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FREE FLOW SPEED IN THE FUNCTION OF WEATHER CONDITIONS ON TWO-LANE ROADS

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Key words: *two-lane road, free flow speed, level of service*

Abstract: *Traffic flow theory establishes two basic terms to define traffic flow speed: space mean speed and time mean speed. Research on how speed in free traffic flow depends on the size of longitudinal gradient is related to the need for determining travel time and operating costs of road users. According to HCM manuals, flow speed has been deprived from its primary role in defining level of service, while domestic recommendations give flow speed the role of primary indicator. Subject matter of this paper is the analysis of free traffic flow speed dependence on different factors, primarily weather conditions. The goal is to formulate deterministic models which optimally describe free flow speed on two-lane roads.*

INTRODUCTION

The term speed traffic flow explicitly refers to a certain mean value of the speed of all vehicles involved in the observed traffic flow.[1] The theory of traffic flow establishes two concepts to define the speed of traffic flow, as well as the corresponding mean values of the speed of all vehicles that make up the observed traffic flow. These are *space mean speed and time mean speed.* In describing the legality of movement of motor vehicles, and considering the conditions of movement of vehicles in the traffic flow and the degree of interaction influence in near perfect traffic and road conditions, the space mean speed and time mean speed receive specific names: free flow speed, speed of the normal flow, speed of the saturated flow and speed of the forced flow. The difference between space mean speed and time mean speed is reflected in the space and time observations. Space mean speed is spatially related to the road segment, and the time for the current state, and is often referred to as the current speed, while the mean time speed is spatially related to the section and the time for the period.

According to the HCM manuals, flow speed has been taken away the primary role in determining the level of service, while the national recommendations of the flow speed is still

[1] Kuzović, Lj., Teorija saobraćajnog toka, Građevinska knjiga, Beograd,1987.

assigned the role of priority indicator. Value free flow speed on two-lane roads in the complex functional dependence of the percentage of the time lag, different types of vehicles, driving-dynamic characteristics of the vehicles and road characteristics (as well as terrain), and directly equated with the flow speed at the level of service A, which is basic prerequisite for an analysis of capacity and level of service roads.

The subject of this paper is to analyze the dependence of free traffic flow speed of the various weather conditions and the formulation of optimal deterministic models that describe the speed of the free-flow on two-lane roads. Different weather conditions are rainy and dry weather, which is reflected on the road pavement , and also changes the technical operational characteristics of road. As a result of different weather conditions, there are discrepancies in the measurement of the free flow speed under varying road and ambient conditions. In our professional public this issue has not received sufficient attention in the past.

The drive speed is one of the main causes of road accidents, so it is understandable that the problem of determining the speed is being given a lot of attention. As a basis for the analysis of speed, a crucial role is played by the analysis of the speed of vehicles in free traffic flow. There are a number of factors that affecting on the speed of vehicles on the road: road conditions, driver, vehicle, traffic conditions, road environment, weather conditions and numerous other factors.

IMPACT OF WEATHER CONDITIONS ON TRAFFIC PARAMETERS

It is expected that the weather may affect the driving conditions negatively through three factors, visibility, road conditions and driving stability:

1. Visibility — Fog, precipitation, darkness/daytime, light reflections;
2. Road conditions — Water, snow, frost, ice storm, dirt, leaves;
3. Stability — Gusts of wind; [Jensen, 2014: 2]

LEVEL OF SERVICE HCM 2010

Because of the wide range of situations in which two-lane highways are found, three measures of effectiveness are incorporated into the methodology of this chapter to determine automobile LOS. [Highway Capacity Manual 2010, 2010: 15-7]

