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New Features in the 2015 German Highway Capacity Manual (HBS2015)

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Abstract

The first version of the German Highway Capacity Manual was published in 2001 (HBS 2001). Now, a new version is published in fall of 2015 (HBS 2015). In the new German Highway Capacity Manual, the major chapters are revised and some of them are totally rewritten. In this paper, an overview of the major developments in the new HBS 2015 is presented before a broad audience on the conference. The audience can get an insight into the content and methodology incorporated within the new HBS 2015. In comparison with the former version, the new HBS2015 is introduced chapter by chapter. Some new methodologies and field dada under consideration are presented. For example, according to the new measurements, the values of capacity for freeway segments are revised and for the on-, off-ramps, and small weaving areas a totally new procedure is developed which considers the traffic flow conditions on the freeways and at on- and off-ramps simultaneously. For signalized and unsignalized intersections, the procedures are revised as well for taking into account the new developments in the past more than 10 years. The new HBS 2015 is expected to be broadly utilised in the traffic planning and assessment process in Germany. The practitioners are given a powerful tool to optimize real world traffic operations in order to enhance traffic performance and to avoid traffic congestions.

Keywords: Capacity Manual, Germany

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1. Introduction

Germany has been involved in traffic engineering research since many decades. Initially, the more popular calculation procedures were mainly based on deterministic considerations. Publication of the US *Highway Capacity Manual* (HCM) in the 1950s spurred interest in the use of stochastic elements combined with empirical research in traffic engineering. Many researchers (Grabe, 1954; Leutzbach, 1956; and Krell, 1958) played an important role in this research. Until 2001 there were different procedures used in German traffic engineering applications. They have never been concentrated into one guideline such as the HCM. Instead, these procedures were incorporated in different highway design guidelines. A new era in the development of traffic engineering guidelines for German conditions began when the Federal Department of Transportation (DOT) commissioned the Ruhr-University in 1989 to develop a prototype for a German *Highway Capacity Manual* (HBS*)*. The first draft for this manual was finished in 1993 and was published a year later by Brilon, Grossman, and Blanke (Brilon et al., 1994).

In Germany, research in the field of highway capacity and quality of service is predominantly funded by the federal DOT since the federal government is the owner of the Germany motorways and the federal highways. The German Federal States administrate and operate the German motorways within their territories on behalf of the federal government. Road research is conducted by the Federal Highway Institute (Bast), by the universities or other institutions. Most guidelines are prepared by the German Road and Transportation Research Association (FGSV).

The first edition of the *German Highway Capacity manual* (*Handbuch fuer die Bemessung von Strassenverkehrsanlagen*, HBS 2001) was published in 2001 (FGSV, 2001). It was introduced by the German federal DOT as the methodological basis for capacity calculations and quality assessments. Similar to the US *Highway Capacity Manual* (HCM 2000 and HCM 20110), HBS 2001 is based on the concept of Level of Service. An overview on the former version of HB S2001 was given by Brilon (1998).

After its publication, HBS 2001 has found wide applications in Germany. Because of the importance for the professionals in the practice, the FGSV decided to up-date this manual. Goals of the updating work are to revise the existing chapters and to complete the content as good as possible. In comparison to the HBS 2001, the methodologies for assessment are given in more details in the new edition.

2. Content of HBS 2015

The 2015 edition of HBS is to be subdivided into three parts – Freeways (A), Rural Highways (L) and Urban Streets (S) – plus a collection of examples in a digital volume 4. Each chapter number is preceded by the letter of the part. This new structure will make it possible to include new material without having to renumber the chapters. Table 1 shows the new structure of the HBS 2015 and the corresponding performance measures (LOS). This allows for the answer to the question if the facility under consideration will be able to cope with the expected demand.

The chapters A2, L2, and S2 of the HBS deal with the fundamental concept for design and assessment procedures. The main topic of these chapters is to provide procedures for determining the peak hour volume in noder to design traffic facilities and calculate capacities.

In the former HBS 2001, the design demands for different traffic facilities are not exactly defined. It is suggested to use the 30th hourly volume in the year as the design peak hour demand. However, it not clearly defined how this 30th hourly volume is estimated. Thus, a modification regarding this topic is needed.

In the new HBS 2015, still the 30th hourly volume is used as the design peak hour demand. However, a functional relationship between the 30th hourly volume in the year and the considered peak hour demand is given. The use of directional peak hour volumes or aggregated peak hour volumes is recommended depending on the specific traffic conditions. The procedure for estimating the proportion of peak hour volumes to the annual average daily volume (ADV) is improved (cf. Lemke, 2011; Walther et al., 2009).

Table 1. Structure of the HBS (FGSV, 2015b)

Volume	Chapter	Performance Measure	Parameter
General	1 Introduction		
	2 Principles and Definitions		
	3 Area of Application		
Part A - Freeways	A1 Purpose and Scope		
	A2 Traffic Demand		
	A3 Freeway Segments	volume-to-capacity	x
	A4 Freeway Diverge, Merge, and Weaving Segments	volume-to-capacity	x
	A5 Freeway Facilities		
Part L – Rural Highways	L1 Purpose and Scope		
	L2 Traffic Demand		
	L3 Segments of Rural Highways	density	k
	L4 Signalized Intersections	delay	t_W
	L5 Unsignalized Intersections	delay	t_W
	L6 Highway Diverge, Merge, and Weaving Segments	density	k
	L7 Rural Highway Facilities		
Part S – Urban Streets	S1 Purpose and Scope		
	S2 Traffic Demand		
	S3 Segments of Major Urban Streets	density	k
	S4 Signalized Intersections	delay	t_W
	S5 Unsignalized Intersections	delay	t_W
	S6 Major Urban Streets Facilities	density	k
	S7 Transit Vehicles Facilities	delay	t_W
	S8 Bicycle Facilities	turbulence rate	S
	S9 Pedestrian Facilities	density	k
	S10 Accesses to Parking Facilities	delay	t_D
Collection of Examples	A		
(digital only)	L		
	S		

