RECENT DEVELOPMENTS IN GERMANY RELATED TO HIGHWAY CAPACITY AND QUALITY OF SERVICE

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ABSTRACT
The contribution reports about research projects and recent developments in Germany. The development of traffic demand and the organization of transport research are described briefly. Recent research findings with regard to the German Highway Capacity Manual (HBS) are listed and summarized comprehensively. The German Guidelines for Traffic Signals (RiLSA) and their English-language version are introduced, and current review activities are reported. Another chapter is a call of the author to establish a comprehensive quality management system for our road infrastructure and operation. For the case of Germany, the state of development in this field is shown, and needs for further research, development, and implementation are identified. Furthermore, a German guideline on the development of strategies for dynamic traffic management is presented, and research findings according the integration of various traffic control and information systems are summarized. Finally, several further developments in the area of highway capacity and traffic control are highlighted.

1. INTRODUCTION

This contribution reports on the latest developments in Germany related to highway capacity and quality of service. The focus is on German motorways (Autobahn), but other interesting developments will be mentioned as well. It may be reminded that no general speed limit is effective on German motorways, but of course, depending on the local situation, in many sections the speed is limited by static signs or increasingly by dynamic signs.

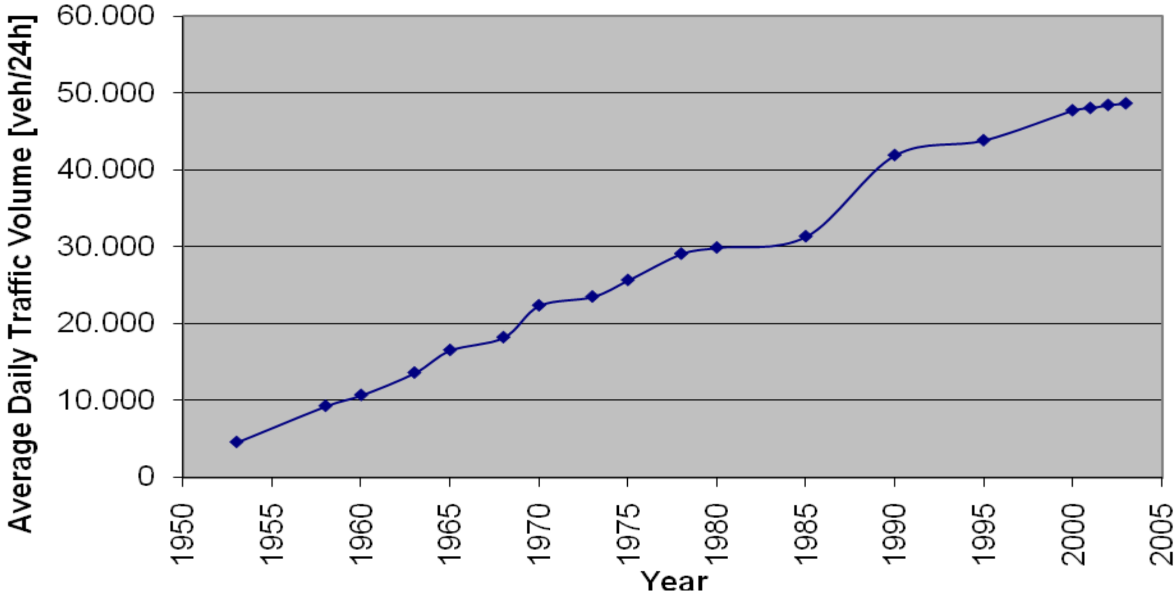

Figure 1: Average Traffic Volume on German Motorway Sections (BMVBW 2003) *corrected*

For many years, the traffic volume on German motorways is increasing continuously (figure 1). This general tendency is also expected for the next years. Especially the heavy vehicle traffic is growing, mainly due to the extension of the European Union by the Eastern European Countries.

Only in the long term, stable or even decreasing traffic volumes may result from socio-demographic developments, which include a cumulative decrease of the German population between 2030 and 2050, and a significant shift in the social groups from younger to elderly people. It is already clear that the changes will be very different in rural areas and conurbation areas. While the prosperous metropolitan areas may see a further growth of population and traffic volumes, the economically weaker rural regions will have to fight against a strong population loss. Consequently, already today the economical efficiency of infrastructure in such regions comes up to be a matter of discussion.

In Germany, research in the field of highway capacity and quality of service is predominantly financed by the Federal Ministry of Transport, Building and Urban Affairs (BMVBS, former BMVBW) since it is the owner of the German motorways. The 16 German Federal States are administrating and operating the German motorways within their territories. Road research is conducted by the Federal Highway Research Institute (BASt – Bundesanstalt fuer Strassenwesen), by German universities or other research institutions. Most guidelines are prepared by the German Road and Transportation Research Association (FGSV – Forschungsgesellschaft fuer Strassen- und Verkehrswesen). Here, high-level experts from administration, research, consulting and industry come together to work out recommendations and to give advices on all topics related to road traffic and transport.