1. ATS reflects mobility on a two-lane highway. It is defined as the highway segment lenght divided by the average travel time taken by vehicles to traverse it during a designated time interval.
2. PTSF represents the freedom to maneuver and the comfort and convenience of travel. It is the average percentage of time that vehicles must travel in platoons behind slower vehicles due to the inability to pass. Because this characteristic is difficult to measure in the field, a surrogate measure is the percentage of vehicles traveling at headways of less than 3.0 s at a representative location within the highway segment. PTSF also represents the approximate percentage of vehicles traveling in platoons.
3. Percent of free-flow speed (PFFS) represents the ability of vehicles to travel at or near the posted speed limit. [Highway Capacity Manual 2010, 2010: 15-7]

The essential structural problem of level of service is that it is a step-function representing discrete ranges of continuous variables. Given this, small changes in a service measure or measures can result in a change in LOS while larger changes in a service measure or measures might result in no change in LOS. This is a never-ending problem in interpreting results. If control delay at a signalized intersection improves from 56 s/veh to 54 s/veh, for example, the LOS improves from E to D. If the control delay improves from 54 s/veh to 40 s/veh, the LOS remains D. [Roess, 2014: 72]

LOS reflects the quality of service as measured by a scale of user satisfaction and is applicable to each of the following modes that use roadways: automobiles, trucks, bicycles, pedestrians, and buses. Quality of service (QOS) is a user (traveler) based perception of how well a transportation service or facility operates. [2009 Quality/Level Of Service Handbook, 2009: 12]

METHOD OF DATA COLLECTION ON THE FIELD

This part shows the map position of sections in which to be measured and cross sections in these sections. Speed is measured on sections of two-lane roads within the rural roads M-4 and M-19 and are located in the Republic of Srpska. The aim of this measurement is to obtain the free flow speed under different weather conditions at different grades. The vehicle speed was measured by a measuring device (radar). All measurements are performed, made only one direction and only on upgrade. Avoided impacts are intersections because all three sections are on rural roads. It has been taken care that the vehicle from which the measurement was carried out of the way so it does not affect the speed of the incoming vehicles. The measuring device is turned off when gaps in traffic to the oncoming vehicle with radar detectors would not have received the signal to get on track measures the speed of the vehicle and the driver reduce the speed of their vehicles, which would affect on the relevance of the measured speed of the vehicles. [Jovović, 2015: 47]

DATA MEASURED ON THE FIELD

Table 1 shows the results of measuring the speed of movement of vehicles that have been measured in the field. Out of every 100 measuring speed of vehicles in the field, for dry and wet pavement, all three sections of which are performing measurements, calculated the average speed of vehicles (AS) and are shown in the table. Results obtained by measurements on the field for the upgrades 1%, 3% and 7%, and for other values upgrades of the average vehicle speed obtained by interpolation of the data collected in the field.

Grade	AS (Dry)	AS(Wet)	ST. DEV. (Dry)	ST. DEV. (Wet)
1%	**73,28 (km/h)**	**71,42 (km/h)**	**11,09835**	**8,97717**
2%	71,86 (km/h)	69,81 (km/h)	-	-
3%	**70,45 (km/h)**	**68,20 (km/h)**	**8,9447**	**9,10211**
4%	69,24 (km/h)	67,21 (km/h)	-	-
5%	68,04 (km/h)	66,23 (km/h)	-	-
6%	66,83 (km/h)	65,24 (km/h)	-	-
7%	**65,62 (km/h)**	**64,25 (km/h)**	**9,8101**	**9,70928**

Table 1. Results of measurements with a calculated standard deviations [Jovović, 2015: 50]

STATISTICAL ANALYSIS OF RESULTS

Regression models for the impact of wet pavement on the free flow speed:

$$\text{Linear model: } B = 3.71 + 0.921\,A$$
$$\text{Square model: } B = -\,10.07 + 1.308\,A - 0.002655\,A^2$$

where:

B – Average speed of vehicles in conditions of wet pavement

A – Average speed of vehicles in conditions of dry pavement

The accuracy of the regression model for made measurement speed of vehicles obtained with an accuracy of 98.5% for the linear model and 98.8% for the quadratic model. [Jovović, 2015: 60]

