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IMPACT OF PERMITTED DRIVING SPEED ON THE DESIGN OF URBAN STREET NETWORK IN LATVIA

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Abstract. Today, an increasing number of necessary infrastructural measures is encountered the purpose of which is to assist in managing the traffic speed thus forming the most important part in speed management policies. This paper reviews the choice of permitted driving speed depending on the defined street category. The existing norms that define road functions and categories for the urban street network in Latvia are evaluated. This paper stresses the need to review the functional classification of the road network with specific attention paid to the importance of each road type and their influence on the drivers' choice of adequate driving speed. A practical study on the efficiency of the chosen road profile (number of lanes, median, etc.) and design parametres (width of driving lanes, longitudinal curvature radius, horizontal curvature radius, etc) in the existing street network has been performed.

Keywords: road functions, road categories, permitted driving speed, road profile, design parameters.

1. Introduction

Different solutions for road infrastructure may greatly influence speed management on roads thus providing positive impact on traffic safety. Results of different studies show that when specific changes are implemented in road infrastructure also the behaviour of road users both in short- and long-term is about to change, as well. For instance, studies of UK Dept of the Environment, Transport and the Regions have shown that in locations where permitted driving speed was changed but no other alterations to infrastructure were implemented the change in actual driving speed was observed for 1/4 of the max permitted driving speed determined with road signs.

Alterations of road infrastructure that are aimed at more harmonic infrastructure and reflect the needs of all road users are important not only as one of techniques for speed management applied by transport administrations, but also because they contribute to the construction of streets and squares in our cities and towns that are safer for pedestrians and vulnerable road users and simultaneously ensure more mobility for motorists (Antov *et al.* 2009; Žilionienė *et al.* 2010).

2. Road functions and road categories

Substantiation of geometrical parametres for road and street network in urban areas is done on the basis of knowledge about interconnections of transport flows in urban traffic (Cameron, Elvik 2010; Ratkevičiūtė *et al.* 2007). The choice of values of a number of dimensions applied in the design of urban road and street network is based on the Latvian construction norms specified in 1992 year *LBN 100: Teritoriālplānošana. Pilsētu un pagastu izbūve* [Territorial Planning. Urban and Town Construction] which in turn is based on the former Russian construction regulations and norms *СниП 1989: Градостроительство. Планировка и застройка городских и сельских поселений* [Building Regulations. Town Planning. Planning and Construction of Urban and Rural Settlements]). The parametres specified in these norms were acquired either in the result of research done in 60-ies to 80-ies on highways outside urban areas or on city highways in sparsely built-up territories or simply taken over from the experience of other countries without any testing in the existing traffic conditions.

2.1. Existing street categories and their basic importance

Categories of city streets in the past were determined according to the classification shown in Table 1 with respect to foreseen transport and pedestrian flows.

It is known that the alteration of road profile with different engineering measures which is aimed at influencing the choice of driving speed is usually done in urban territories, but is rather rare in sparsely built-up areas. Unfortunately the author has observed that in Latvia different infrastructural measures the aim of which is speed

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management are used rarely even in cities with densely built-up territories. In the middle ages the gates of fortified towns required different behaviour of road users. The idea of gates is also applied in the modern architecture in many cities and towns as one of the most important speed management techniques that creates the need for different road user behaviour in transit zones between the roads outside built-up areas and the roads inside built-up areas where much lower speed is required in order to protect vulnerable road users (Lama *et al.* 2006; Lazda, Smirnovs 2009).

Traffic calming which is used to physically ensure lower traffic speed and reduce the amount of traffic has a long history, as well. Initial trials were carried out in Radburn (USA) in the end of 20-ies when urban streets and squares were transformed with the aim to reduce the amount of traffic. This approach was further developed in Europe in 60-ies when the first guidelines in Sweden stipulated the development of urban areas with ring-type road systems. This idea spread in other countries, as well. Since then the speed management in urban territories with infrastructural measures became very popular and saved many lives all over the world.

Since 90-ies traffic calming and other speed management techniques are implemented not only in urban areas but also on roads outside urban areas, for example, in Denmark, the Netherlands, Germany and the United Kingdom. Alterations in infrastructure connected with speed management are now widely used for traffic calming on urban streets with many variations suited both for motorways and urban arterial streets that require speed management due to safety problems with increasing high-speed traffic flow.

