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ASSESSMENT OF THE CAPACITY OF ROADS WEAVING SEGMENTS

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Driving style is affected by development of cars and it has influence on the capacity of designed elements of roads and highways. Therefore, based on research, more accurate methods for assessing the capacity of road infrastructure are being developed. This paper presents the results of the research of weaving segments. It is focused on capacity assessment of these sections within the Czech Republic. Attention is focused especially on weaving segments in urban conditions with high traffic volume and on road sections with a speed limit less than 80 km per hour. Research verified the possibility of using these purposes by existing methodology developed for roads with a speed limit up to 80 km per hour.

Keywords: weaving segment; capacity assessment; weaving segment operation; level of service (LOS)

1. Introduction

Development of cars influences driving style, and so it has the effect on the capacity of the designed road elements. For this reason, this is being researched in the Czech Republic as well as abroad (Chao Yang *et al*., 2012). Moreover, more accurate methods for capacity assessments of road networks are being developed. Our research was focused on the assessment of the safety and capacity of the weaving segments. The research was supported from the Conceptual development at the Faculty of Civil Engineering of the VSB – Technical University of Ostrava.

Weaving segment on a road is defined as a segment where the traffic flows in the same conveying direction are changed. Weaving is a driving maneuver, where the cars are gradually merging and diverging (merging and diverging conflict points are distant from each other - see Fig. 1a) or a crossing of vehicles at a slight angle up to 15 ° (merging and diverging conflict points are near or identical - see Fig. 1b).

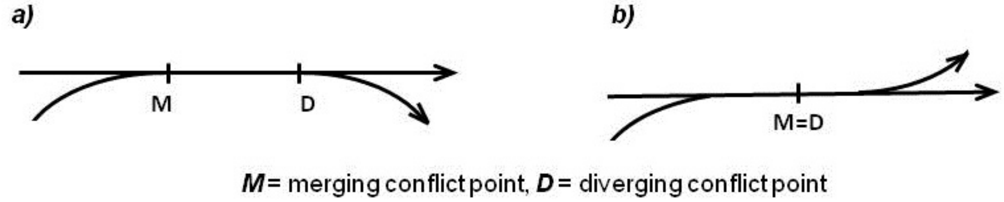

Figure 1. Weaving as a driving maneuver

Various methods of assessment for weaving segments on the roads have been used in the past in the Czech Republic. Assessment method for weaving segments already existed in the earlier edition of the Czech Technical Standard CSN 73 6102 Design of Intersections on Highways of the 1995 (Czech Standardization Institute, 1995). According to this standard, there can be addressed both, the capacity of long weaving segments (e.g. on intersections of roads), and the capacity of short weaving segments (e.g. on roundabouts). The question is how much the procedure mentioned above is correct. Practical experience has shown that extremely short weaving segments are not very safe and should not be newly built. In the current edition of the Czech standard CSN 73 6102 from 2012 (Office for Standards, Metrology and State Testing, 2012) the assessment method for weaving segments is no longer included.

The issue of the capacity of weaving segments is now in the Czech Republic solved in a separate standard called Technical Conditions of Ministry of Transport TP 236 The Flyover Junctions Capacity

Assessment (Ministry of Transport CR, 2011). Unfortunately, the methodology contained in the standard only allows the assessment for weaving segments of length from 150 m to 500 m for roads with a design speed of 80 km/h. There is not contained the capacity assessment methodology of weaving segments for lower speeds neither methodology for short weaving segments in urban areas. Capacity of road weaving segments in urban conditions is a limiting factor for achievable travelling time of public transport and is reflected in the evaluation of quality the public transport, which is dedicated e.g. Olivkova (2016). Authors of methodology recommend the use of traffic modelling for these cases. There are not also solved very short weaving segments within the roundabout (this is applied in particular for multi-lane roundabouts, i.e. level-and interchanges). Existing international standards cannot be used to Czech conditions because of national differences, i.e. different traffic laws, different mentality of drivers etc.

2. Basic Hypothesis

In our study, we tested the hypothesis whether it is possible to use the methodology defined in the TP 236 also for weaving segments on urban roads with a speed limit up to 50 km/h. In the Czech Republic, these weaving sections are frequently used on urban roads with heavy traffic in large cities and industrial areas, both between on- and off-ramps at flyover junctions and in road sections between two neighbouring intersections on multi-lane roads.

