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DEFINING THE VEHICLE MOVEMENT PARAMETERS ON SIGNALIZED INTERSECTIONS APPROACHES

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Abstract

Signalized intersections are, from the point of capacity and level of service, as a rule, critical points in street network. In order to determine the capacity and the level of service on signalized intersections, and to define the optimum signal plan we should know the characteristics and parameters of vehicle movement on intersection approaches. Conditions of traffic flow and parameters upon which they are defined, change in accordance with traffic light signals. Changes of traffic light signals are critical periods when vehicle movement order changes, which means that vehicles accelerate or decelerate. Knowing characteristics of traffic flow, especially the way vehicles accelerate and decelerate on intersections approaches in different traffic conditions, can be of use for optimal clearing interval determinating, as well as cycle length and signal phase distribution. In the literature, there is a small number of recommendations with a wide range of recommended values of the traffic flow parameters on signalized intersections approaches. If there are, the recommendations are general and they generally don't treat the influence of traffic flow structure, location of the intersection in street network, geometry of the intersection, approaches configuration, signal phase plan,etc. In addition, it is known that some traffic flow parameters have been changed during the time due to changes in vehicles drive-dynamic capabilities that participate in traffic flow. This paper presents the results of researches which are performed in past few years on Novi Sad intersections in different traffic conditions.

Keywords: signalized intersection, cycle, speed, acceleration, deceleration

1 Introduction

Traffic regulation by traffic light signalization is a common way of establishing a preferred mode of traffic at intersections in situations when they work at low level of service or for some reason traffic safety is worsened. As well as satisfying strict security criteria, light signal timing at the intersections should ensure coordination between traffic flow requirements and intersection capacity. Programming of traffic light signals, or the definition of signal plans in the cyclic process is a procedure that is based on capacity analysis. In this procedure it is necessary to use the values of certain traffic flow parameters regardless of whether it implements the classical analytical method or by using specialized software applications. Typically, the values of the traffic flow parameters are used on the grounds of recommendations within the applied procedure having been checked. The parameter values of vehicle movements in the real traffic flow, besides geometrical characteristics of intersection, are affected by traffic flow characteristics and environment, but their influence is hard to assess with usual procedures. The methodology for capacity calculation, such as HCM, recommends local measurements to define the values of some parameters of traffic flow [1], especially the parameters related to the vehicle gap intervals disregarding the way of traffic regulation [2]. In many researches it was proved that there are significant differences in the values of these parameters, and that they are affected by the parameters of vehicle movement as well as numerous factors which are not directly related to the flow requirement [3]. Because the analysis procedures uses the recommended values of the traffic flow parameters that does not correspond to the real traffic conditions. Sometimes at the signalized intersections there can be traffic slowdown although there had been action previously taken for capacity opportunities reconciling and flow requirements. Beside vehicle speed, knowing the size of vehicle deceleration and acceleration at on the intersection approaches make possible to define common modes of vehicle motion. Recommendations for vehicle acceleration and deceleration at the intersection approaches are general for all types of intersections and very different, so depending on methodology accelerations are in range of 1.0-3.9 m/s^2, and the decelerations are in range of 1.2-5.0 m/s^2 [4]. Intersections edge radii, entering approach configuration the geometric layout on intersection and required visibility lengths depend directly on the intersection approach speed [5]. Knowing the vehicle movements is necessary, for analysis of traffic accidents at intersections [6]. Knowing signal plans and parameters of the usual regime of vehicle movement on the signalized intersection approaches allows conducting analyses and connecting the movement of vehicles with the work of certain light signals. Analyses like these are necessary in the procedures of determining the omissions of the participants of traffic accidents in cases where intersections don't have video surveillance.

2 Method

In order to determine the appropriate traffic flow parameters at signalized intersections there was a research done on a defined sample of vehicles whose movements were analyzed by video post-processing. Measurement of traffic flow by processing recorded video files is one of the oldest, and the safest methods [7], [8].

Figure 1 Greenshields measurement in 1933

Research about characteristics of traffic flow parameters were conducted at the intersections of the Novi Sad primary street network in more locations over a long period of time. This research [9], whose results were partially presented in this paper was conducted in the period from March to June 2009. The recording was performed with cameras that were mounted and fixed on the roofs around the intersection. In this way, the recording angle was wider and it increased the accuracy of measuring. The research was done in dry weather conditions with a dry road and good visibility.

For video processing and analyses, next software tools were used: Nero ShowTime, Adobe Premiere Pro 1.5, Microsoft Excel and MiniTab 14. Nero ShowTime was used for showing video files, and for counting traffic on separate drive lanes in input and output approach legs of every recorded intersection. Adobe Premiere Pro 1.5 was used for video files processing, because in this software video file can be slowed down and stopped with minimal time interval of 0.04 seconds, which allow to achieve high accuracy. This software also has an option of putting layers with static lines over the existing video recording. This possibility was used to mark real distances on every intersection recording. Knowing this distances was necessary to determine values of all parameters of the flow for which measurements were conducted.