2. PREPARING A NEW VERSION OF THE GERMAN HIGHWAY CAPACITY MANUAL

2.1 General Remarks

The first edition of the German „Handbuch fuer die Bemessung von Strassenverkehrsanlagen" (HBS) was published in 2001. It was introduced by the Federal Ministry of Transport, Building and Urban Affairs as the obligatory methodological basis for calculating the capacity of roads and for assessing the quality of traffic flow when planning Federal Highways. Similar to the US Highway Capacity Manual, HBS is based on a concept of levels of service. An overview on the current version of HBS (2001) was given by BRILON (1998) on the Third International Symposium on Highway Capacity held in Copenhagen.

Following its publication, HBS found a wide range of users. Because of its great importance for practical work, the FGSV decided to up-date this manual. The co-ordination of the reviewing and up-dating process is done by the steering committee KV 6 "Dimensioning Road Traffic Facilities", chaired by HARTKOPF. The members of this group represent all relevant working groups of FGSV dealing with transport planning, road design, traffic management, and infrastructure management. The major part of the work is done in a working group (AK 3.18.1 "Methods of Calculation") under the chair of GROSSMANN. Several sub-groups of this committee elaborate the various chapters of the new HBS considering new research findings and the experience from the application of this manual since 2001.

Goals of the review process are to update the existing chapters and to fill gaps in the contents. With the HBS, it should be possible to assess the level of service for all road users, including general motorized traffic, public transport, cyclists and pedestrians. Compared with HBS 2001, the basic advice for the assessment should be given in more detail and differentiation in the new edition. The users´ perspective should be considered in a stronger way in the quality criteria and levels of service. Additionally, the new generation of German guidelines for motorways, rural roads and urban roads should be considered.

The explanations in this chapter on the foreseen modifications and extensions of HBS are following very closely a report of BAIER, KELLERMANN, and GROSSMANN (2005) given in the German scientific journal *Strassenverkehrstechnik*.

2.2 Planned Modifications and Extensions

2.2.1 Traffic Demand and Capacity (Chapter 2)

This chapter of HBS contains some basics for the application of the dimensioning and quality assessment procedures in HBS. This regards the procedures to determine the peak hour volume considered as the basis for dimensioning traffic facilities and to determine the capacity.

At Ruhr University Bochum a comprehensive statistical analysis of highway capacity has been conducted considering that this is not a constant value but a random variable. Traffic counts of one year from motorway bottlenecks have been analyzed. Empirical results show that the stochastic variations of the capacity fit very well a Weibull-distribution. It could be shown that freeways can be operated most efficiently at a degree of saturation of 90 %. The developed procedures include a whole-year analysis to assess the traffic flow quality and to evaluate the effects of road construction projects and control measures. For this, the sum of delay over a whole year or the number of congestion hours per year was used as measures of traffic flow performance. [BRILON, ZURLINDEN, and GEISTEFELD (2004). BRILON and GEISTEFELD (2004). REGLER (2004). BRILON, REGLER, and GEISTEFELD (2005)] Details on the "Randomness of Capacity and its Application" are presented by BRILON, REGLER, and GEISTEFELD on this symposium. Although these new results indicate a very valuable path for further research, the procedures seem to have not the necessary maturity so far. Hence, the next HBS will continue to use the 30^{th} hour as the basis for dimensioning. However, comprehensive comments will address the probability of traffic flow disruptions depending on the degree of saturation.

In the current version of HBS, the determination of the traffic volume for which highway facilities are dimensioned was found to be not satisfactory with regard to accuracy and transparency. ARNOLD and BOETTCHER (2005) analyzed 1.759 whole year observations of hourly traffic volumes on the German federal road network. The peak hour volumes have been identified, and the characteristic patterns of peak hour volumes between the 30^{th} and 200^{th} hour have been analyzed. Estimation procedures for peak hour volumes have been derived. The use of directional peak hour volumes or aggregated peak hour volumes is recommended depending on the specific situation. Furthermore, the differences between choosing the 30^{th} hour or the 50^{th} hour have been investigated. It was found that with mostly weekday traffic the 50^{th} hour values are only about 1.0 % to 2.5 % below those for the 30^{th} hour. A statistical measure has been developed to consider the proportion of heavy vehicles in the road engineering and design process. The procedure to estimate the proportion of peak hour volumes to annual average daily traffic (so-called K-factors) was improved. (ARNOLD 2005)

Current research projects in this area address the estimation of relevant peak hour volumes from short-term traffic counts on urban roads. Another topic is the prognosis of peak hour volumes, which consider the shift of traffic in time and space due to oversaturation. A current project by WALTHER et. al. aims at improvements of the prognosis of traffic demand. The assessment of traffic quality in oversaturated situations needs more research, as well. On the one hand, procedures should allow a differentiation between short-term and long-term oversaturation. On the other hand, a differentiation seems to be necessary between frequent regular oversaturations in peak hours and other oversaturations, which are not regular and limited in time.