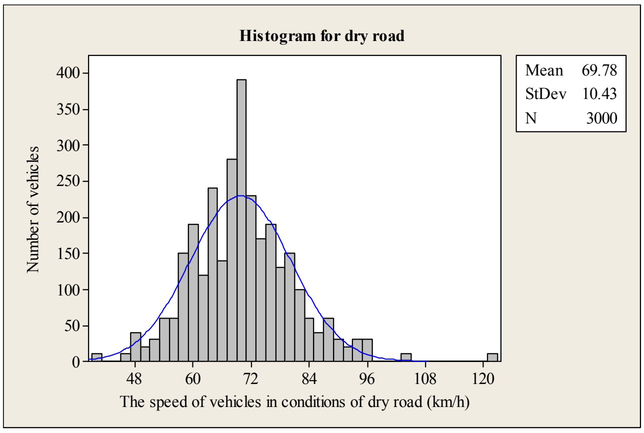

Figure 1.

Figure 1 shows the measured speed on the field under conditions of dry pavement. A curve that represents normal distribution shows that the number of vehicles moving at a speed of 70 km/h above the expected according to normal distribution.

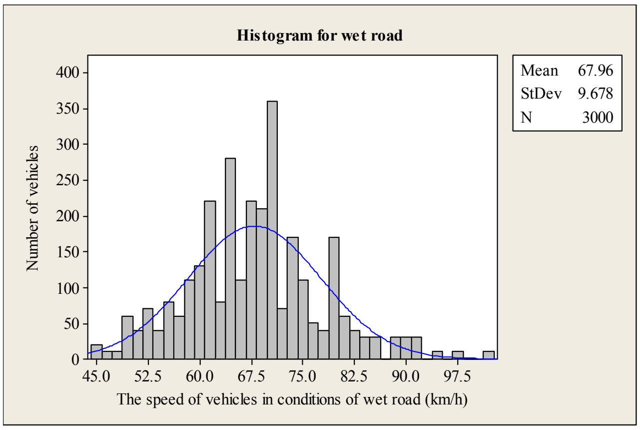

Figure 2.

Figure 2 shows the measured speed on the field under conditions of wet pavement. A curve that represents normal distribution shows that the number of vehicles moving at speeds of 60, 65 and 70 km/h above the expected according to normal distribution.

Figure 3 shows the comparison of the speed of vehicles in conditions of dry pavement and wet pavement measured on all sections. On the part of the diagram which shows wet pavement we can see 180 vehicles were moving at a speed of 80 km/h and 390 vehicles were moving at a higher speed than 80 km/h. For vehicles that are moving at speeds of 80 km/h and higher is assumed that it is the drivers who are daily using sections and know their characteristics and also to be attributed to the dynamic driving characteristics of their vehicles.

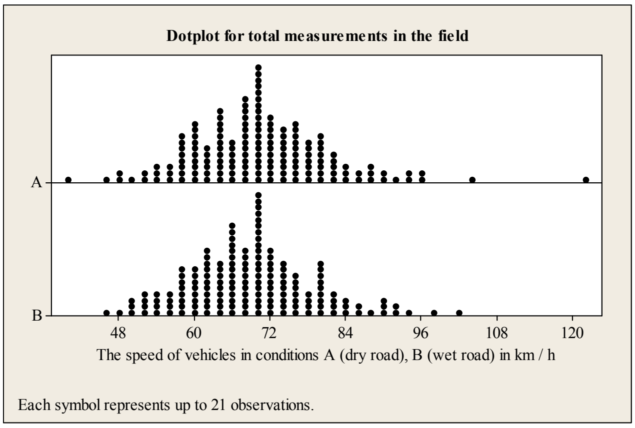

Figure 3.