The Institute for Traffic Engineering and Management at Ruhr-University has provided significant contributions to the development of the new HBS 2015. In this paper the major revisions in the new HBS 2015 are introduced chapter by chapter, especially for the chapter Freeway Segments (A3), Freeway Diverge, Merge, and Weaving Segments (A4), and Signalized Intersections (S4 and S5).

3. Basic Freeway Sections (Chapter A3)

In Germany, there is no general speed limit on freeways. In addition, passing on the right-hand lane is not allowed, and this rule is generally followed by drivers. As a result, the right-hand lane is preferred for normal driving except when passing. This rule causes a lot of lane changing maneuvers. Furthermore, the speed limit for trucks is only 80 km/h. Those rules and characteristics together generate a special traffic flow and speed relationship on German freeways where a significant influence of volume on average speed occurs.

The former HBS 2001 recommends the volume/capacity-ratio (v/c-ratio) to assess the quality of traffic flow on German freeways with two or three lanes each direction. The database was based on the measurements from Ponzlet

(1996). The database is now extended. The studies by Brilon, Geistefeldt et al. (2007, 2010), in addition to Friedrich, Engelmann (2003), have provided important new findings on capacities and relationships between traffic volumes and speed on freeways. Numerous values have been modified and complemented (cf. Geistefeldt, 2015). In the new HBS 2015, also the freeways with 4 lanes each direction is incorporated.

The Level of Service (LOS) is defined depending on the degree of saturation (Table 2).

Table 2. LOS for freeways depending on the degree of saturation

LOS	Degree of Saturation at LOS (xLOS)
A	⩽ 0.30
B	⩽ 0.55
C	⩽ 0.75
D	⩽ 0,90[1)]
E	⩽ 1.00
F	–

[1)] 0.92 for sections with Variable Speed Limit

The proposed capacity in HBS 2015 for different freeway segments and regulations of speed limit on freeways is illustrated in the flowing **Fehler! Ungültiger Eigenverweis auf Textmarke.** and Table 4.

Table 3. HBS design capacities (veh/h) for basic freeway segments with a grade < 3 %, valid for a length of the upgrade not less than 500 m (FGSV, 2015b)

No. of lanes each direction	Speed Limit	Capacity C [veh/h]							
		Long distance freeways				Metropolitan traffic freeways			
		Percent of heavy vehicles				Percent of heavy vehicles			
		≤ 5 %	10 %	20 %	30 %	≤ 5 %	10 %	20 %	30 %
2	None	3700	3600	3400	3200	3900	3800	3600	3400
	T120	3800	3700	3500	3300	3900	3800	3600	3400
	T100/T80/VSL	3800	3700	3500	3300	4000	3900	3700	3500
	Tunnel	3700	3600	3400	3200	3900	3800	3600	3400
3	None	5300	5200	4900	4600	5700	5500	5200	4900
	T120	5400	5300	5000	4700	5700	5500	5200	4900
	T100/T80/ VSL	5400	5300	5000	4700	5800	5600	5300	5000
	Tunnel	5300	5200	4900	4600	5700	5500	5200	4900
4	None	7300	7100	6700	6300	7800	7600	7100	6600
	T120	7400	7200	6800	6400	7800	7600	7100	6600
	T100/T80/ VSL	7400	7200	6800	6400	8000	7800	7300	6700
2 + h.s.r.[1)]	T100/ VSL	4700	4600	4400	4200	5200	5000	4700	4400
3 + h.s.r.[1)]	T100/ VSL	6300	6200	5900	5600	7000	6800	6400	6000

* Tnnn=speed limit for nnn km/h, VSL=Variable Speed Limit [1)] h.s.r. = hard shoulder running

Table 4. HBS design capacities (veh/h) for basic freeway segments with a grade ⩾ 3 %, valid for a length of the upgrade not less than 500 m (FGSV, 2015b)

No. of lanes each direction	Grade	Capacity C [veh/h]							
		Long distance freeways				Metropolitan traffic freeways			
		Percent of heavy vehicles				Percent of heavy vehicles			
		≤ 5 %	10 %	20 %	30 %	≤ 5 %	10 %	20 %	30 %
2	3 %	3600	3500	3300	3100	3800	3700	3500	3300
	4 %	3400	3300	3100	2900	3600	3500	3300	3100
	5 %	3100	3000	2800	2600	3300	3200	3000	2800
3	3 %	5200	5100	4800	4500	5600	5400	5100	4800
	4 %	4900	4800	4500	4200	5300	5100	4800	4500
	5 %	4500	4400	4100	3800	4900	4700	4400	4100
4	3 %	7100	6900	6500	6100	7600	7400	6900	6400
	4 %	6800	6600	6200	5800	7300	7100	6600	6100
	5 %	6200	6000	5600	5200	6700	6500	6000	5500
2 + h.s.r.1)	3 %	4600	4500	4300	4100	5100	4900	4600	4300
	4 %	4400	4300	4100	3900	4900	4700	4400	4100
	5 %	4100	4000	3800	3600	4600	4400	4100	3800
3+ h.s.r.1)	3 %	6200	6100	5800	5500	6900	6700	6300	5900
	4 %	5900	5800	5500	5200	6600	6400	6000	5600
	5 %	5500	5400	5100	4800	6200	6000	5600	5200