In 60-ies and 70-ies guidelines for urban planning with specific respect to traffic safety were developed in Sweden. These guidelines recommended the creation of such traffic environment that had simple planning and was easy to comprehend by the road users.

Table 1. Street categories and their basic importance specified in the norms (*LBN 100*; *СниП 1989*)

Street category	Street importance
Highways (arterial roads)*:	– high-speed transport connections within urban territory;
– high-speed (crossings only in separate grades)	– exits to main roads outside urban areas, to airports, recreation areas, other urban areas.
– regulated flow (crossings mostly at grade)	– transport connections between urban districts in specific directions and sections outside residential areas that have intensive, mostly freight traffic; – exits to main roads outside urban areas.
City arterials (arterial streets)*:	
1. Urban importance (general urban importance)*	
– free flow (crossings in main directions only in separate grades)	– transport connections between urban districts and centres, as well as, to other arterials and roads outside urban areas;
– regulated flow (crossings with highways and arterials mostly at grade)	– transport connections between urban districts and centres; – exits to other roads and arterials and roads outside urban areas.
2. District importance	
– transport and pedestrian	– transport and pedestrian connections between urban territories and public centres; – exits to other arterials.
– pedestrian and transport	– pedestrian and transport (mostly public transport) connections within separate urban territories.
Streets of local importance (local streets and roads):*	
1. Residential streets;	– pedestrian and transport (except freight and public transport) flow within residential territories; – exits to regulated roads and arterials.
2. Freight transport streets;	– mostly freight and car transport within industrial areas; – exits to urban roads.
3. Pedestrian streets and roads;	– pedestrian traffic to workplaces and recreation areas, service centres, public transport stops, including public centres.
4. Park roads;	– pedestrian and transport traffic in parks and forest territories.
5. Access roads;	– transport accesses to residential and public buildings and their groups and other buildings within city blocks.
6. Cycling roads	– cycling on tracks where no other vehicles are allowed.

* – differences between the previously mentioned sources of reference are given.

Further concepts were developed in 80-ies and 90-ies that specifically stressed the adequacy of road structure so that the road users could themselves choose appropriate driving speed. As indicates in *Organisation for Economic Co-operation and Development, European Conference of Ministers of Transport and OECD/ECMT Transport Research Centre (The JOINT OECD/ECMT)* report of 2006 *"Speed management"* the proposed concepts emphasised the need for structuring the road network and adapting uniform and consequent design principles that would contribute to the reduction of the variability of different road profiles in the road network.

Having analyzed experience of other countries in which climatic weather is similar in Latvia, it is concluded that it would be to use a narrower carriageway lanes than in the existing local design rules. For example, according *Roads and Transportation Association of Canada "Geometric Design Guide for Canadian Roads"* of 1986 year, lane width for free flow of arterial street having more lanes in each direction is related to design speed 80 km/h, lane width is 3.5 m.

SWOV Institute for Road Safety Research in 1994 report *"Infrastructure Design and Road Safety"* says that at prevailing speed 70 km/h, which is equivalent to an appropriate design speed of 80 km/h, the width of the lane arterial street is 3.5 m. Besides, the arterial street with distribution function, the width of lane is from 3.0 m to 3.25 m, that is considerably less than the Latvian design standard set (Table 2).

2.2. General road functions

Based on different references the author has come to conclusion that in general the following three basic road functions may be defined:

Traffic flow function.

Roads with traffic flow function may ensure long-distance traffic efficiently. Inter-urban motorways and highways and sometimes urban arterial streets have the flow function. Other modes of transport and vulnerable road users on such roads have to be strictly separated. The number of access and exit points is limited and the distance between crossings is considerable.

Traffic distribution function.

Roads with traffic distribution function provide opportunity for the road users to access and exit from any urban and rural territory in the whole length of the road. Crossings are more frequent and all types of manoeuvres in crossings are allowed. Such roads are also used by different types of public transport.