ANALYSIS OF THE RESULTS MEASURED ON THE FIELD USING THE METHOD HCM 2010

HCM 2010						
	Dry pavement			**Wet pavement**		
	Section 1	Section 2	Section 3	Section 1	Section 2	Section 3
FFS (km/h)	75.31	75.00	68.08	72.10	72.00	66.75
ATS (km/h)	72.26	70.48	60.19	69.36	66.47	58.30
PTSF (%)	28.50	38.70	41.40	30.50	36.20	38.40
PFFS (%)	95.90	93.60	88.40	96.20	92.00	88.90
v/c	0.07	0.10	0.25	0.07	0.11	0.22
LOS(ATS)	C	C	D	D	D	E
LOS(PTSF)	A	B	B	A	B	B
LOS(PFFS)	A	A	B	A	A	B

Table 2. Analysis of the results measured in the field using HCM 2010 [Jovović, 2015: 62]

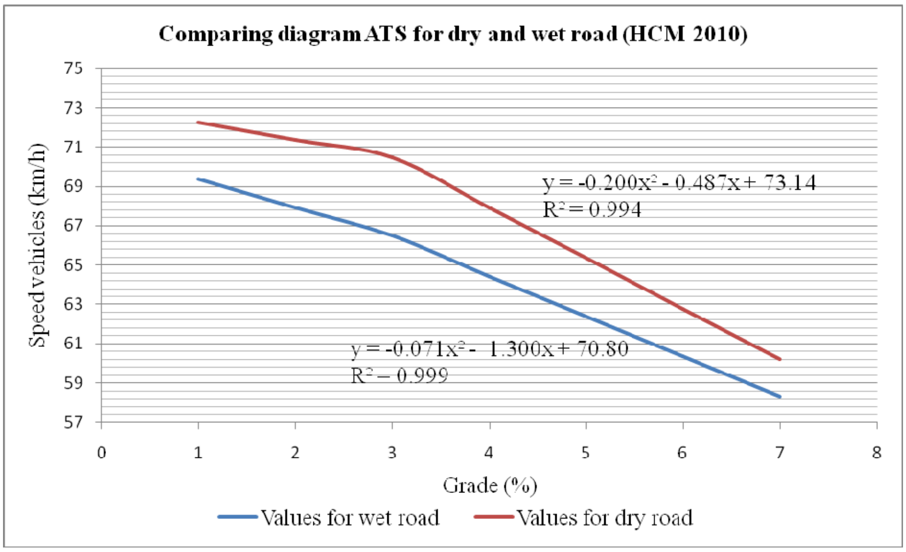

Figure 4.

Figure 4 shows a diagram for average travel speed using the HCM method 2010 for conditions of dry and wet pavement. It can be seen that the use of these methods obtained lower values speed for wet pavement, which confirms the assumption that weather conditions affect on the speed.

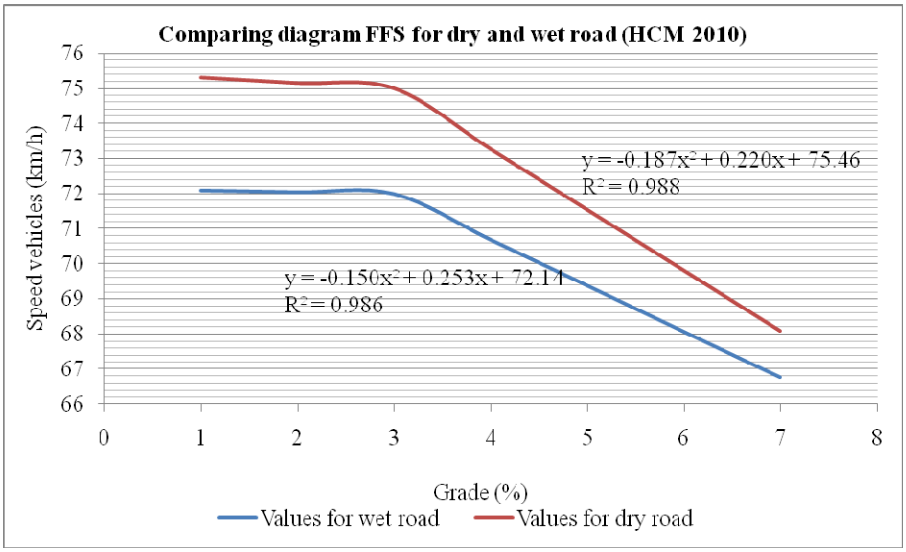

Figure 5.

