periodica polytechnica

Civil Engineering
54/2 (2010) 127–136
doi: 10.3311/pp.ci.2010-2.08
web: http://www.pp.bme.hu/ci

RESEARCH ARTICLE

Recommendations for new capacity values on freeways

István Fi / *János* Galuska

Received 2009-10-27, revised 2009-12-17, accepted 2010-11-08

Abstract

By the analysis of the traffic data collected loop detectors we can get information about the capacities of different freeway sections.

The results and the analysis of the measurements able to show the real maximum traffic volume:2300-2400 pcphpl.

According to the recent regulations the maximum tolerable traffic volumes are much lower than these and lower than 2200 (capacity in HCM).

We recommend using the HCM capacity values and the HCM Level of Services (LOS) categories in Hungary.

By these 20% higher capacity value are more rational from the point of view of the national economy.

Keywords

traffic data analysis · highway capacity · level of services

Acknowledgement

This work is connected to the scientific program of the "Development of quality-oriented and harmonized R+D+I strategy and functional model at BME" project. This project is supported by the New Hungary Development Plan (Project ID: TÁMOP-4.2.1/B-09/1/KMR-2010-0002).

Special thanks to Péter Bocz and Gabriella Devecseri for their help in the completion of measurements.

István Fi

Department of Highway and Railway Engineering, BME, H-1111 Budapest, Műegyetem rkp. 3., Hungary
e-mail: fi@uvt.bme.hu

János Galuska

National Infrastructure Development closed Ltd, NIF Ltd, H-1134 Budapest, Váci út 45., Hungary
e-mail: janos.galuska@nif.hu

1 Introduction

Loop detectors are able to collect data from the traffic of the freeways. By the analysis of the data we can get information about the capacities of the freeways. These loops are able to measure the speed as well. For the measurement the best is to choose sections tend to be overloaded.

The sections were chosen according to the above mentioned criteria. One part of the data came from the pioneer system called MARABU (MAnagement of TRAffic Around BUdapest), the traffic control centre of M0 ringroad. This system is suitable for monitoring on-line the traffic flow at chosen junctions, besides saving the data in order to generate the average-speed and traffic volume relationship. Besides, three other sections were chosen, one of them from the southern Danube-bridge of M0, the others from M1 and M3 freeways. All of them are so called Raktel loop detectors. We used for the analysis the values of Table 1.

1.1 Monitored sections

With one exception, the traffic data were collected from the whole section, that means from 2×2 lanes. The exception is the left carriageway of the M1 freeway at the M0-M1 interchange, as the loops are not working there.

Tab. 1. The chosen sections of the analysis

Freeway	Section	Location	Monitored lanes	System
M0	15+440	(Danube bridge)	2×2	Raktel
M0	$\sim 0+000$	M0-M1 jct.	2×1	MARABU
M0	$\sim 3+700$	M0-M7 jct.	2×2	MARABU
M0	$\sim 18+500$	M0-51101 jct.	2×2	MARABU
M0	$\sim 28+700$	M0-M5 jct.	2×1	MARABU
M1	$\sim 15+350$	M0-M1 jct.	2 (right carriageway)	MARABU
M1	20+290	(Biatorbágy)	2×2	Raktel
M3	28+700	(Gödöllő)	2×2	Raktel
M5	$\sim 16+500$	M0-M5 jct.	2×2	MARABU
M7	$\sim 15+800$	M0-M7 jct.	2×2	MARABU

1.2 Duration of the monitoring

The length of the useful interval of measurement variated depending on the amount of data:

- All yearly data (2007) were available on the southern Danube-bridge of M0 ringroad;
- 3 months data were available from the system 'MARABU' (September 2007, March 2008 and April 2008);
- Data were available from 1^{st} of January, 2007 until 6th of May, 2007 from the "Raktel" detectors on M1 and M3 motorway.

2 The traffic-flow analysis of the Hungarian motorways and highways

The raw data were collected into electronical files:

The data from the southern Danube-bridge was available in processed format (in MS-EXCEL format (number of vehicles – without specifying classes – and their average speed)) for each hour.

In system "MARABU", every detector records in each minute the number and average speed of passenger cars and heavy vehicles (HV) then sends the data to the traffic control center. So the collected values are available together in text format. Each row of the file includes the measured values of a detector at the minute.

The 'Raktel' loops on M1 and M3 freeway collects the traffic data for an hour, but the software results pre-defined speed categories for the vehicles, instead of average speed values. The final text file includes the number of vehicles of each hour, and a classification according to speed categories. The pre-defined speed categories can be read from the header of the data files. Number of HVs are collected separately and the system calculates the average speed of them.