Figure 2 Position of recorded intersections in the street network of Novi Sad

Lines on recordings are connected with some fixed points, more exactly, immobile objects, such as public lighting poles, horizontal signalization on road, etc. For each vehicle, in previously prepared Microsoft Excel tables information's about the intersection, approach, arm, lane, maneuver as well as period when the recording was conducted was entered. During the parameters determining the interaction between the vehicles from opposite approach and the interference for maneuver execution were taken into account. Vehicles which passed the intersection without stopping were specially separated, as well as the vehicles which had interference due to turning pedestrians or vehicles in front of it, or vehicle from the opposite phase when turning on the allowed right turn. This way of vehicle classification is very important because the analysis showed that the interference and interaction between vehicles in flow, in defined categories may have a significant impact on the value of certain parameters.

Figure 3 Video recordings processing in Adobe Premiere Pro 1.5

3 Results

In this paper just some of the results of measuring vehicle moving parameters on signalized intersections will be shown. In full research [9], values of parameters on every approach of recorded intersection are analyzed, regarding previously defined influence factors.

3.1 Speed measurement results

The results of speed analysis were performed for left and right turn maneuvers. During the analysis of right turn, vehicles which the speed under 6 kmph were excluded from analysis. This made the sample of 1,000 vehicles. The results are shown in the next table depending on the initial speed and depending on the interference when maneuver were done.

Table 1 Average values of speed during right turn maneuver

Average speed (kmph)	INFLUENCES						
	$V_0=0$		Total	$V_0\neq0$		Total	Σ
Maneuver	interference	free		interference	free		
Right on green light	11.99	17.30	15.06	15.50	22.05	19.26	19.10
Right on allowed r.t.	11.38	12.72	11.39	12.15	17.09	14.02	13.50
Total	11.43	16.92	12.01	13.74	20.39	17.00	16.43

Table 2 Table 2. Right turn maneuver speed variance

Speed variance	INFLUENCES						
	$V_0=0$		Total	$V_0\neq0$		Total	Σ
Maneuver	interference	free		interference	free		
Right on green light	2.75	1.23	3.06	3.05	3.21	4.24	4.25
Right on allowed r.t.	2.10	0.00	2.09	2.34	2.79	3.24	3.15
Total	2.15	1.46	2.56	3.09	3.72	4.41	4.43

Left turn and U-turn analysis included a sample of 1190 vehicles with the speed above 0.0 kmph at any moment during moving. The results of analysis are shown in the following table

Table 3 Average values of speed during left turn and U-turn maneuvers

AVERAGE SPEED								
Maneuver		**1S**	**1P**	**US**	**UP**	**SS**	**SP**	**Total**
T1	left	13.74	15.51	14.42	18.83	22.07	27.67	18.39
	U-turn							16.39
T2	left	15.54	17.52	20.56	22.15	26.66	28.67	23.14
		Average left turns (without U-turns)						19.32

Table 4 Variance of speed during left turn and U-turn maneuvers

VARIANCE								
Maneuver		**1S**	**1P**	**US**	**UP**	**SS**	**SP**	**Total**
T1	left	2.27	2.72	3.16	3.83	4.05	4.76	5.07
	U-turn							3.99
T2	left	2.19	1.74	3.99	4.27	3.60	4.34	4.98

The analysis found that there are certain dependance between the speed of maneuver and vehicle traffic flow. The following picture shows an example dependance of left turn speed from separate left turn lane and the intensity of traffic flow.

3.2 Acceleration measurement results

In the study a sample of 1.433 vehicle was analyzed. Initial speed of those vehicles was 0 kmph. Vehicles were separated according to the position in the line 762 vehicles were the first vehicles in the line, while the 671 vehicles were second in the line. The lowest value of measured acceleration, was 0.27 m/s^2.

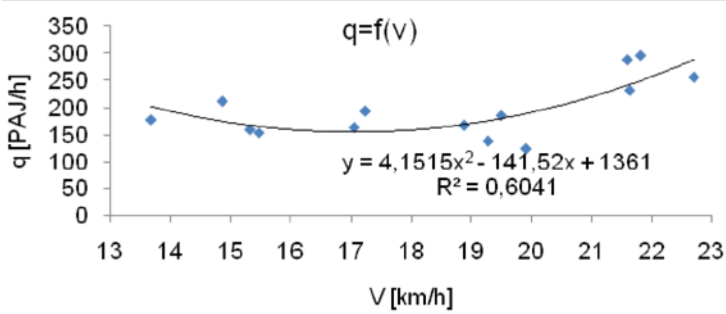

Figure 4 Dependance of left turn maneuver speed and traffic flow intensity

Table 5 Average values and variance of acceleration regarding vehicle position in the line

	Acceleration of n-th vehicle in the line (a[m/s²])		Distance (m)	
Average value (a)	n=1	n=2	S(n=1)	S(n=2)
	2.208	1.892	8.65	10.38
Variance (a)	0.552	0.501		

During the analysis it was determined that there is a relationship between acceleration and traffic flow intensity. The following pictures gives the dependence of acceleration of the first, and second vehicles in the column and traffic flow intensity.