1) h.s.r. = hard shoulder running

4. Entrances, Exits (on- and off- ramps) and Weaving Segments at Freeways (Chapter A4)

The capacity and performance of entrances, exits, and small weaving segments has been studied by Westphal (1995). Although this investigation focused on urban freeways with speed limits of 80 or 100 km/h, Westphal's procedures are also recommended by the HBS 2001 for all types of freeways. In recent years, numerous studies have been conducted into different elements of grade-separated junctions that have not been covered so far (Brilon and Betz, 2007; Friedrich et al., 2006 and 2008; Weiser et al., 2006). A new uniform one-piece model to determine the level of service developed by Wu is used for the diagrams (cf. Wu and Lemke, 2015). The new HBS 2015 uses a combined volume-to-capacity ratio for determining the the level of service at entrances and exits as well as at small weaving segments.

Given the volume-to-capacity ratios on the major freeway (x_{HO} and x_{HU}) and on the ramps (x_E and x_A), the combined volume-to-capacity ratio of the total merge or diverge (including small weaving) segment (here x_M and x_D) can be directly calculated as follows.

$$x_M = \sqrt[a]{x_E{}^a + x_{HO}{}^a} \quad and \quad x_D = \sqrt[q]{x_A{}^a + x_{HU}{}^a} \tag{1}$$

The combined LOS of the total merge or diverge segment can be then obtained according to the predefined x-value of LOS (cf. Table 2).

If the service volume-to-capacity ratio for the merge or diverge segment is predefined ($x_{M,LOS}$ and $x_{D,LOS}$), the allowed volume-to-capacity ratios on the major freeway (x_{HO} and x_{HO}) and on the on-ramp or off-ramp (x_E and x_A) can be calculated from the following equations.

$$q_{E,LOS} = C_E \cdot x_{M,LOS} \cdot \sqrt[a]{1-\left(\frac{q_{HO}}{C_{HO} \cdot x_{M,LOS}}\right)^a} \quad \text{and} \quad q_{A,LOS} = C_A \cdot x_{D,LOS} \cdot \sqrt[a]{1-\left(\frac{q_{HU}}{C_{HU} \cdot x_{D,LOS}}\right)^a} \tag{2}$$

With these functions, the traffic quality (LOS) for different values of q_{HO} and q_E (or q_{HU} and q_A respectively) can be obtained directly. The types of considered diverge, merge, and small on-sided weaving segments are depicted in Fig. 1 and Fig. 2. The parameters used are shown in Table 5 and Table 6. Using this model of combined volume-to-capacity ratio diagrams for all types of merge, diverge, and small weaving segments of the current German design guidelines RAA (FGSV, 2008a) are constructed in HBS 2015. Parameters for all types of diverge, merge, and small weaving segments of the current German design guidelines RAA (FGSV, 2008a) are given for producing diagrams using eq. (2). These parameters can also be used for calculating the combined volume-to-capacity ratio (eq.(1)). In Fig. 3, two examples of those diagrams are illustrated for the on-ramp type E 1-2 and the off-ramp type A 1-2.

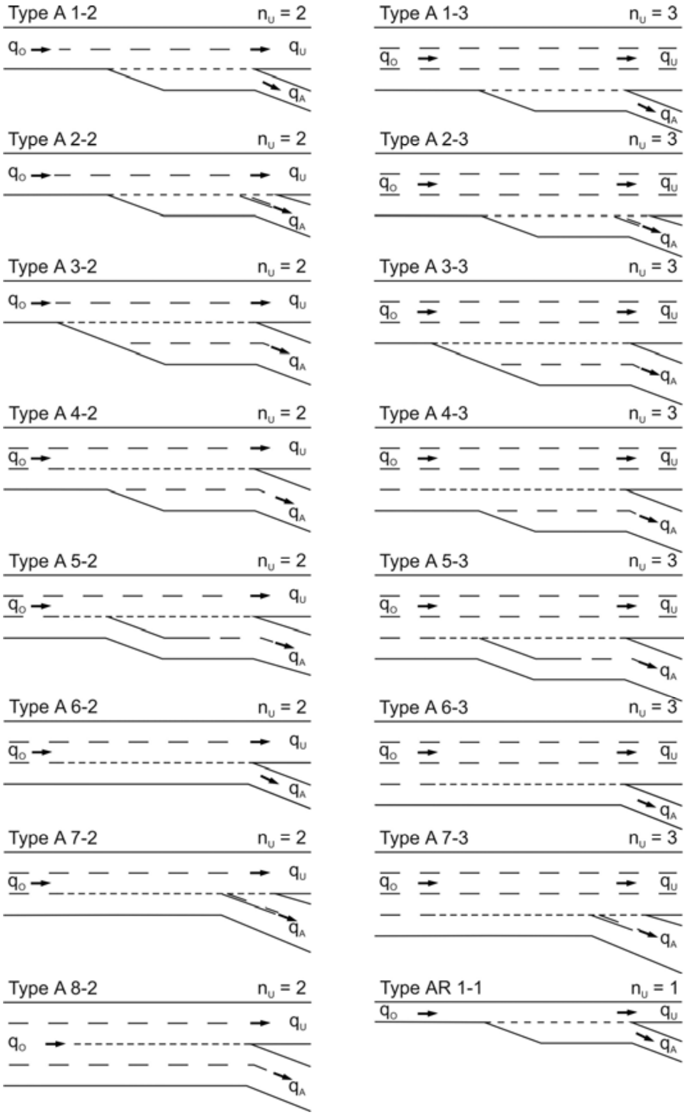

Fig. 1. Diverge Segments (off-ramps) on freeways in HBS 2015 according to FGSV (2008a)