2.2.2 Freeway Sections (Chapter 3)

The current version of HBS recommends the volume/capacity-ratio (v/c-ratio) only to assess the quality of traffic flow on freeway sections with two or three lanes per direction. Meanwhile, a change in the structure of this chapter came up which divides the determination of the v/c-ratio from the estimation of travel speeds. Furthermore, a simpler approach to estimate travel speeds for short steep road sections shall be introduced.

The impacts of reducing the number of lanes from 3 to 2 have been investigated by FRIEDRICH et al. (2003). The major result was that the capacity of sections with such lane subtraction is lower than the capacity of sections with two continuous lanes. The loss of capacity in sections with a lane subtraction varies between 14 and 18 %, depending on the location within or outside conurbation areas and on the speed limit.

PISCHNER et al. (2003) could show that line control systems (dynamic speed control systems) do not increase capacity. But a more homogenous distribution of the volumes on the lanes could be observed, and the probability of traffic flow disruptions decreases by up to 70 %. Usually, there is no significant impact of line control systems in situations with low traffic volumes at levels of service A, B, or C.

The current HBS version considers only freeways with two or three lanes per direction. So far, sections with four lanes per direction are not used frequently in Germany, but a more frequent use in future is expected due to increasing traffic volumes. In most cases such sections will be located in conurbations, and they will have short distances between intersections. BRILON and GEISTEFELD are currently investigating the application criteria, design standards, and traffic flow on such four-lane sections. The results will contribute to enhance the recommendations in HBS.

2.2.3 Grade-separated Intersections (Chapter 4)

Till now, entrances, merge areas, and exits are treated as separate elements of the intersection in the HBS procedures. To allow an integrated assessment of these elements considering their mutual impacts BRILON and BETZ are currently developing a new procedure for HBS. Based on available HBS procedures, SCHNABEL and KORN (2004) proposed how total capacities for total intersections can be calculated instead of capacities of individual lanes or flows only.

To enhance the HBS, which does not consider all types of elements, currently FRIEDRICH, IRZIK, and HOFFMANN are investigating traffic safety and traffic flow on two-lane entrance ramps at three-lane sections.

Another recently finished project of FRIEDRICH, IRZIK, and HOFFMANN (2006) deals with exit ramps of type A2 according to RAL-K-2 (FGSV 1976). This project aims to develop recommendations for traffic signs and markings to optimize traffic flow and the use of the two exit lanes. It should also assess the quality of traffic flow on this type of exit ramps. WEISER et al. (2005) investigated traffic safety and traffic flow at various types of freeway exits with lane subtractions (diverge areas). Criteria for application and recommendations for the design, the markings and traffic signs have been elaborated.

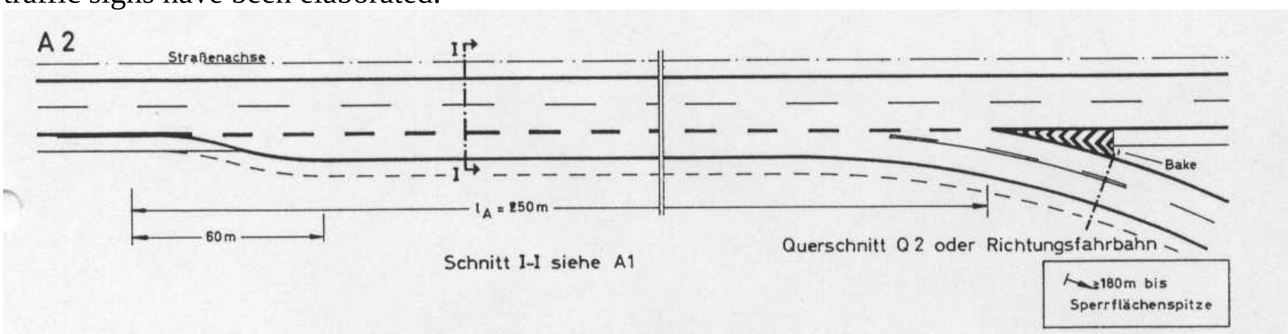

Figure 2: Freeway Exit Type A2 [FGSV 1976]

2.2.4 Rural Highway Sections (Chapter 5)

Background information on the procedures in HBS dealing with the capacity and traffic quality of 2-lane rural highways has been published by BRILON and WEISER (2004). As a major conclusion, they recommend to introduce a procedure for an integrated assessment of consecutive sections and intersections.

Recently, the 2+1 operation of road sections found quite a lot of attention in research. WEBER and LOEHE (2003) worked on traffic safety and traffic flow on b2+1 routes carrying mixed traffic. BRANNOLTE, BASELAU, and DONG (2004) developed a procedure for 2+1 operation with a separate determination of the traffic quality for each direction and consequently a different assessment of the one-lane and two-lane sections. The impact of the number and length of the sections is considered by correction factors. Traffic density is the most relevant quality criteria for roads with 2+1 operation, as well. FRIEDRICH, DAMMANN, IRZIK (2005) investigated the improvement standard and overtaking behavior on 2+1 road sections.

