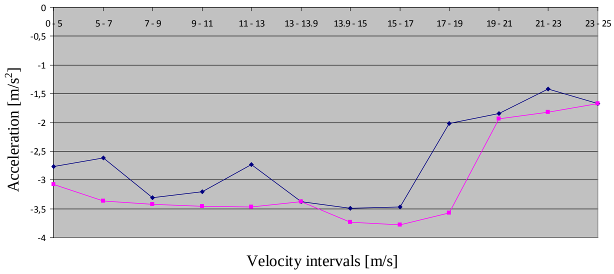

Fig. 22 *Range of the maximum deceleration of the vehicles of the category N1 related to the interval of the speed*

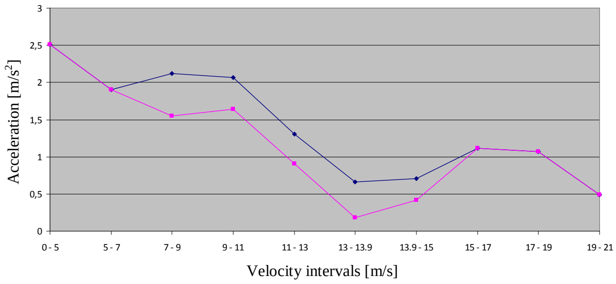

Fig. 23 *Range of the maximum acceleration of the vehicles of the category N2 related to the interval of the speed*

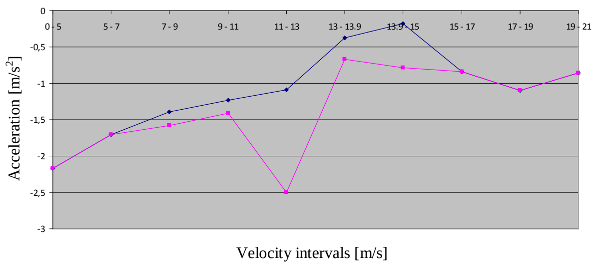

Fig. 24 *Range of the maximum deceleration of the vehicles of the category N2 related to the interval of the speed*

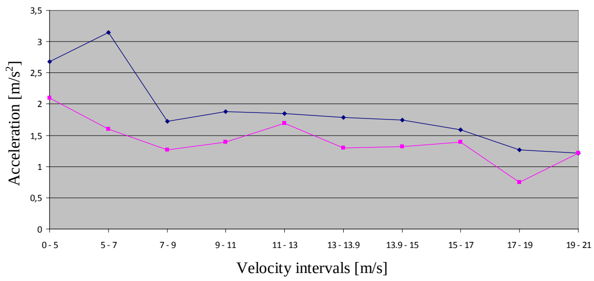

Fig. 25 *Range of the maximum acceleration of the vehicles of the category N3 related to the interval of the speed*

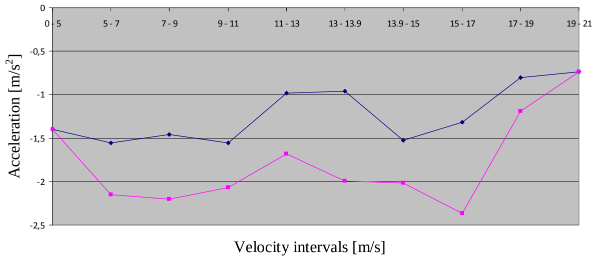

Fig. 26 *Range of the maximum deceleration of the vehicles of the category N2 related to the interval of the speed*

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

[1] Aleksandar Kostikj, “Application Of Intelligent Transport Systems Technique For Increasing The Flow Of Vehicles And Of Traffic Safety In Urban Environments”, PhD thesis, Faculty of Mechanical Engineering, Ss. Cyril and Methodius University in Skopje, December 2011.

[2] Aleksandar Kostikj, Milan Kjosevski, Ljupcho Kocarev, “Determination Of Traffic Flow And Its Structure In Urban Environment As One Of The Fundamental Macroscopic Traffic Stream Parameters”, 24th JUMV International Automotive Conference “Science and Motor Vehicles 2013”, April 2013, Belgrade, Serbia.

[3] Aleksandar Kostikj, Milan Kjosevski, Ljupcho Kocarev, “Development and calibration of a single lane urban traffic simulator”, Proceedings of IEEE 2013 International Conference on Connected Vehicles and Expo (ICCVE), pp. 494-500, 2-6 December 2013, Las Vegas, Nevada, USA.

[4] Aleksandar Kostikj, Milan Kjosevski, Ljupcho Kocarev, “Validation of a microscopic single lane urban traffic simulator”, IEEE 2014 International Conference on Connected Vehicles and Expo (ICCVE), 3-7 November 2014, Vienna, Austria.

[5] Baher Abdulhai, Lina Kattan, “Traffic Engineering Analysis”, In Myer Kutz (Ed.), “Handbook of Transportation Engineering”, McGraw-Hill Companies, 2004.

[6] Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles, http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2007L0046:20130701:EN:PDF

[7] Koppa R.J., “Human factors”, In N. Gartner, C.J. Messer and A.K. Rathi (Ed.), “Revised Monograph of traffic flow theory”, http://www.tfhrc.gov/its/tft/tft.htm.