2.1. Weaving segments assessment according to TP 236

The capacity of weaving segment is intended by maximal intensity of traffic flows in this weaving. The intensity of traffic flows in weaving on straight two traffic lanes of road (see Fig. 2) according to the TP 236 is calculated from equation:

$$I_R = I_{H11} + I_N, \quad (1)$$

where:
I_R - intensity of traffic flows in weaving (pc/h),
I_{H11} - intensity of traffic in lane neighbouring with additional lane (pc/h),
I_N - intensity of traffic flow which is connecting from on-ramp on junction (pc/h).

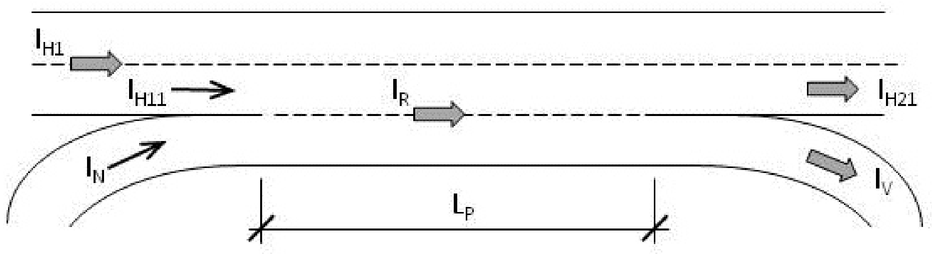

Figure 2. Scheme of weaving segment on flyover junction

Functions for intensity and capacity on the weaving segment with length *Lp* lower than 250 m is defined by equation:

$$I_N = 1850 \cdot a_v - 0.3968 \cdot I_{Hl}, \quad (2)$$

where:
I_N - intensity of traffic flow which is connecting from on-ramp on junction (pc/h),
a_v - degree of saturation defined by equation (3),
I_{Hl} - intensity of traffic flow on the main road before the assessed weaving segment (pc/h).

In general, the degree of saturation expresses the ratio between intensity and capacity:

$$a_v = I / C, \quad (3)$$

where:
I - traffic intensity on the assessed element (pc/h),
C - capacity of the assessed element (pc/h).

Degree of saturation for LOS assessment on weaving segment with length *Lp* lower than 250 m can be expressed from the equation (2):

$$a_v = (I_N + 0.3968 \cdot I_{HI}) / 1850. \quad (4)$$

The capacity of weaving segment is reached when $a_v = 1$. Grades of assessment for the level of service (LOS) are defined in TP 236 in this way: A (very good) for $a_v \le 0.30$; B (good) for $a_v \le 0.55$; C (satisfying) for $a_v \le 0.75$; D (sufficient) for $a_v \le 0.90$; E (instable) for $a_v \le 1.00$; F (inconvenient) for $a_v \ge 1.00$.

The capacity of weaving segment (LOS E/F) is reached according to equation (2) when the values of intensity of traffic flow on the main road I_{H1} are in the range from 630 pc to 3150 pc and correspondingly intensities of connecting traffic flow from on-ramp of junction I_N in the range from 1600 pc to 600 pc.

The capacity of weaving is influenced by length of weaving segment *Lp*. The length shorter than 150 m significantly reduces available capacity and methodology included in TP 236 is not defined for this short weaving segments. As an upper limit length of weaving *Lp* can be considered approximately distance 500 m, when the mutual influence of weaving flows is already very small.

2.2. Other options for assessment of weaving segments

Each country has different methodology for assessment for the capacity of weaving segments. For example, according to the Highway Capacity Manual (Transportation Research Board, 2000), density is the significant criterion for assessment for the level of service of a weaving segment and for the capacity assessment. The capacity of a weaving segment is represented by any set of conditions that result in an average density of 27 pc/km/ln for freeways or 25 pc/km/ln for highways (LOS E/F).

Evaluation the level of service (LOS) can be also carried out on based average time of delay or according to achievable cruising speed.

3. Methodology

We conducted observation of real weaving segment with high traffic intensity for the verifying of fundamental hypothesis. Our aim was to verify the relevance of the use of computational method (mentioned above) on the data from real road traffic. This project was not focused on traffic simulation which is too lengthy for the initial traffic studies in the process of urban planning. A simple and sufficiently accurate procedure is required for processing of urban planning documentation. Using of a computational method appears to be adequate for these purposes.