2.2.5 Signalized Intersections (Chapter 6)

A major improvement will be possible in the new HBS by avoiding overlapping with the German Guidelines for Traffic Signals RiLSA (FGSV 1992, 2003a, b). Since RiLSA is currently updated as well (see chapter 3 of this contribution), there is the opportunity for a reconcilement between the responsible FGSV working groups.

For practical application, basic knowledge is missing on the estimation of delays and queue lengths under realistic conditions. So far, the influence of neighboring intersections cannot be considered, and there is no procedure applicable for assessing signal co-ordinations. Furthermore, procedures are only valid for fixed-time control.

WU (2005) found that the adaptation of green times to random deviations of the traffic flow plays only a subordinated role compared with the adaptation of the green time to the traffic flow patterns during the peak-hour. Based on this, he developed a relatively simple procedure to assess traffic-actuated signal control, which may be included in the next version of HBS.

SCHNABEL, SCHOLZ, and POHL (2005) investigated the saturation flow rates at traffic signals based on comprehensive empirical studies in the City of Dresden. The results correspond relatively well with the values recommended in HBS 2001. The basic value of 2.000 vehicles per hour was confirmed. The influences of heavy vehicles and the slope on the saturation flow rate have been analyzed in particular (table 1).

Table 1: Saturation Flow Rates at Approaches of Signalized Intersections in Vehicles per Hour (SCHNABEL, SCHOLZ, and POHL 2005)

Heavy Vehicles	0%		10%		20%		30%	
	HBS	Dresden	HBS	Dresden	HBS	Dresden	HBS	Dresden
Gradient 0,0%	2000	2000	1860	1800	1540	1600	1380	1300
+ 2,5%	1835	2000	1710	1800	1410	1600	1265	1300
+ 3,0%	1800	1950	1680	1750	1385	1550	1240	1250
+ 4,0%	1750	1850	1630	1600	1345	1450	1205	1200
+ 5,0%	1700	1650	1585	1350	1310	1250	1170	1150

FRIEDRICH and FISCHER (2002) elaborated a scheme to compare the traffic quality for different road users. This integrates a definition of different degrees of prioritization of public transport vehicles. Basis of this definition is the average delay of the road users. It is a consequence of prioritization, that the average delay of public transport passengers never should be higher than the delay of other road users. In addition, this research project developed a procedure to determine the traffic quality for pedestrians at traffic signals. It considers the delay at traffic signals and the density in the waiting zone as well as on the crosswalk.

Further research needs have been identified in the equivalency values (passenger car units) which should allow a more differentiated consideration of the different types of heavy vehicles. A current research project at Ruhr University Bochum, which aims at investigating the interrelations of Green Waves and traffic-actuated control, may provide information on this issue.

2.2.6 Unsignalized Intersections (Chapter 7)

While current HBS procedures allow the assessment of the traffic quality for motorized traffic only, BRILON and MILTNER (2003) developed on the basis of former research projects a procedure for unsignalized intersections to determine the traffic quality for pedestrians and cyclists as well. The modular approach allows considering the right-of-way for turning movements and pedestrian crosswalks. A verification of this procedure seems to be necessary before its inclusion in the HBS.

BRILON and WEINERT (2002) proposed a procedure for intersections with right-of-way for turning traffic movements.

Traffic roundabouts with two lanes and an outer diameter between 40 m and 60 m are a quite new type of intersection in Germany. BRILON and BAEUMER (2004a, b) investigated traffic safety and traffic quality at this type of roundabouts. It was found to be safe and efficient, although lane changing on the carriageway proved to be a significant source of conflicts. The capacity of single-lane entries is much higher at double-lane roundabouts than at compact single-lane roundabouts. A second entry lane has only a rather limited effect on the capacity of a double-lane roundabout. Based on these results an adaptation of HBS procedures was proposed and published as a guideline (FGSV 2004). It is foreseen to be included in the new HBS version.

A procedure for intersections regulated by „priority to the right“ has been developed by BOLTZE and STEPHAN (2003). This research included comprehensive empirical studies on traffic safety and traffic quality at this type of intersection. The limits of use (level of service D) are app. 800 veh/h for intersections and 900 veh/h for T-junctions. The capacity limits are app. 900 veh/h and 1000 veh/h respectively. WU (2003) developed a mathematical model for this type of traffic regulation, which basically confirms the results of BOLTZE and STEPHAN.

Further research seems to be necessary on the influence of the distribution of traffic on different traffic streams as well as on the impacts of neighbored signalized intersections on traffic flow at unsignalized intersections. Under discussion is the current approach to determine one traffic stream as being decisive for the quality of the total intersection (in most cases the left-turning movement of the sub-ordinate approach), because it does not consider the absolute traffic volume of this stream.