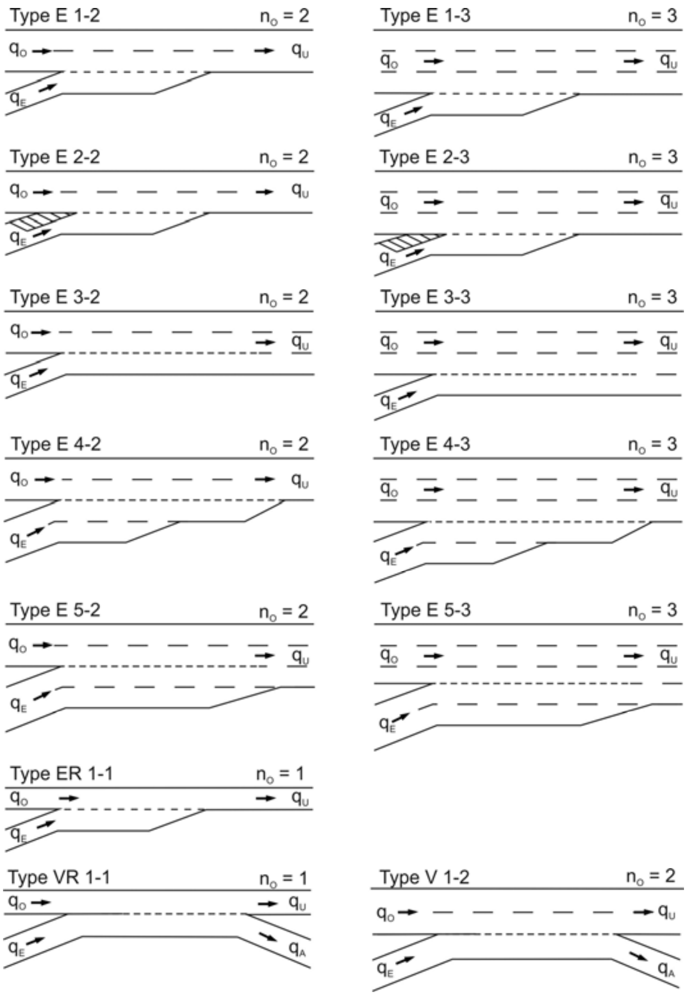

Fig. 2. Merge segments (on-ramps) and small weaning segments freeways in HBS 2015 according to FGSV (2008a)

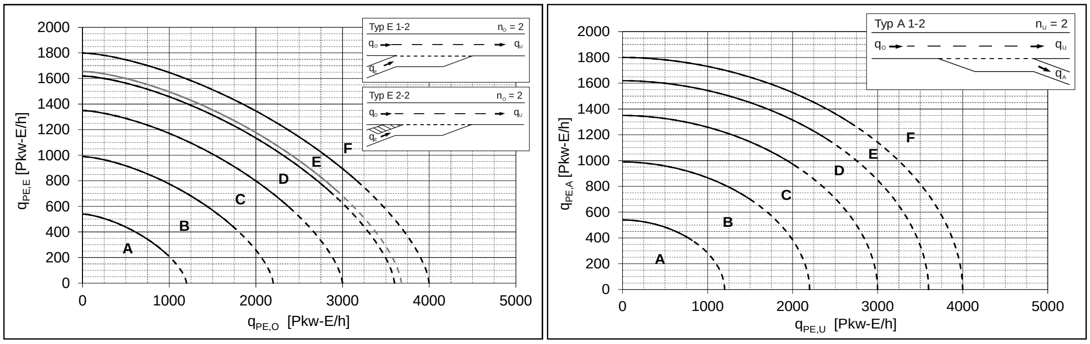

Fig. 3. Examples of diagrams: on-ramp type E 1-2 / E2-2; off-ramp type A 1-2 (Translation: Typ = Type; Pkw-E, PE = pc)

Table 5. Parameters for diverge segments (off-ramps) in HBS 2015

Type	a [-]	C_A [pc/h]	C_{HU} [pc/h]
A 1-2	1.9	1800	4000
A 1-3	1.9	1800	5800
A 2-2	1.2	3060	4000
A 2-3	1.4	3060	5800
A 3-2	1.1	3600	4000
A 3-3	1.3	3600	5800
A 4-2/A 5-2	1.9	3600	4000
A 4-3/A 5-3	2.5	3600	5800
A 6-2	2.7	2000	4000
A 6-3	4.0	2000	5800
A 7-2	2.0	3060	4000
A 7-3	2.9	3060	5800
A 8-2	6.0	3600	4000
AR 1-1	1.2	1800	2000

Table 6. Parameters for merge segments (on-ramps) and small weaving segments in HBS 2015

Type	a [-]	C_E [pc/h]	C_{HO} or C_{VO} [pc/h]
E 1-2 / E 2-2	1.5	1800	4000
E 1-3 / E 2-3	2.1	1800	5800
E 3-2	2.7	2000	4000
E 3-3	3.8	2000	5800
E 4-2	1.05	3600	4000
E 4-3	1.3	3600	5800
E 5-2	1.8	3800	4000
E 5-3	2.4	3800	5800
ER 1-1	1.2	1800	2000
VR 1-1	1.4	1800	2000
V 1-2	1.5	1800	4000

Compared to the model in the previous HBS 2001, the new model in HBS 2015 has the following advantages: a) a uniform function for all types of freeway merge, diverge, and weaving segments, b) traffic quality assessment for three critical areas in one step (on-ramp/off-ramp, major freeway upstream/downstream, merge/diverge/weaving maneuver area), c) all boundary conditions satisfied, and d) easy calibration.