We processed all 3 kinds of input files with our own software, which calculated the number and average speed of cars for each hour between 5 am and 7 pm (14 hours duration, daily 14 data) in two categories: passenger cars and "non-passenger cars" (e.g. lorries, trucks). The number of measured data are shown in Table 2. These numbers are not the same in each case because there were some problems with the loops of the system "MARABU" or with the connection between them and the control centre, so data for some period were missing.

As we mentioned before, the database of the detector at M0 section 15+440 included just number of vehicles without any categories, in order to transfer the values into pc-unit, we took the data from the neighbouring junction at Szigetszentmiklós (road nr. 51101), as we had the rate of "non-passenger cars" within the entire traffic flow. But taking into consideration that data from the above mentioned junction for the whole year 2007 were not available, the rate of HV could not taken as an absolutely correct value, but it shows a tendency.

For transferring the hourly data to pc-unit, we took 1.5 as the pc-unit factor for "non-passenger cars" (source: HCM [1] in case of general plain site E_T pc-unit factor for trucks and buses is 1.5).

It can be recognised from the analysis of the chosen year (2007, M0 Danube-bridge, shown on Figs. 1,2), that it is not possible for the traffic volume to exceed a maximum value. The results of the measurements can be represented with spots in a diagram. The graph turns back after reaching a certain rate of speed. In the case of the overtaking lanes of M0 ringroad, it indicates a traffic load close to the maximum possible volume, which means in this case a traffic volume of 2300-2400 pcph.

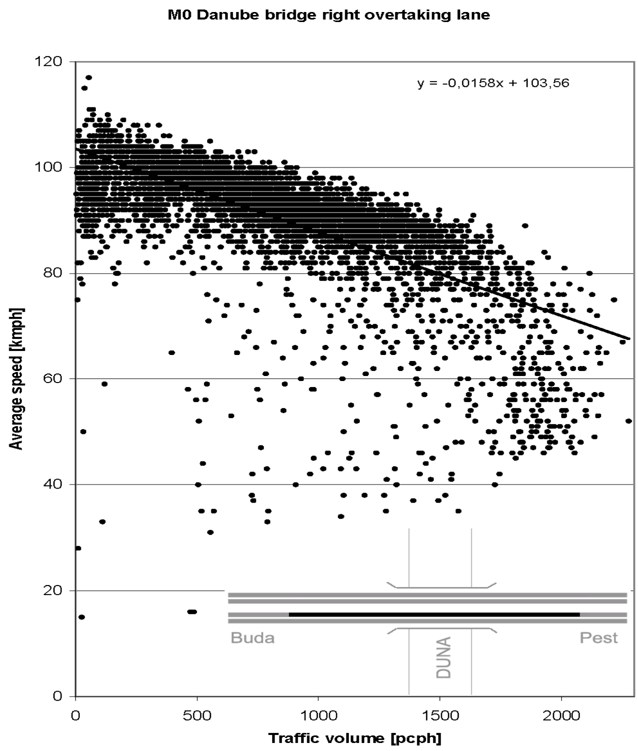

Fig. 1. The speed-traffic volume relation of the right overtaking lane of M0 ring-road

By the ongoing analysis of the database from the M0 Danube-bridge, after illustrating the resulted values on Fig. 3 and Fig. 4, it became obvious, that the demanded traffic load sets around 2300-2400 pcph on the relatively narrow (3.5 metres) traffic lanes (according to HCM 2000 [1], the lane width is not dominant factor in capacity).

We adapted regression lines for the speed - traffic volume relation for the overtaking and travelling lanes of freeways. The equations are collected in Table 3, and graphically shown on Figs. 5-8.

In the overtaking lanes of M0 motorway (Fig. 5) – in spite of the 80 km/h speed limit of the section – the free-flow speed set around 100 km/h, which value decreased by the growth of the traffic volume. The highest decrease was observed in the right lane of M7 intersection. The reason of this was the impeding effect of the on-ramp traffic.

On the travelling lanes of M0 motorway (Fig. 6) the free-flow

Tab. 2. Number of data taken for the analysis

Motorway	Section	Lane	Number of data	Max. traffic-volume [Vehicle-unit/hour/lane]
M0	15+440	right travelling	5045	2300
		left travelling	5045	2120
		right overtaking	5045	2276
		left overtaking	5045	2412
M0	$\sim 0+000$	right travelling	823	846
		left travelling	823	683
M0	$\sim 3+700$	right travelling	642	994
		left travelling	640	1250
		right overtaking	642	934
		left overtaking	640	849
M0	$\sim 18+500$	right travelling	905	1554
		left travelling	905	1368
		right overtaking	905	1923
		left overtaking	905	1729
M0	$\sim 28+700$	right travelling	900	1804
		left travelling	900	1763
M1	$\sim 15+350$	right travelling	510	836
		right overtaking	510	518
M1	20+290	right travelling	1590	1426
		left travelling	1590	1340
		right overtaking	1590	1874
		left overtaking	1590	1829
M3	28+700	right travelling	1764	1503
		left travelling	1764	1602
		right overtaking	1764	1973
		left overtaking	1764	2193
M5	$\sim 16+500$	right travelling	900	1060
		left travelling	900	1602
		right overtaking	900	1493
		left overtaking	900	2031
M7	$\sim 15+800$	right travelling	423	1620
		left travelling	602	2486
		right overtaking	423	2005
		left overtaking	660	2775