2.2.7 Urban Arterials (Chapter 8)

A procedure to assess the quality of traffic flow on urban arterials was missing so far in HBS. Meanwhile, BAIER et al. (2003) proposed a procedure assessing the traffic flow on the sections outside the influence of major intersections. In this procedure various impacts are considered, e.g. left-turn movements at minor intersections, parking, or bus stops. BRILON and SCHNABEL (2003) prefer to consider travel speed in the whole network including links and nodes, because travel speed is mainly influenced by intersection control. In another project, STEINAUER, BAUR, et al. are currently investigating the traffic flow on major urban arterials where trams and cars use the same road space. This project aims at developing a procedure to assess the quality of traffic flow for cars as well as for trams. Further needs for research have been identified to consider all road users in various types of urban arterials.

2.2.8 Public Transport (Chapter 9)

The new chapter 9 will include the traffic flow of public transport vehicles on separate lanes and at (local) public transport stops. The assessment of traffic flow for busses and trams mixed with general traffic will be addressed in chapters 6, 7 and 8. While the quality of traffic flow at bus stops was already included in HBS 2001, a new assessment concept has been elaborated for separate bus lanes by BAIER et al. (2001). In this new concept, it is also considered that other road users (such as taxis, cyclists, or HOV´s) are allowed to use the separate bus lane. The procedures related to public transport vehicle capacity will be excluded from the HBS. A separate guideline shall be elaborated for the assessment of the general quality of service offered by public transport systems (availability in space and time, etc.).

2.2.9 Bicycles (Chapter 10)

The missing procedure for dimensioning bicycle traffic facilities was developed by FALKENBERG et al. (2003). It was confirmed that some aspects, which have a major impact on travel speeds (such as gender and age), could hardly be included in a traffic engineering assessment. Instead, the number of changes of direction per km in relation to the traffic volume seems to be an appropriate measure for the quality of service. But results so far are limited to one-direction flow and a minimum width of cycle lanes of 1,50 m. A new version of this chapter was drafted and is currently undergoing the process to come to an agreement of the various FGSV-working groups dealing with bicycle traffic. Research needs have been identified with regard to the level of service for different forms of bicycle regulations. Also the impact of grades and disturbing impacts from other road users need further research.

2.2.10 Pedestrians (Chapter 11)

The former procedure for pedestrian facilities was improved by ALRUTZ et al. (2003). A summary of their results was published by BOHLE, IRZIK, and MENNICKEN (2004). Based on this, a revised version of this chapter was drafted and concerted with other relevant working groups of FGSV. The procedure should only be used in situations with high demand. Further advice on the quality of service for pedestrians is included in chapters 6 and 7.

2.2.11 Parking (Chapter 12)

So far, this chapter only includes the check-in and check-out systems of parking facilities. Research needs have been identified with regard to the general quality of service of parking facilities. This enhanced quality assessment may include the time needed to reach a parking space in a garage or on a parking lot, including driving maneuvers and considering the size of the parking facility, the internal access system, and the v/c-ratio.

2.2.12 Integrated Assessment

The current version of HBS only deals with the assessment of individual, homogenous traffic facilities. An integrated assessment of consecutive sections and intersections is not included. Furthermore, there is no interconnection with the road network assessments as they will be included in the new Guidelines for Integrated Network Planning (RIN) which are currently being elaborated containing a functional road hierarchy, procedures to assess the quality of links between cities, and quality thresholds for road sections.

Further integration seems to be necessary because the road users do not reflect the quality of individual infrastructure elements but assess their whole trip from origin to destination. BRILON, W. and SCHNABEL, W. (2003) worked on the integrated assessment of the quality of traffic flow on major urban roads, without a differentiation between intersections and links. Several current research projects are addressing this aspect of integrated assessment. FRIEDRICH and PRIEMER are working on the impacts of oversaturation at individual elements on the quality of road links.

STEINAUER, SCHLUCKLIESS, and BECHER are investigating the interrelations of traffic flow at level junctions and on two-lane rural roads. STEINAUER, BAUR, et al. are researching on the traffic quality in urban road networks considering the quality of traffic flow at individual intersections and links.

3. RiLSA – THE GERMAN GUIDELINES FOR TRAFFIC SIGNALS

3.1 Edition 1992

The German "RiLSA – Richtlinien fuer Lichtsignalanlagen" (Guidelines for Traffic Signals) (FGSV 1992) reflect a specific and detailed knowledge, grown over many years of scientific research and practical experience.