It is to be noted, that the unit used in this chapter is passenger car per hour (pc/h) for vehicle volume and capacity. Thus, all vehicular volumes are required to be transformed in to pc/h. For heavy vehicles, a passenger-car equivalent PCE of $E_{HV} = 2$ pc/truck is used. For upgrade loop-ramps, the value is risen to $E_{HV} = 2.5$ pc/truck.

Because the upstream and downstream freeways may have different capacities depending what type of freeway is actually involved and the unit of freeway capacities is different (veh/h), some of those freeway capacities can be less than the capacities calculated in this chapter (cf. the areas with dotted line in Fig. 3). Thus, the upstream or downstream freeway cross-sections have to be examined against the corresponding freeways capacities. The capacities of basic freeway segments in HBS 2015 are given in Table 3 and Table 4.

5. Two-lane Rural Highways (Chapter L5 and L6)

The procedure in the former HBS 2001 dealing with the capacity and traffic quality of 2-lane rural highways was introduced by Brilon and Weiser (1998, 2003). In the case of segments of rural highways, only two-lane rural highways have been addressed so far. In the new HBS 2015 (Chapter L5), 2+1-sections (Brannolte et al., 2004) and short sections of four-lane dual-carriageway segments (Maier and Berger, 2012) can also be assessed. The assessment of two-lane rural highways, which in the past was done on a cross-section basis, is converted to a directional assessment (Weiser et al., 2015). The influencing parameters are still the grade and the bendiness. The performance measure for rural highway segments in general is the traffic density. While for single carriageways (two-lane and 2+1-roads) the density per lane is the relevant measure, on short segments of dual carriageways in the rural highway network the density applies to the entire carriageway (2 lanes) (cf. Wu and Lemke, 2015). Thus, the chapter now considers all new cross sections types from the German rural highway design guidelines RAL (FGSV, 2012).

In addition a new chapter L6 for Entrances and Exits (on- and off- ramps) is incorporated for rural highways.

6. Signalized Intersections (Chapter S4 and L4)

This chapter is totally revised compared to the former HBS 2001, because some fundamental parameters and calculation procedures are not more up to date. For example, the basic saturation flow rate is recalibrated and the delay formula is substituted by a new one which considers also the coordination and peak-hour effect. In the new HBS 2015, the chapter for signalized intersection (S4 and L5) is improved by avoiding overlapping with the *German Guidelines for Traffic Signals,* RiLSA (FGSV, 1992, 2003, 2015a).

The procedures for signalized intersections in HBS 2015 are comparable with HCM 2010 in many aspects. Compared to the previous HBS 2001, the new HBS 2015 is modified in the following aspects:

- No signal design procedure included, signal design is carried out using RiLSA 2015 (FGSV, 2015a)
- All procedures are developed for traffic performance assessments
- A effective green time $g_e = g + 1$ is used
- More accurate adjustment factors for saturation flow rate
- A new model for delay calculation accounting for coordination and instationarity in peak-hour
- New procedures for shared short-lanes
- New values for LOS definition

It should be noted, that for intersections with the same input data, the new HBS 2015 will deliver different LOS values compared to the old HBS 2001.

As a basic concept, the new HBS 2015 focuses only on the assessment of traffic performance at signalized intersections given a predefined signal timing plan. The procedure for traffic signal design is referred to RiLSA 2015. That is, in HBS 2015, the green time g and the cycle time c are given as input parameters which should be estimated beforehand according to RiLSA 2015. In contrast to the previous HBS 2001, an effective green time g_e is used for further calculation instead of the length of the indicated green time g. The effective green is defined as the green time g plus 1 second. That is,

$$g_e = g + 1$$

with g = indicated green time, s
g_e = effective green, s

The basic saturation flow rate S_o is 2,000 pc/h/ln. That is, a basic saturation headway $t_{H,0} = 1.8$ s is used for the base condition. For taking into account external conditions, the basic saturation flow rate is than adjusted as following.

$$S = \frac{3600}{t_H} = \frac{3600}{f_{HV} \cdot f_1 \cdot f_2 \cdot t_{H,0}}$$

with S = adjusted saturation flow rate, veh/h/ln
t_H = adjusted saturation headway, s
S = adjusted saturation flow rate, veh/h
f_1 = max (f_b, f_R, f_s), -
f_2 = min (1, f_s), -
f_{HV} = adjustment factor for heavy vehicles in traffic movement, -
f_b = adjustment factor for lane width b, -
f_R = adjustment factor for turning radius R, -
= adjustment factor for approach grade s, -
$t_{H,0}$ = base saturation headway, s
= 1.8 s

The adjustment factor for heavy vehicles in traffic movement is calculated as

$$f_{HV} = \frac{q_L + 1.75 \cdot q_{truck+bus} + 2{,}5 \cdot q_{trailer}}{q_{veh}}$$

with f_{HV} = adjustment factor for heavy vehicles in traffic movement, -
q_L = flow rate of light vehicles (cars, vans, and motorcycles), veh/h
$q_{truck+bus}$ = flow rate of trucks and buses, veh/h
$q_{trailer}$ = flow rate of trailers, veh/h
q_{veh} = total flow rate, veh/h
= $q_L + q_{truck+bus} + q_{trailer}$

The adjustment factor for lane width s, tuning radius R, and approach grade s are given in HBS 2015 in form of diagrams.