Tab. 3. Values of a1 and a0 invariants for the motorway sections between interchange

Motorway	Section	Lane	Peak-hour traffic vol. [pcph]	Equation of the regression line
M0	15+440	right travelling	2300	S = -0.0059×F + 80.1
		left travelling	2120	S = -0.0075×F + 76.7
		right overtaking	2276	S = -0.0158×F + 103.6
		left overtaking	2412	S = -0.0154×F + 97.6
M0	$\sim 0+000$	right travelling	846	S = -0.0042×F + 79.5
		left travelling	683	S = -0.0069×F + 82.1
M0	$\sim 3+700$	right travelling	994	S = 0.0005×F + 75.2
		left travelling	1250	S = -0.0026×F + 82.8
		right overtaking	934	S = -0.0202×F + 97.8
		left overtaking	849	S = -0.0115×F + 107.3
M0	$\sim 18+500$	right travelling	1554	S = -0.0104×F + 92.0
		left travelling	1368	S = -0.0121×F + 92.8
		right overtaking	1923	S = -0.0099×F + 101.2
		left overtaking	1729	S = -0.0152×F + 102.5
M0	$\sim 28+700$	right travelling	1804	S = -0.0052×F + 64.7
		left travelling	1763	S = -0.0092×F + 69.3
M1	$\sim 15+350$	right travelling	836	S = -0.0039×F + 108.9
		right overtaking	518	S = -0.0098×F + 129.4
M1	20+290	right travelling	1426	S = -0.0104×F + 109.1
		left travelling	1340	S = -0.0238×F + 120.1
		right overtaking	1874	S = -0.0078×F + 129.3
		left overtaking	1829	S = -0.0133×F + 130.6
M3	28+700	right travelling	1503	S = -0.0079×F + 109.3
		left travelling	1602	S = -0.0081×F + 115.4
		right overtaking	1973	S = -0.0062×F + 131.3
		left overtaking	2193	S = -0.0084×F + 139.0
M5	$\sim 16+500$	right travelling	1060	S = -0.0069×F + 100.4
		left travelling	1602	S = -0.0108×F + 93.9
		right overtaking	1493	S = -0.0088×F + 125.7
		left overtaking	2031	S = -0.0093×F + 115.0
M7	$\sim 15+800$	right travelling	1620	S = -0.0068×F + 125.1
		left travelling	2486	S = -0.0264×F + 155.6
		right overtaking	2005	S = -0.0066×F + 99.2
		left overtaking	2775	S = -0.0101×F + 123.3

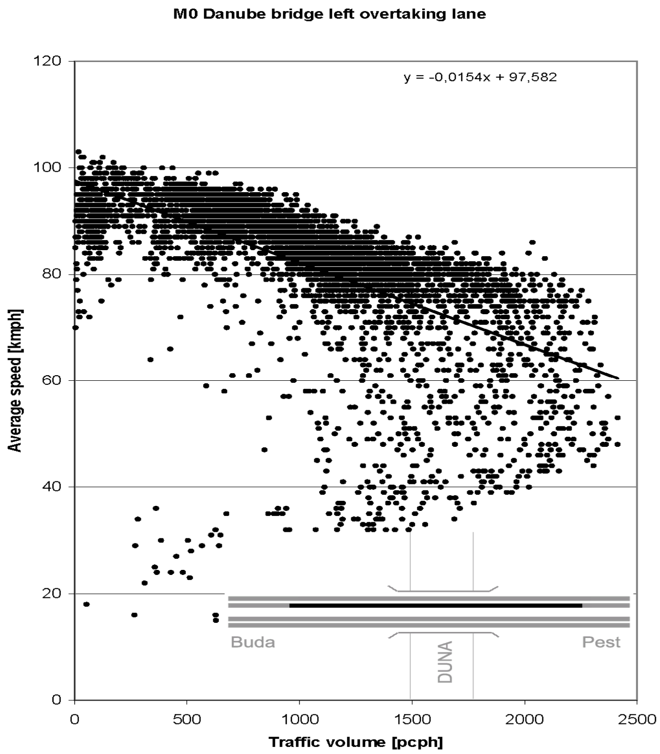

Fig. 2. The speed-traffic volume relation of the left overtaking lane of M0 ring-road