On 140 pages, comprehensive information is provided on how to design, build and operate traffic signals. Basic principles of traffic signalization are explained, including signal sequences and criteria for the use of traffic signals. A chapter on signal programme design explains the signal programme structure, the determination of transition times (amber and red+amber) and intergreen times, and gives information on the boundary conditions for green and red times. Detailed information is given on the impacts of traffic signal control on the intersection layout (lanes, traffic islands, stop-lines, kerb radii, markings, and signing). Various control strategies are described, control and assessment parameters are explained, and advice on the development of the control algorithm is given. Further chapters deal with the design principles of Green Waves, and with the particular consideration of public transport vehicles, pedestrian traffic and bicycle traffic. Technical information on lightning design, design of the optical units, the number and position of signal heads, traffic signs at signalized intersections, and electrical installations is included. The last chapter deals with acceptance, operation, and maintenance. Several annexes provide further information.

3.2 Partial Revision 2003 and English-language Version

The "Partial Revision 2003 of the RiLSA" (FGSV 2003b) updated the contents of RiLSA. Adaptations have been made to reflect that compilation methods for cycle lengths and green times had been included in HBS (FGSV 2001). The chapters on "Signal Safeguarding" and on "Additional Installations for Blind and Partially Sighted Persons" have been revised. New versions of the chapters on pedestrian crossing of separate railways and on the signalization for cyclists have been included. Further advice on advanced control algorithms and guidelines on co-ordinated traffic signal settings on arterials and in networks are supplemented. New appendices address the quality management of traffic signals and the German "right-turn on red"-regulations.

To intensify and facilitate the discussion and co-operation with foreign colleagues, an English-language version of the guidelines has been published (FGSV 2003a). This translation already includes some of the modifications that have been made by the "Partial Revision 2003 of the RiLSA" (FGSV 2003b). Recently, a translation to Chinese language was prepared by LI (Tongji University, Shanghai).

3.3 Preparing a New Edition

A complete new version of RiLSA is currently elaborated in the FGSV-working group AA 3.16 "Verkehrsbeeinflusung innerorts" (Urban Traffic Control) chaired by BOLTZE. The major work of the review is done in the working group AK 3.16.16 "Neufassung RiLSA" (New Version of RiLSA) chaired by B. FRIEDRICH.

The new edition will include many detailed findings of research from the recent years. A thorough review of new research findings and their assessment with regard to the new version of RiLSA was conducted by BOLTZE, FRIEDRICH, et al. (2006).

Examples for major changes include that the contents of separate chapters on the particular consideration of public transport vehicles, pedestrian traffic, and bicycle traffic will be integrated in the other chapters. Comprehensive recommendations on the quality management for traffic signals will be included as a new chapter. This chapter was drafted in a research project by BOLTZE and REUSSWIG (2005). According to the progress in signal control algorithms, traffic-actuated control will gain more attention. Annexes will be integrated in the main text, and examples will be published separately.

4. TOWARDS A COMPREHENSIVE QUALITY MANAGEMENT

This chapter describes some considerations of the author, which may help to identify further needs for research, development, and implementation.

4.1 Introduction

Our traffic infrastructure is an important locational factor, which contributes significantly to the attractiveness of our countries, regions, and cities. Hence, it is a priority task for our society to ensure the functionality of the transport network and its high quality. Although in Germany a population decrease until 2050 has to be expected, there will be a further increase of traffic demand in the coming years on major parts of the road network. It is very likely that new weak points in our transport systems show up. The quality of traffic will decrease with increasing traffic volumes, if we do not take appropriate countermeasures. At the same time, we will have more and more pressure to make an efficient use of scarce financial resources. All together, the shaping and further development of our transport systems will become more and more a comprehensive management task. Very different requirements have to be considered, and many processes must be controlled in a coordinated way. The major control parameter for this management process must be the quality with regard to traffic flow, safety and environment.

4.2 State of Development

In our society, in many areas of production and services quality management procedures are already well established. They became important elements of a successful business management. In traffic and transport such approaches to quality management came up quite late due to increasing privatization and market-orientation only. But even in road traffic, which is not shaped by market-oriented supplier-customer-relationships, we already have quite many approaches to ensure high quality. In the case of Germany, we have comprehensive guidelines and normative regulations for many matters of road design and traffic control. All of this contributes to a common understanding of quality and to a high quality. With regard to traffic safety we even have normative procedures to check for the safety of roads in the design stage and also during operation. Experiences so far show the success of such approaches. We can thus explicitly confirm that today's experts show comprehensive efforts to ensure and improve the quality of our urban traffic control systems. But we have to be aware, that these efforts to reach a high quality generally are marked by isolated approaches and reaction on pressing deficiencies, by intuition and individual knowledge, by limitation of available resources, and by limitation of available methods and procedures. Also by reasons of efficiency, the existing efforts to ensure quality must be brought together to a comprehensive systematical approach of quality management.

4.3 Objectives of a Quality Management

Primary objective of a quality management is to ensure and to improve the quality. Further important objectives are efficient processes and the efficient use of resources. Scarce financial means must be used goal-oriented and efficient, and this makes it more and more important to set the right priorities. Another important objective of quality management is to make the quality verifiable. This supports the communication with politicians and with the public. It may also support a positive image or may be an advantage in competition. The verification of the quality also allows supervision by higher-level institutions and it supports the legal situation with regard to liability and compensations. This verification of the quality becomes even more important where private companies operate the transport systems.