In the new HBS 2015, capacities for different movements and different lane configurations (critical points, cf. Fig. 4) can be calculated: 1) Capacity of protected signal groups, 2) Capacity of permitted or partially permitted left-turn movements, 3) Capacity of permitted or partially permitted right-turn movements, 4) Capacity of share lanes, and 5) Capacity of share short-lanes.

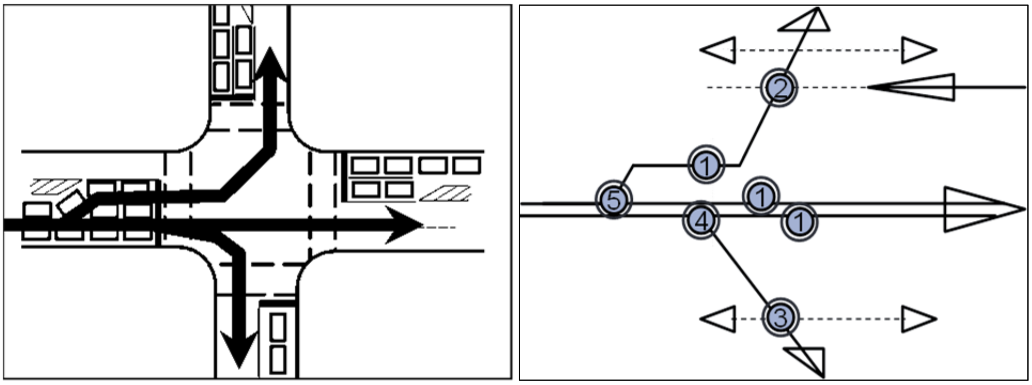

Fig. 4. Critical points of capacity estimation at signalized intersections.

Aa a totally new feature of the chapter for signalized intersections the procedure for capacity of share short-lanes is introduced. Normally, the capacity of share lanes can be easily calculated using the well-known formula

$$c_{sh} = \frac{\sum q_i}{\sum \frac{q_i}{c_i}}, \; veh/h/ln$$

However, if there is an additional short lane for the tuning movement at the approach (cf. Fig. 5), the capacity would be underestimated by this formula. In HBS 2015, a new procedure (Wu, 1997, 2007) is incorporated for dealing with this problem.

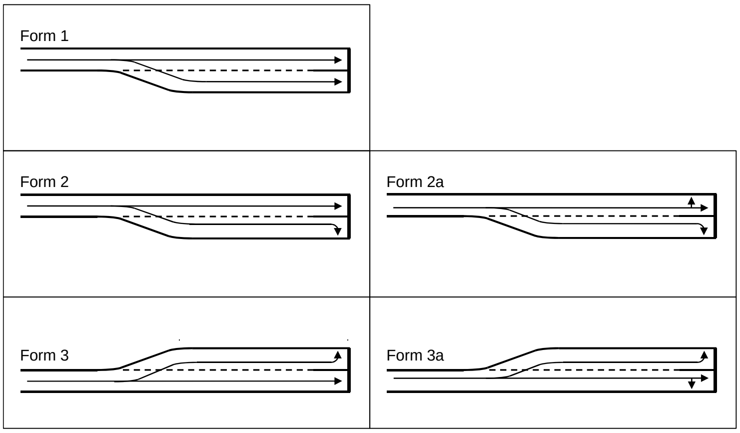

Fig. 5. Possible layouts of shared short-lanes at signalized intersections.

In general, the capacity of a shared short-lane is a function of different parameters. If the capacity within a cycle time is considered, the capacity of a shared short-lane can be expressed as (cf. Fig. 6)

$$n_{c,K} = f(n_{c,1}, n_{c,2}, a_1, a_2, n_K)$$

with $n_{c,K}$ = capacity of the shared short-lane within a cycle time, veh
$n_{c,1}, n_{c,2}$ = capacity of separate lane 1 and 2 within a cycle time, veh
n_K = number of waiting places within the short-lane, veh
a_1, a_2 = proportion of flows of stream 1 and 2 with $a_1 + a_2 = 1$, -

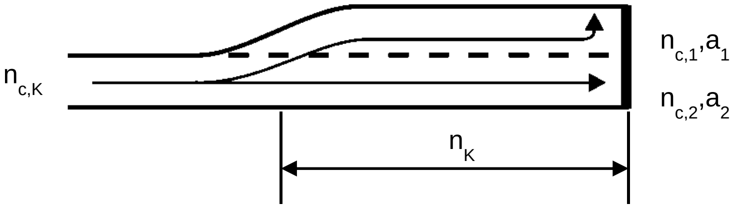

Fig. 6. Parameters for capacity of shared short-lanes.

For lane configurations depicted in Fig. 5, diagrams are provided in order to estimate the capacity of the shared short-lanes both for overlapped and not-overlapped green times. Fig. 7 shows an example for the parameters $n_K = 3$ und $a_2 = 0.3$. For partially overlapped green time the capacity can be obtained by interpolation.