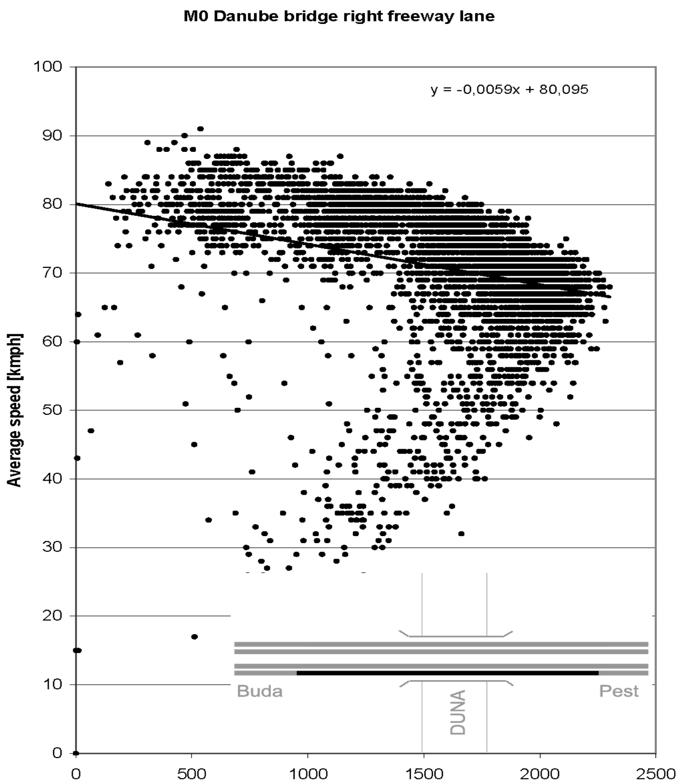

Fig. 3. The speed-traffic volume relation of the right travelling lane of M0 ring-road

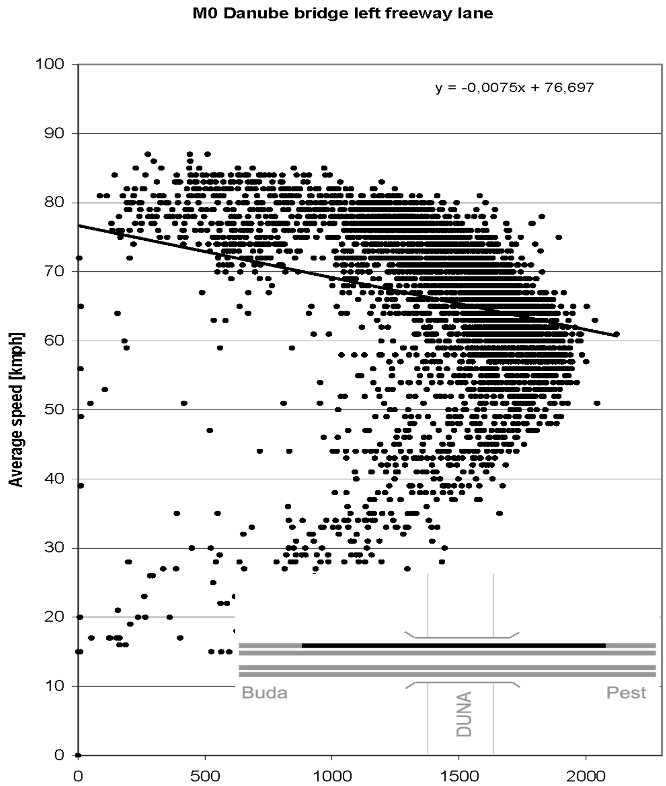

Fig. 4. The speed-traffic volume relation of the right travelling lane of M0 ring-road

speed set around 80 km/h. Here it could be also observed that the speed decreased by the volume growing, but this was less significant than in the overtaking lanes. The reason of this should be sought in the narrow lane width. In case of high traffic, with significant heavy vehicle traffic, drivers become more cautious.

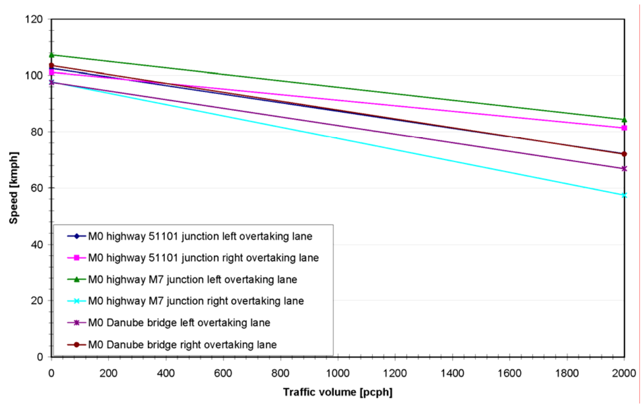

Fig. 5. Speedtraffic volume relations on the overtaking lanes of M0 motorway

In the overtaking lanes of highways (Fig. 7) the free-flow speed set around 120 km/h (± 5 km/h). Here the speed had a linear ∼ 0.010 decrease on all freeways. Only the left lane of M7 freeway is an exception from this, because it lays in a downgrade section so the free-flow speed could reach a high (150 km/h) value. This value variates quite steeply by the traffic volume. In case of 2000 pcph traffic it gets close to the speeds