Figure 5 shows a diagram of the free flow speed using methods HCM 2010 under dry and wet pavement. It can be seen that the use of these methods obtained lower values speed for wet pavement, which confirms the assumption that weather conditions affect the speed.

DISCUSSION AND CONCLUSIONS

Analyzing the results of the measured speed of the vehicle on the field by the impact of weather conditions, specifically in this case the conditions of dry and wet pavement confirmed the starting hypothesis that weather conditions affect the free flow speed. In the first section, which has a longitudinal gradient of 1% of the average vehicle speed under dry pavement to 1.86 km/h (2.54%) higher than the average speed of vehicles in terms of wet pavement. In the second section having a longitudinal gradient of 3% of the average speed of vehicles on dry pavement is 2.25 km/h (3.19%) higher than the average speed of vehicles in terms of wet pavement. In the third section with an average longitudinal gradient of 7% of the average speed of vehicles on dry pavement is 1.37 km/h (1.55%) higher than the average speed of movement in terms of wet pavement. The largest decrease in the average speed of the vehicle is measured on the second section, and at least a reduction of the average speed of the vehicle is measured on the third section.

The analysis of the measured values in the field using HCM 2010, the values we obtained describe the state of flow. Free flow speed for the section 1 for the dry pavement is 3.21 km/h (the difference between dry and wet pavement 4.3%) higher than the free flow speed on this section in terms of wet pavement. On the section 2, the free flow speed in conditions of dry pavement is 3 km/h (the difference between dry and wet pavement is 4%) higher than in the conditions of wet pavement on the same section. Third section has the smallest difference in free flow speed and it is 1.33 km/h (the difference between dry and wet pavement is 2%). The average travel speed is reduced on the all three sections in the conditions of wet pavement compared to dry pavement conditions.

On the first section average travel speed in conditions of dry pavement is 2.9 km/h (the difference between dry and wet pavement is 4%) higher than speed in conditions of wet pavement. In the second section average speed travel in conditions of dry pavement is higher 4.01 km/h (the difference between dry and wet pavement is 5.7%) as compared to conditions when is pavement wet. Reducing average travel speed is at least on the third section and it is 1.89 km/h (the difference between dry and wet pavement was 3.1%). Percent of free-flow speed shows that the flow in a high percentage of free so that lower speed than expected can not be justified by following slower cars and creating a column.

Directions for further research: constant and continuous monitoring of the speed of movement of vehicles, using the device for precise measurement of the speed of movement of vehicles. By constantly monitoring the speed of the vehicle could be formed local manual for the capacity of roads and reliably identify which factors and in what way affect the flow of traffic.

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ОПРЕДЕЛЯНЕ НА СВОБОДНАТА СКОРОСТ НА ДВИЖЕНИЕ НА ПРЕВОЗНИТЕ СРЕДСТВА В ЗАВИСИМОСТ ОТ МЕТЕОРОЛОГИЧНИТЕ УСЛОВИЯ ПРИ ДВУЛЕНТОВИТЕ ПЪТИЩА

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СЪРБИЯ

Ключови думи: *двулентов път, свободна скорост на движение, ниво на обслужване*

Резюме: *В теорията за движението на превозните средства съществуват два основни термина: средна пространствена скорост и средна времева скорост. Изследванията, отнасящи се до това как скоростта при свободно движещите се превозни средства зависи от дължината на наклона на отсечката, са свързани предимно с необходимостта от определяне на времето за пътуване и променливите разходи за пътниците. Основната цел на настоящата разработка е да се анализира от какви фактори зависи скоростта на движение на превозните средства, като акцент се поставя върху метеорологичните условия. Идеята е да се създаде модел, чрез който оптимално да се опише скоростта на движение на превозните средства по двулентови пътища.*