The hourly capacity of the shared short-lane is than

$$c_K = n_{c,K} \cdot 3600/C, \text{ veh/h/ln}$$

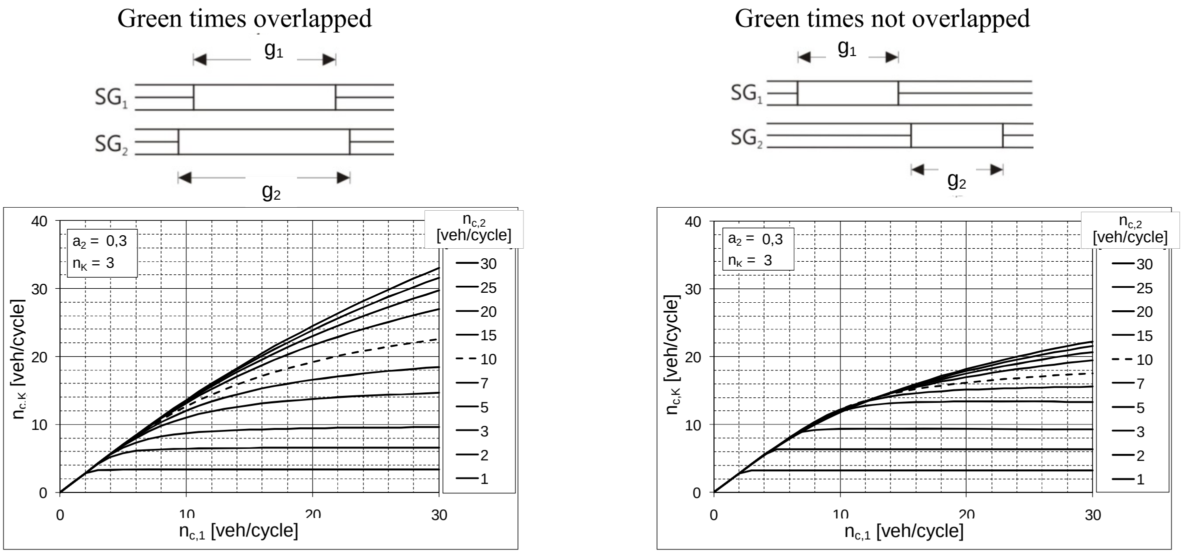

Fig. 7. Capacity of shared short-lanes at signalized intersections for an example with $n_K = 3$ und $a_2 = 0.3$.

The main criteria for signalized intersections in HBS 2015 are delays. For automobile and public transport on public transport only lane, the averaged delay d is used for defining Level of Service. For pedestrians and cyclists, the maximum delay d_{max}, is the criteria (see Table 7).

Table 7. LOS Criteria for signalized intersections in HBS 2015

LOS	Automobile	Public transport on public transport only lane	Pedestrian and cyclist
		Average delay d [s]	Maximum delay d_{max} [s]
A	≤ 20	≤ 5	≤ 30
B	≤ 35	≤ 15	≤ 40
C	≤ 50	≤ 25	≤ 55
D	≤ 70	≤ 40	≤ 70
E	> 70	≤ 60	≤ 85
F	--- 1)	> 60	> 85 2)

1) The LOS F is always apply for $q > c$.
2) Maximum cycle time (90 s) minus 5 s.

The average delay d for automobile is calculated according to the predefined procedures in HBS 2015. The maximum delay d_{max} for pedestrians and cyclists is equal to the red time $r = c - g_e$. The average delay for automobile is calculated according to a model developed in Germany (Brilon and Wu, 1990; Wu, 1997, 2014). The model can take into account the instationarity in the peak-hour using an instationarity factor f_{in}. The instationarity factor f_{in} is calculated according to the flow pattern in the peak-hour. In HBS 2015, a more realistic approximation (cf. flow pattern HBS 2015 in Fig. 8, left) is used. This approximation can better take into account the peak-hour effect compared to the approximation in HBS 2001 (cf. flow pattern HBS 2001 in Fig. 8, left). The resulted difference in the delay calculation is depicted in Fig. 8, right. For $f_{in} > 1$, the delay values from HBS 2015 are normally higher than the delay values from HBS 2001 in the area between the degree of saturation $x = 0.8$ and 1.0 because of the peak-hour effect.

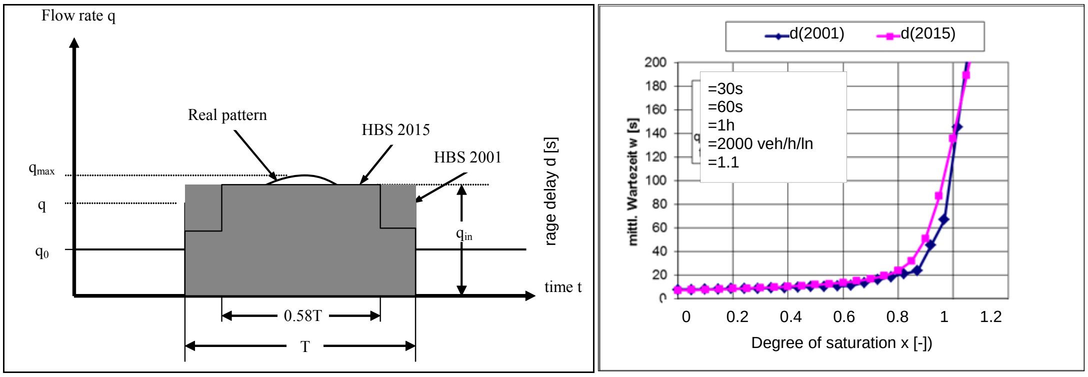

Fig. 8. Flow patterns considering instationarity factor $f_{in}=q_{in}/q$ (left) and the effect in delay calculation (HBS 2001 vs HBS 2015).