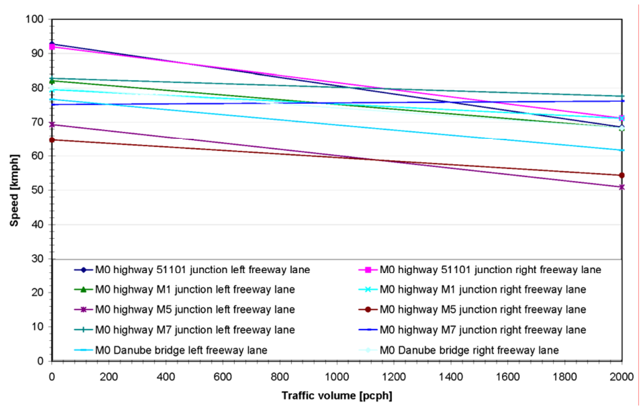

Fig. 6. Speedtraffic volume relations on the travelling lanes of M0 motorway

of other freeways.

Diagrams of the freeway lanes (Fig. 8) show 100-110 km/h free-flow speed. The gradients of the straights variate between 0.004 - 0.010 values. Bigger difference was found only on M1 travelling lane (right lane of Biatorbágy measure point).

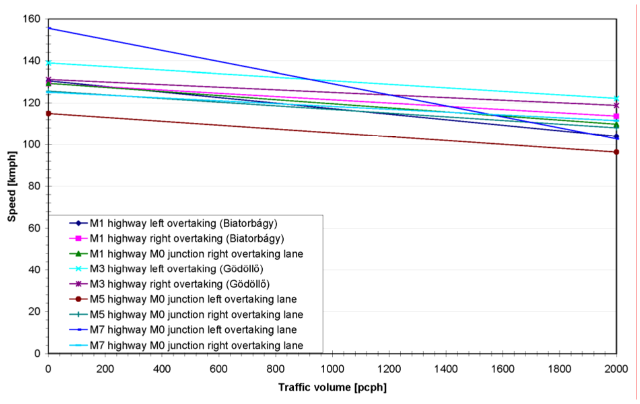

Fig. 7. Speedtraffic volume relations on the overtaking lanes of M1-M3-M5-M7 highways

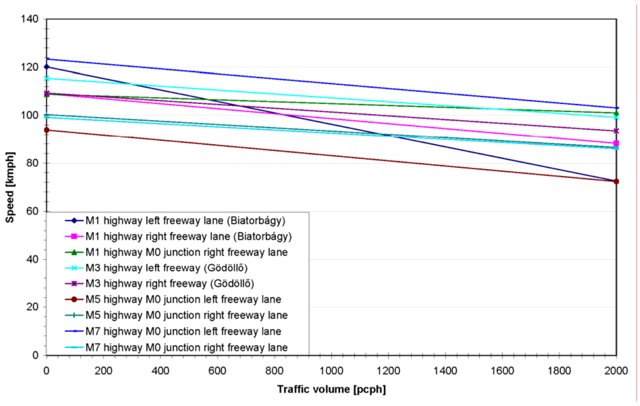

Fig. 8. Speedtraffic volume relations on the travelling lanes of M1-M3-M5-M7 highways

3 New recommendations for highways and highway intersection capacities

3.1 Capacity of freeway lanes according to the Hungarian regulations

According to the previous and the recent regulations (Közutak tervezése ÚT 2-1.201:2008 [2, 3]) only the tolerable, and the eligible LOS is allowed to be taken into consideration during traffic design.

Table 4 contains the allowed traffic volume values (for all types of rural highways without level crossings).

3.2 Capacity values of HCM 2000

The HCM [1] defines five **A** to **E** levels of service. Table 5 contains the densities for each LOS (**A** to **D**) for freeway sections according to HCM 2000. Densities for LOS **E** are stated in Table 6.

Densities for LOS **A** to **D** are based on professional background. But densities of LOS **E** depends on the typical free-flow speed of the given location. By reaching the sixth level LOS **F** the congested traffic moves into a continuous queue or stops or it starts to waving and the values of the density varies in wide range. HCM [1] defines the relationships between LOS, flow, and speed by using the basic speed-flow curves (see Fig. 9).