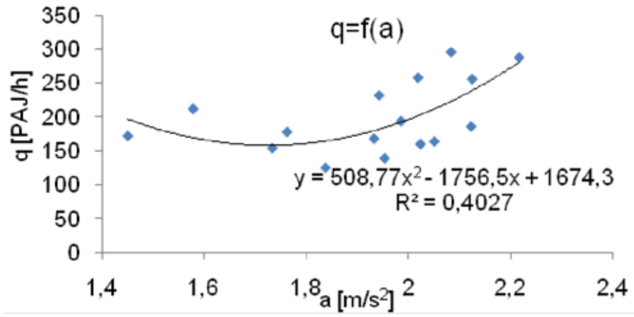

Figure 5 Dependance of acceleration of the first vehicle in the line and traffic flow intensity

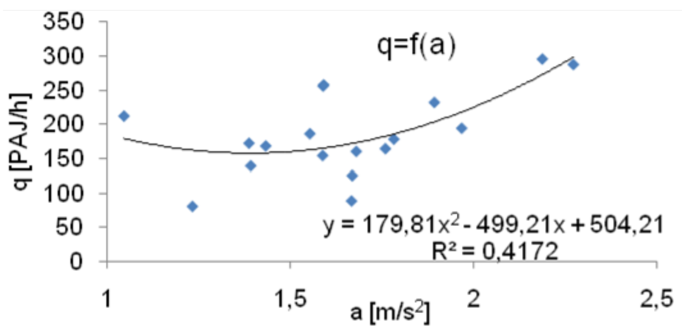

Figure 6 Dependance of acceleration of first vehicle of the second in the line and traffic flow intensity

3.3 Deceleration measurement results

Example size for deceleration was 1.317 vehicles, of wich 696 vehicles was first in a line while 621 vehicle were the second in a line. Minimal measured deceleration value was 0.2 m/s². Following tables show results of research

Table 6 Average values and variance of deceleration regarding vehicle position in the line

	Deceleration of n-th vehicle in row (b[m/s²])		Distance (m)	
Average value (b)	n=1	n=2	S(n=1)	S(n=2)
	1.439	1.403	10.55	12.14
Variance (b)	0.538	0.548		

During the analysis it was determined that there is a relationship between deceleration and traffic flow intensity. The following pictures show the dependence of acceleration of the first, and second vehicles in the column and traffic flow intensity.

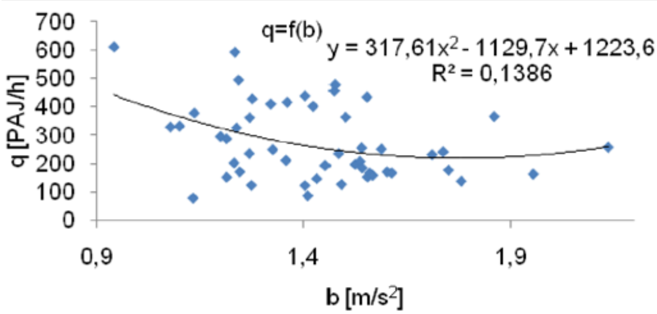

Figure 7 Dependence of deceleration of the first vehicle in the line and the traffic flow intesity

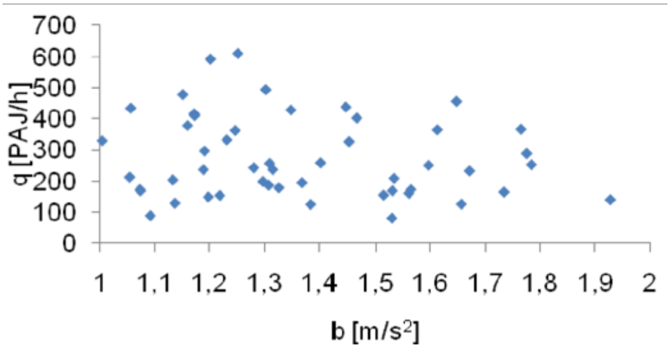

Figure 8 Dependence of deceleration of the second vehicle in the line and the traffic flow intesity

4 Conclusions

The research results showed that there are many factors which have influence on the parameters of vehicle movements at signalized intersections. Vehicle speed when turning left and right is quite equalized and ranges from 15-25 kmph, as well as speed on entering approach intersection leg, which is also quite equalized and only a small number of vehicles achieved average speed over 20 kmph. The biggest impact on vehicle speed are interference by pedestrians and cyclists, while the size of the flow has a small impact. The average value of acceleration for the first vehicle in the column is about 2.2 m/s^2, but significant number of vehicles in signalized intersections have made acceleration which is greater than the recommended limits for comfortable acceleration of 2.5 m/s^2.The values of the acceleration of second vehicles in the line were about 0.3 m/s^2 less compared to the first vehicle. The dependance between acceleration and traffic flow intensity insignificant. Measured average value of deceleration in signalized intersections are on the lowest level of comfortable deceleration, even for vehicles that are in the line. The research didn't show that there was any relationship between traffic flow intensity and deceleration. In further research it would be useful to compare these results with the results of research which are conducted in different cities and different configuration of approach intersection leg.

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