For observation was chosen weaving segment on flyover junction of Waterfront Captain Jaros and Bubenska Street in Prague (see Fig. 3). Waterfront Captain Jaros is important traffic way along the river Vltava. Bubenska Street leads traffic from the northern town further along Hlavka Bridge over the river Vltava into the centre of Prague. Length of the weaving segment between on-ramp and off-ramp is *Lp* = 148 m (measured according to the scheme on Fig. 2) and speed limit is there 50 km/h.

Figure 3. Flyover junction of Waterfront Captain Jaros and Bubenska Street in Prague (Mapy.cz, 2015)

A total of five observations were carried out in the morning peak-hour. Time sections have been selected for observation so that the maximum (as greatest as possible) traffic intensity was in the all traffic lanes. The situation in morning peak-hour is on the Figure 4.

Figure 4. Photo from observation of weaving segment

The video record was taken from each observation. For each observation interval the vehicles census was carried out manually from the video, which was played on a computer in the office. Data from all observations are summarized in Table 1.

Table 1. Data from observing

Record number	Observation time	Number of vehicles in observation time					
		before the weaving segment		connection from on-ramp		turn to the off-ramp	
		I'_{HI}	b_{pv}	I'_N	b_{pv}	I'_V	b_{pv}
	(h:min:sec)	(veh)	(%)	(veh)	(%)	(veh)	(%)
1	0:17:06	577	2	71	6	328	2
2	0:12:18	347	2	41	5	275	3
3	0:15:28	375	2	68	3	112	4
4	0:30:13	954	2	140	6	550	2
5	0:06:20	221	2	22	9	137	2
Note: I'_V = intensity of traffic flow turning to the off-ramp in junction b_{pv} = heavy-vehicles ratio in traffic flow							

4. Research Results

Assessment of weaving segment was realized for each of five analyzed records according to the methodology included in the TP 236. Results are presented in Table 2.

Table 2. Weaving segment assessment

Record number	Calculated flow rate (from Table 1)		Degree of saturation according to equation (4)	Level of service (LOS) assessment
	I_{HI}	I_N	a_v	
	(pc/h)	(pc/h)	(-)	
1	2075	265	0.59	C
2	1253	152	0.35	B
3	1478	272	0.46	B
4	1932	294	0.57	C
5	2132	227	0.58	C

Shorter time sections with high traffic load (by visual assessment LOS E) occurred in each monitoring period when the movement of vehicles had more the character of stop-and-go. As well shorter time sections with very low traffic load (by visual assessment LOS A) occurred in each monitoring period when the movement of vehicles was free, and the distance between vehicles was the order of several tens of meters. The LOS value in the table for each record represents an average value for the entire period of observation.

5. Discussion

As mentioned, according to the Highway Capacity Manual (Transportation Research Board, 2000) for the capacity of a weaving segment is represented by any set of conditions that results in an average density of 25 pc/km/ln for highways (LOS E/F). During our observation was detected density 60 pc/km/ln in the analysis record no. 5 for the achievable speed of around 22 km/h. There was detected LOS C (degree of saturation $a_v = 0.58$).

Achievable cruising speed of 22 km/h when passing weaving segment is really significantly less than the design speed of 80 km/h considered in the methodology for evaluation by TP 236. Therefore, there was necessary to find a suitable process for verifying value of LOS which was discovered in our case. In view of the fact that Waterfront Captain Jaros is urban road (according to the Czech National classification functional group B), can be used for assessment LOS appropriately also methodology according to CSN 73 6110 Design of Urban Roads (Czech Standardization Institute, 2006). There is the evaluation criterion for LOS the achievable cruising speed on the assessed section. By assessment according to this rule is reached LOS C/D on observed weaving segment (when LOS C is defined by the achievable average cruising speed of 25 km/h and LOS D is then defined by the average cruising speed of 20 km/h).

It is therefore obvious that the assessment LOS of weaving segment by method according to TP 236 gives approximately similar results as if the assessment was carried out according to criteria specified in CSN 73 6110. This indicates enough reliability of the methodology defined by TP 236 for use for weaving segments with a speed limit lower than 80 km/h.

6. Conclusions

In the end we can state according to the results of research is possible in Czech conditions apply evaluation methodology through the degree of saturation according to the TP 236 as a simplified method for the approximate determination of capacity and LOS for weaving segments in urban conditions (i.e. for roads with a speed less than 80 km/h and length of weaving segment shorter than 150 m). This allows making preliminary assessments of weaving segment before it is carried out time-consuming LOS assessment using traffic simulation modelling as recommended by the TP 236 (Ministry of Transport CR, 2011), which best represents the traffic operation.

Acknowledgement

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