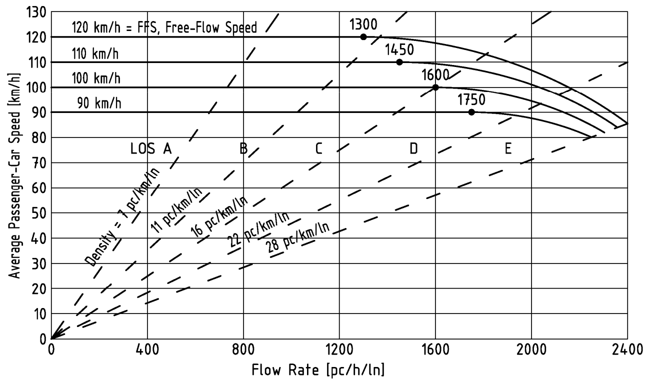

Fig. 9. Speed-flow curves with LOS criteria for highways

3.2.1 Free-Flow Speed

Estimation of free flow speed is based on a base free-flow speed value (100 km/h for highways) which is modified with different factors that have an identified effect on free-flow speed. These adjustment factors are:

- adjustment for lane width,
- adjustment for lateral clearance,
- adjustment for median type,
- adjustment for access-point densities.

The LOS criteria (the maximum density, the average speed, maximum value of v/c, and the corresponding maximum service flow rate) for different free-flow speeds are summarized in Table 7.

Tab. 4. Allowed capacities of freeway lanes according to ÚT 2-1.201:2008

Rural area	Eligible F_m	Tolerable F_e
	Allowed traffic volume belonging to LOS pcph	
Freeway (per lane)	1200	1700
Expressway (two lanes per direction) in one direction (per lane)	1100	1600
Multilane highway (per lane)	1200	1400
Two lane highway (two lanes together)	1400	2000

Tab. 5. LOS criteria for freeway segments

LOS	Maximum density [pc/km/ln]
A	7
B	11
C	16
D	22

Tab. 6. LOS **E** criteria for freeway segments

Free-Flow Speed [km/h]	Maximum density [pc/km/ln]
100	25
90	26
80	27
70	28

The corresponding maximum service flow rate of lanes can be calculated using the following equation:

$$F_{maxi} = C \times (v/c)_i$$

where:

- F_{maxi} maximum service flow rate belonging to LOS "i" [pcphpl],
- $(v/c)_i$ maximum volume to capacity ratio belonging to LOS "i",
- C 2200 [pcphpl].

The capacity calculation of HCM can be used to converse the ideal flow rates to actual flow rates according to the followings:

$$F_i = F_{maxi} \times w_{15} \times N \times f_{HV} \times f_t$$

where:

- F_i service flow rate belonging to LOS "i", near the actual traffic and geometry conditions, in one direction, for N lane [veh/h],
- F_{maxi} maximum service flow rate belonging to LOS "i" [pc/h/ln],
- w_{15} peak 15-min period factor,
- N number of lanes in one direction,
- f_{HV} adjustment factor for heavy vehicles, and
- f_t adjustment factor for tourists and strangers.

To compare the above mentioned Hungarian regulation with the American HCM two basic differences can be noticed:

- Instead of A – E LOS only two levels are used. The F_m the design and the F_e the so-called intervention (when the capacity can only be risen with an intervention).
- The tolerable capacity is significantly lower than 2200 the capacity of HCM recommendation.

Nevertheless it is good to see that the number of publications in the field of service level has been risen lately [4–9]. The publication of Dr. Tóth-Szabó [4], and Dr. Jankó et al. [5] should be mentioned, where they clearly commit themselves to the use of LOS A to E in the Hungarian practice. These publications have positive effect on the professional acceptation of LOS and as a result of this on the traffic safety.

3.3 Analysis of the peak 15-min factor

HCM methodology uses the quardrupled of peak 15-min traffic volume. To be able to compare the capacity values with each other we have made the following analysis.

For the determination of the ratio between the peak hour traffic and the quardrupled peak 15-min traffic the following method was applied:

- Based on 3 months long measurement the traffic data of the cross sections were available in each 15-min in pcph unit.

$$V_{15,i}$$

- We made hourly traffic from the traffic data (the summary of the four 15-min traffics in an hour);

$$V_j = \sum_{1}^{4} V_{15,i}$$

- The maximum traffic value was chosen from the hourly traffic volumes;

$$V_{\max} = \max(V_j)$$

- We put the 15-min traffic volumes into descending order, then we chose the 50 highest 15-min traffics;

Tab. 7. LOS criteria for highways (HCM 2000)