4.4 Making Quality Management Operational

The starting point of a quality management is the definition of a quality policy and quality aims. Relevant dimensions of quality in the case of road facilities are mainly traffic safety and the quality of traffic flow. Further areas, e.g. environmental impacts, may be added.

Criteria for the assessment of the traffic quality have to be derived out of a set of objectives. The effort to measure these criteria has to be considered prior to the definition of the criteria. Available information and data should be used. Fundamental advice on the specification of the traffic quality is given in the current guidelines. If we look at road transport facilities as a product, it becomes important to ensure the satisfaction of the customers (road users). Further research is needed to give the user’s point of view more consideration in the quality assessment.

Based on the criteria for the quality assessment a monitoring scheme for the traffic quality should be developed and implemented. The scheme should be documented in a quality management manual. This includes the definition of processes and responsibilities as well as the allocation of resources for the quality management. Finally, we may discuss the formal certification of the responsible institutions regarding their quality management.

A comprehensive quality management has to follow a modular approach, embracing planning, implementation and operation of the traffic infrastructure. All individual elements and systems have to be included. Even the traffic management as a process has to be integrated. Urban, spatial and environmental planning should be included into the quality management in its advanced stage. In this way, a hierarchy is generated with interdependencies and synergies between many different processes.

4.5 Outlook

A quality management may appear to cause additional costs. But regularly measures to ensure a high quality of the various systems are realized already. Through systematizing them synergies can be achieved and the overall costs can be even reduced. The more a quality management becomes a routine business the cheaper it will be. Furthermore, a quality management leads to a more efficient and purposive operation of systems, resulting in various benefits. Through the knowledge of the achieved and perceived quality, scarce resources can be focused on the most efficient measures to tackle the problems at hand. A better efficiency can be expected, leading to either reduced costs or a higher quality.

In Germany, the importance of quality management gains more and more awareness. In FGSV, an interdisciplinary working group has been established to deal with quality management across the various committees, including road construction, facility management, transport planning, traffic engineering and traffic management. For specific systems, e.g. traffic signals (see chapter 3), detailed advice on quality management processes has already been elaborated. But many needs for further research, development and implementation can be identified in this field. The discussion on a formal certification of institutions in road traffic regarding their quality management has not even started. Obviously, it is a long way to reach a comprehensive quality management for our overall transport system.

5. STRATEGIES FOR DYNAMIC TRAFFIC MANAGEMENT

Dynamic traffic management strategies are predefined concepts in which – initiated by certain events – one or more selected measures are realized. For example, such measure may be the deviation of a traffic stream, and the systems to realize that measure may be roadside variable message signs, a radio broadcast system, individual navigation systems, or others. So we have a clear hierarchy of strategies, measures and systems. Of course, strategies must be planned systematically. Advice on the planning method has been published by FGSV (2003c).

The comprehensive basic investigations include the definition of the set of objectives, the definition of the investigation area and the strategic network, the documentation of the responsibilities, an analysis of existing technical systems (detection systems, control systems, information systems), the capacity and demand analysis, a systematical investigation of events and problems, and the selection of appropriate measures. Based on this, the strategies can be defined and assessed, e.g. using tools for microscopic simulation of traffic flow. The outcome of this planning process is a catalogue of strategies, which predefine our actions for all likely situations. A Traffic Management Plan may be the appropriate new planning instrument to document the results of such planning process.

The integration of all available traffic control and information systems, even if operated by different institutions, is an important pre-requisite for a comprehensive and efficient traffic management. The necessary physical integration can be derived from the needs for functional integration. BOLTZE and BRESER (2005) found that the linking of different systems – especially when they are operated under different responsibilities – might have four different basic structures (figure 3).