Table 2. Calculation parameters for urban streets specified in norms (*LBN 100; СниП 1989*)

Street category	Design speed, km/h	Driving lane width, m	Number of lanes	Min horizontal curvature radius, m	Max longitudinal fall, 0/oo	Sidewalk width,
Highways (arterial roads)* :						
– express	120	3.75	4–8	600	30	–
– regulated traffic	80	3.50	2–6	400	50	–
Arterials (arterial streets)*:						
Urban (general urban importance)*						
– free flow	100	3.75	4–8	500	40	4.5
– regulated flow	80	3.50	4–8	400	50	3.0
District importance						
– vehicle and pedestrian	70	3.50	2–4	250	60	
– pedestrian and vehicle	50	4.00	4	125	40	2.25
						3.0
Local importance (local roads and streets):*						
– residential streets	40	3.00	2–3**	90	70	1.5
	30	3.00	2	50	80	1.5
– freight transport streets	50	3.50	2–4	90	60	1.5
	40	3.50	2	50	70	1.5
– park roads	40	3.00	2	75	80	–
Access roads						
– main	40	2.75	2	50	70	1.0
– secondary	30	3.50	1	25	80	0.75
Pedestrian streets						
– main	–	1.00	according to	–	40	according to
– secondary	–	0.75	calculat.	–	60	design
Cycling roads						
– separated	20	1.50	1–2	30	40	–
– isolated	30	1.50	2–4	50	30	–

* – differences between the previously mentioned sources of reference are given

** – one lane is used for car parking

Traffic destination or access function.

Roads with access function allow actual access to properties in the whole length of the road or street. Both crossings and interchanges ensure traffic exchange. Engineering measures may be needed in order to ensure appropriate low speed.

2.3. General road categories

In order to choose the most appropriate road profile that will greatly influence traffic flow and safety, the road function has to be defined and also the road category has to be determined that would show the location of road (roads in urban areas or outside urban areas) and road type (e.g., motorway) (Table 3).

The general idea is that the roads depending on their function are self explaining. Therefore based on the above mentioned the characteristic cross-profiles and crossing layouts, as well as, type of use and max permitted driving speed have to be determined according to road function types. In addition to that, the placement of horizontal and vertical road furniture has to conform to the main road function and followingly the determined appropriate speed.

2.4. Design speed

Depending on goals both the design and permitted speed is applied in the planning of urban roads and streets. The design speed in Latvia is defined as the max possible driving speed (depending on stability on road and safety conditions) of a single vehicle at normal weather conditions and normal skid resistance of vehicle tyres on roadway surface. This speed is determining the design of geometrical parametres and, first of all, the choice of road cross- and longitudinal profile.

With the increase of the level of mobilisation high design speeds may not be efficiently implemented at extensive road loading. The world experience shows that a stabile trend to reduce the design speed in the road network developed already in 80-ies. It mostly concerns road design, but in urban areas it relates to the design of high-speed urban arterials.

The values for design speed specified in the temporary Latvian construction norms were taken over from the design norms of the Russian Federation used in 60-ies to 80-ies. At present they do not reflect the actual situation on roads and streets and do not allow the incorporation of urban environment limitations created by urban use of land and densely built-up areas. The experience of different countries shows that the values for design speed specified in the temporary Latvian construction norms for all street categories exceed the values specified in the European countries by 10 to 30 km/h.

The level of speed restrictions is determined in relation to the total min costs. However, considering that not all parametres may be expressed in monetary terms, the restrictions of permitted driving speed are chosen according to priorities. The priority for roads is the total number of road traffic accidents and their severity. For city arterial streets the priority is road capacity, and for local road network it is the safety of vulnerable road users.

If the permitted driving speed is considered from the point of view of max road capacity, then the lowest threshold of this speed has to be considered. However, if traffic safety is in question, the highest threshold of driving speed has to be considered. From the point of view of max road capacity the permitted speed on highways should be not less than 80 km/h but on urban arterial streets – not less than 60 km/h due to shorter distances between traffic nodes (Lazda, Smirnovs 2011).

In accordance with the *European Transport Safety Council (ESTC)* report in 1995 *"Reducing Traffic Injuries Resulting Form Excess and Inappropriate Speed"* road design speed may be defined as "the max speed that may be safely and comfortably maintained in the conditions of free traffic". This definition differs greatly from the past design speed definition used in Latvia which was based on the condition that vehicle was driving on the road solely but not in traffic flow.