Free-Flow Speed [km/h]	Criteria	LOS				
		A	B	C	D	E
100	Maximum density$_i$ [pc/km/ln]	7	11	16	22	25
	Average speed$_i$ [km/h]	100.0	100.0	98.4	91.5	88.0
	Max. volume to capacity ratio$_i$ $(v/c)_i$	0.32	0.50	0.72	0.92	1.00
	Max. service flow rate$_i$, F_{maxi}, [pc/h/ln]	700	1100	1575	2015	2200
90	Maximum density$_i$ [pc/km/ln]	7	11	16	22	26
	Average speed$_i$ [km/h]	90.0	90.0	89.8	84.7	80.8
	Max. volume to capacity ratio$_i$ $(v/c)_i$	0.30	0.47	0.68	0.89	1.00
	Max. service flow rate$_i$, F_{maxi}, [pc/h/ln]	630	990	1435	1860	2100
80	Maximum density $_i$ [pc/km/ln]	7	11	16	22	27
	Average speed $_i$ [km/h]	80.0	80.0	80.0	77.7	74.1
	Max. volume to capacity ratio $_i$ $(v/c)_i$	0.28	0.44	0.64	0.85	1.00
	Max. service flow rate$_i$, F_{maxi}, [pc/h/ln]	560	880	1280	1705	2000
70	Maximum density$_i$ [pc/km/ln]	7	11	16	22	28
	Average speed$_i$ [km/h]	70.0	70.0	70.0	69.6	67.9
	Max. volume to capacity ratio$_i$ $(v/c)_i$	0.26	0.41	0.59	0.81	1.00
	Max. service flow rate$_i$, F_{maxi}, [pc/h/ln]	490	770	1120	1530	1900

- We divided the traffic of the actual hour of the 50 highest 15-min traffics with the quardrupled 15-min traffic. Finally we received 50 ratios;
- The average of the 50 ratios gave us the 15-min factor for the busiest 50 15-minutes. The value of this:

$$w_{15} = \frac{\sum_{1}^{50} \frac{V_j}{4 \times V_{15,i}}}{50}$$

- With this ratio it became possible to compare the Hungarian and the American practices related to capacity.
- With the 15-min factor we determined in the relevant peak hour the quardrupled value of the probable highest peak 15-min.

$$V_{\max,15} = \frac{V_{\max}}{w_{15}}$$

Table 8 shows these factors.

It can be set out from the table that the values of the peak 15-min factors set around 0.93 with few exceptions.

1 In both measured cross sections of M0 ringroad the low value of w_{15} arises in the overtaking lanes. The reason of this could be that in case of congestion the overtaking lanes are suddenly used more frequent, so the value of w_{15} follows this sudden peak with decreasing.

2 In the measured cross section of M7 highway on the right side, in both lanes the value of w_{15} converges to 1. The reason of this can be the long upgrade, wich makes the flow of the vehicles constant speed. In the opposite direction (left side), on the downgrade the value of w_{15} becomes a little bit lower than 0.93.

Generally in the above mentioned situations the $w_{15} = 0.93$ value is recommended as peak 15-min factor (as the ratio of peak hour and quardrupled peak 15-min period). Table 9 contains the data of M0 ringroad on the southern side of Danube-bridge. We can count with the highest traffic here. Traffic data were available for each hour. We have chosen the maximum traffic of each lane. With w_{15} factor this can be calculated to quardrupled peak 15-min value.

If we take the philosophy of HCM we can say that the maximum value of the lane traffic can be set around: $2200 \times w_{15}$, that is $2200 \times 0.93 \sim 2050$. On the other hand it can be recommended to use the 2200 pcphpl the HCM 2000 recommendation as the possible traffic volume also in Hungary. By these 20% higher capacity values the network development can be planned more rational which would also be important for the national economy.

On the third part it can be suggested in different Hungarian urban traffic analysis and modelling work, (for example publication of Schuchmann [10]) the dealing with the real peak hour factor calculating on the base of the peak 15-min factors (w_{15}).

4 Conclusions

According to the previous and the recent regulations (Közutak tervezése ÚT 2-1.201:2008 [2], only the tolerable, and the eligible LOS is allowed to be taken into consideration during traffic design. The HCM 2000 defines five **A** to **E** levels of service. Comparing the Hungarian regulation with the American standards HCM two basic differences can be noticed. The first: Instead of A – E LOS only two levels are used. The F_m the design and the F_e the so called intervention (when the capacity can only be risen with an intervention).

The second: The tolerable capacity is significantly lower than 2200, the capacity of HCM recommendation.