The effect of the signal coordination is also considered using a progression adjustment factor f_{k1} and an upstream filtering adjustment factor f_{k2} (cf. also TRB, 2010). The progression adjustment factor f_{k1} is a function of the proportion of platoon P_{pl} and the arrival time of platoon t_a within the cycle time c (see Fig. 9). The upstream filtering adjustment factor f_{k2} is a function of the upstream degree of saturation x_u. The effect of the actuated signal control is neglected in the delay calculation in HBS 2015.

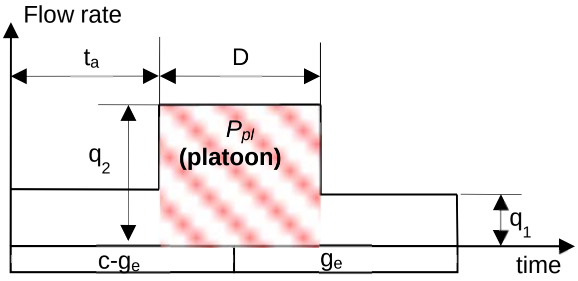

Fig. 9. Proportion of platoon P_{pl} and arrival time of platoon t_a the cycle time c.

7. Unsignalized Intersections (Chapter L5 and S5)

Calculation procedures for unsignalized intersections have been developed cooperatively by American, Australian, and German researchers since many years. The new German version of the corresponding chapter tries to contribute some additional improvements in this area.

In HBS 2001 and HBS 2015, the basic capacity is calculated by Siegloch's formula. The critical gaps and follow-up times were estimated by comprehensive investigation in German (Brilon and Weinert, 2001). The problem of two-stage priorities was resolved like in HCM 2010.

Improvements that have not yet been included in HCM 2010 include:

- Impedance factors for rank 4 movements: The current HCM-solution is based on Grossmann's (1991) simulation results. Wu (1998) has found a theoretical approach to that problem that enables a more precise estimation of impedance effects.
- HCM 2010 does not address the mixed and short lanes on traffic performance properly. Mixed lanes are lanes used by different movements. Short lanes are lanes in which different movements interfere with each other when the assigned lanes are too short to accommodate the maximum queue. In HBS 2001, the theoretical procedure developed by Wu (1997) is incorporated for minor approaches. Unfortunately, the procedure for the mixed and short lanes was incorrectly adapted to major approaches with mixed and short lanes. In the new HBS 2015, the procedure for the mixed and short lanes in major approaches is revised.

- In HCM 2010, capacity calculations for roundabout entries are based on a calculation method described by Brilon, Bondzio, and Wu (1997). This method is now recalibrated for taking into account the new developments in geometric design in the roundabout construction such as the mini-roundabouts, turbo-roundabouts etc.

According to those innovations, the unsignalized chapter in HBS 2015 has a rather high standard regarding theoretical background. In addition, it has been possible to gain many findings from studies on the parallel updating of the guidelines on traffic signals (FGSV, 2015a). For stop-controlled intersections, the gap acceptance method has been modified on the basis of approaches from the conflict matrix method (cf. Brilon and Miltner, 2003; Maier et al., 2012). There are new findings on roundabouts from Brilon and Bäumer (2004) and Brilon and Wu (2008). Based on a study by Baier et al. (2014), now also mini-roundabouts are covered by HBS 2015. Brilon and Geppert (2015) developed a framework for the assessment of turbo-roundabouts which were included not in HBS 2015 but in the working paper on turbo-roundabouts (FGSV, 2015c). A new method for intersections where the driver on the right has the right of way has been included (cf. Boltze and Stephan, 2003).

8. Major Urban Arterials (Chapter S6)

In the former HBS 2001, there are no procedures for assess the quality of traffic flow on major urban arterials. In the new HBS 2015, a procedure is incorporated. With this procedure, the traffic flow quality on the sections outside the influence of major intersections can be assessed (cf. Baier et al., 2003; Lank et al., 2009; Sümmermann et al., 2009).

9. Pedestrians, Bicycles, Public Transit, and Parking (Chapter S9, S8, S7, and S10)

Much emphasis in Germany is put on safe and comfortable operation of traffic for non-motorized road users and for public transit systems. In the former HBS 2001, only the service quality for passengers inside the public transport vehicles (busses, trams) is considered. In the new HBS 2015, the traffic flow of public transport vehicles on separate lanes and at (local) public transport stops are included (cf. Köhler and Eikenberg, 2007). In this new procedure, also other road users such as taxis, cyclists, or HOV's are allowed to use the separated bus lane. The assessment of traffic flow for busses and trams mixed with the general traffic will be addressed in the other chapters. The procedures for capacity inside the public transport vehicles are excluded from HBS 2015. A separate guideline shall be developed for the public transport systems. A new chapter for bicycles is introduced in the new HBS 2015. The existing chapters for pedestrians and parking systems are improved (cf. Falkenberg et al., 2003; Baier et al., 2001).

10. Summaries

Major contents of the new *German Highway Capacity Manual* (HBS 2015) are presented. It shows that many results of recent research projects are included into the new HBS 2015. In the main context, the new HBS 2015 is comparable with the HCM 2010 in many aspects.

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