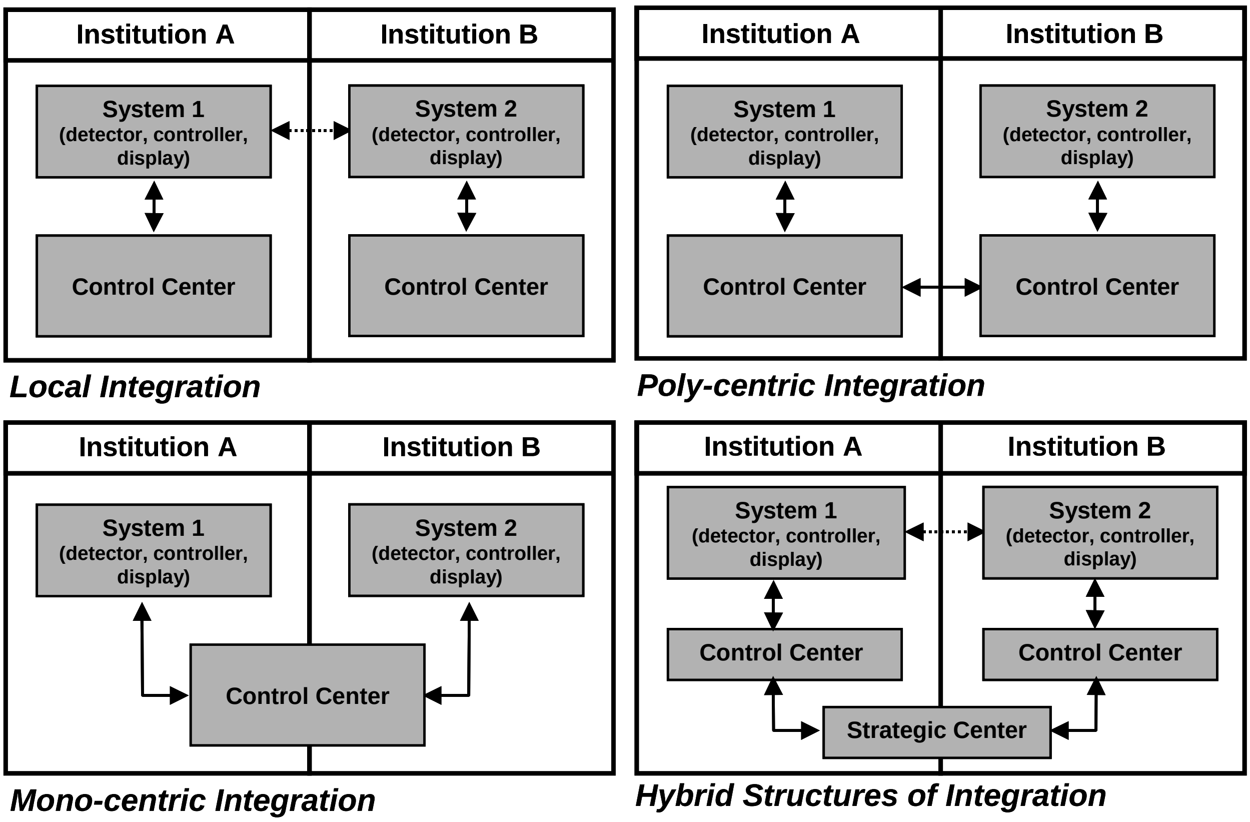

Figure 3: Basic Structures for the Physical Integration of Traffic Control Systems

BOLTZE and BRESER also proposed an appropriate method for planning this physical integration integrated in the planning process for traffic management strategies. Local integration means a direct link between systems (in most cases between the controllers). Poly-centric integration means that each institution has its own control centre, and that the link is built up between these control centres. Mono-centric integration means that different systems are linked to one control centre. This control centre may be in the responsibility of one institution only or as shown in this graph in the responsibility of several institutions. Of course, hybrid forms of integration are possible. All these forms of integration have their specific advantages and disadvantages, and the optimum solution has to be identified carefully. In Germany, there is a clear tendency towards the poly-centric structure, because it allows keeping the responsibilities in those institutions where they have been allocated so far.

In a follow-up project, more detailed concepts for the data network and the data exchange are currently elaborated by BOLTZE, BUSCH, et al.

6. FURTHER DEVELOPMENTS OF INTEREST

In 2005, a **road-pricing scheme for heavy vehicles** has been introduced for the German motorways. After technological problems in the first stage of introduction, meanwhile the tolling system, which is based on satellite positioning (GPS) and mobile communication (GSM), works satisfactory.

New **integrated guidelines for freeways** (RAA – Richtlinien fuer die Anlage von Autobahnen) and **integrated guidelines for rural roads** (RAL – Richtlinien fuer die Anlage von Landstrassen) are on the way to be prepared.

The **standardization of dynamic display panels** on German motorways was facilitated by the publication of a guideline on the standard design and application of dynamic direction signs with integrated congestion information (dWiSta). The guideline was published by BASt and BMVBW (2004). Background information is reported by HARTZ and SCHMIDT (2004).

Basic advice on the planning methodology and on the various aspects of integration for ITS (functional, physical, institutional) has been documented in a **Manual for Intelligent Transport Systems** (Leitfaden Verkehrstelematik) to support the planning and deployment in cities and counties (BOLTZE, WOLFERMANN, and SCHAEFER 2005. To be published by BMVBS in 2006).

A **software program BABSIM** has been developed on behalf of the Federal Highway Research Institute for the simulation of traffic flow on highway sections including single-lane entrances and exits. This software package is currently enhanced to consider all types of entrances and exits.

The history and current applications of the **fundamental diagram of traffic flow** have been documented by a working group chaired by KUEHNE (FGSV 2005).

New developments of **ramp metering** in Germany have been reported by TRUPAT and TEPPER (2004). The existing preliminary guidelines on ramp metering systems are currently under revision.

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