Tab. 8. Determination of peak 15-min factor

SIGN of DETECTOR	HIGHWAY	JUNCTION	SIDE	LANE	MAX (pcph)[1] V_{max}	15-min FACTOR[2] w_{15}	MAX(pc/4× 15-min) calculated[3] $V_{max,15}$	MAX(pc/4× 15 min) real[4]	NUMBER of DATA (hour)
A	B	C	D	F	G	H	I	J	K
DET0_3L_8	M0	M0-M7	left	travelling	1137	0.93	1232	1308	637
DET0_3L_9	M0	M0-M7	left	overtaking	772	0.85	941	944	638
DET0_3R_12	M0	M0-M7	right	travelling	904	0.93	974	974	641
DET0_3R_13	M0	M0-M7	right	overtaking	849	0.90	963	1016	641
DET0_9L_16	M0	M0-Szm	left	travelling	1244	0.91	1371	1356	903
DET0_9L_17	M0	M0-Szm	left l	overtaking	1572	0.82	2020	1798	904
DET0_9R_47	M0	M0-Szm	right	travelling	1413	0.94	1504	1498	903
DET0_9R_48	M0	M0-Szm	right	overtaking	1748	0.86	2074	1770	904
DET5_2L_32	M5	M0-M5	left	overtaking	1846	0.94	1984	1956	900
DET5_2L_33	M5	M0-M5	left	travelling	1457	0.94	1560	1606	900
DET5_2R_53	M5	M0-M5	right	overtaking	1357	0.92	1500	1772	900
DET5_2R_54	M5	M0-M5	right	travelling	964	0.92	1055	1148	900
DET7_3L_35	M7	M0-M7	left	travelling	2260	0.88	2611	2718	542
DET7_3L_36	M7	M0-M7	left	overtaking	2523	0.91	2803	2882	639
DET7_3R_39	M7	M0-M7	right	travelling	1473	0.98	1503	1536	423
DET7_3R_40	M7	M0-M7	right	overtaking	1823	0.96	1897	1938	417

1 The maximum hourly traffic in the measured cross section (in the lane) during the measured period;

2 The average of the peak 15-min factors of the 50 busiest peak 15-min;

3 The theoretically possible quardrupled peak 15-min traffic belonging to the maximum hourly traffic (quotient of G and H columns);

4 The quardrupled peak 15-min traffic of the given cross section (in the lane) during the measured period.

Tab. 9. Values of quardrupled peak 15-min traffic

Highway	Side, lane	max. hourly volume [pcph]	4 × max. peak 15-min traffic [pcph]
M0	right travelling	2300	2473
15+440	left travelling	2120	2280
(Danube bridge)	right overtaking	2276	2447
	left overtaking	2412	2594

On the base of our above detailed study it can be recommended to use the 2200 pcphpl as the possible traffic volume of freeway sections (as freeway lane capacity) also in Hungary. By these 20% higher capacity values the network development can be planned more rational which would also be important for the national economy.

We suggest a more detailed classification of traffic flows on the Hungarian highway network. Similarly to more European countries, five A-E levels of services of traffic demands can be recommended.

The different LOS categories have to be characterized by traffic density and traffic volume per capacity ratio. These are the parameters for Hungarian highway network which have to be worked out in the near future.

References

1 *Highway Capacity Manual*, Transportation Research Board National Research Council, Washington, D.C., 2000.

2 *Road Planning*, 1986. in Hungarian.

3 *Road Planning*, 2008. in Hungarian.

4 **Tóth-Szabó Zs**, *The interpretations of the level of road service*, Közúti és Mélyépítési Szemle **58**, no. 7. in Hungarian.

5 **Jankó D, Tóth-Szabó Zs, Kovács F, Szénási S**, *The determination of the level of road service by traffic measurements' data*, Közúti és Mélyépítési Szemle **58**, no. 8. in Hungarian.

6 **Chodur J**, *Capacity Models and Parameters for Unsignalised Urban Intersections in Poland*, Journal of Transportation Engineering **131** (2005), no. 12, 924–930, DOI 10.1061/(ASCE)0733-947X(2005)131:12(924). http://cedb.asce.org/cgi/WWWdisplay.cgi?0530494.

7 **Brilon W, Geistefeldt J, Zurlinden H**, *Implementing the Concept of Reliability for Highway Capacity Analysis*, Transportation Research Record: Journal of the Transportation Research Board, DOI 10.3141/2027-01, (to appear in print). http://trb.metapress.com/content/u700713ur834410r/.

8 **Zegeer J, Blogg M, Nguyen K, Vandehey M**, *Default Values for Highway Capacity and Level-of-Service Analyses*, Transportation Research Record:

Journal of the Transportation Research Board, DOI 10.3141/2071-05, (to appear in print). http://trb.metapress.com/content/jwp3q53777416281/.

9 **Luttinen T**, *Movement Capacity at Two-Way Stop-Controlled Intersections*, Transportation Research Record: Journal of the Transportation Research Board, DOI 10.3141/1883-23, (to appear in print). http://trb.metapress.com/content/572k784u46044nnl/.

10 **Schuchmann G**, *Road network vulnerability-evaluation of measures in ranking damages and developments*, Periodica Politechnica-Civil Engineering **54** (2010), no. 1, 61–65.