In the essence the needed design speed depends on road function and thus on the desired driving level. If a road has several functions depending on the urban use of land, the lowest of the speed levels appropriate to each function has to be applied. At present the following limits of driving speed are applied in the European cities:

- 70–80 km/h on roads with traffic flow function;
- 50 km/h on roads with traffic distribution function;
- 30 km/h on roads with access function.

Table 3. Road categories and road functions according *The JOINT OECD/ECMT* report in 2006

Environment	Road category	Road function
Outside urban areas	Motorways (inter-urban)	Flow
	Main roads	Flow
	Motorways (inter-urban main roads)	Flow
	Main roads outside urban areas	Flow/distribution
	Secondary roads outside urban areas	Access
In urban areas	City arterials (urban)	Flow
	City arterials and main roads	Flow/distribution
	Urban roads	Access

However, if high speed is desirable because of the road function, the road quality and roadside safety furniture has to be in the appropriate level. Alternative for the improvement of road standard is the reduction of speed limits and the actual speed in accordance with the road standard and risks.

Undoubtedly the design speed may never be lower that the determined max permitted driving speed. On the other hand, it is also not wise to determine much lower max permitted driving speed than the design speed. This may discredit the reliability of max permitted driving speed.

In addition to that, it is important that design speed in sparsely built-up areas is consequent in as long road sections as possible. If the design speed is essentially reduced in any location the road profile has to be changed and appropriate road sings and markings have to be provided.

Driving speed, traffic flow capacity, etc. are the things that determine the desired level of traffic comfort and traffic safety. When planning the street network one has to understand clearly what the necessary or the desired speed on road should be. In accordance with *ESTC, The JOINT OECD/ECMT* and Danish Road Directorate report in 1991 *"Urban Traffic Areas. Road Planning in Urban Areas"* these desired speeds in urban environment could be classified in four main groups: low speed (0–20 km/h); medium low speed (30–40 km/h), medium high speed (50–60 km/h) and high speed (70–80 km/h).

When planning and designing roads one has to monitor consequently that the road users respect this desired speed (Hauer *et al.* 1982). When choosing the desired speed, road conditions, content of traffic flow, road user groups, road function and category have to be taken into account. The next step after defining the desired speed for each specific street is the choice of geometrical parametres depending on the design speed.

Therefore when planning and managing the traffic in urban street network the road owners have to be very careful in the choice of geometrical street parametres. In the essence they should be chosen not according to a specific road category as it was done in Latvia in the past years but according to real needs, namely, road function, traffic conditions and needs, financial conditions and also traffic safety requirements.

3. Results of the study

A practical study was carried out on 30 arterial streets with different applied design speeds in order to evaluate the substantiation of the chosen road profile and consequently street geometrical parametres in the existing street network. In random order the streets with different profiles (median, number of lanes, etc.) and different geometrical parametres (width of driving lanes, sidewalk width, etc.) were inspected and the appropriate V_{design} and installed road signs for max permitted driving speed were registered. Table 4 shows the summary of roadway widths, lane numbers, lane widths, sidewalk widths, as well as, design speeds (V_{design}) and max permitted driving speeds (V_{perm}) of the inspected streets.

A problem when a street in the existing street network has high category but its function is low or traffic conditions is often encountered in Latvia. As the street category for city arterials is usually high, high V_{design} was applied accordingly and automatically high geometrical parametres were implemented, as well. As the function of the street or traffic conditions are low, the road owner with respect to traffic organisation or traffic safety has been forced to decrease the desired driving speed on road. In the result unnecessarily expensive infrastructure has been created in the urban street network. Existence of good geometrical street parametres and inadequately low permitted max driving speed contributes to the violation of road traffic regulations thus creating unnecessary tension in the society and hindering traffic safety.

Practical study showed that the street function is incorrectly determined for most of the streets in the existing

Table 4. Geometrical parametres of streets in urban street network

Street No.	Carriageway width, m	Number of lanes	Lane width, m	Sidewalk width, m	V_{perm},	V_{design},	Recommended (actual) function	Recommended V_{design} (V_{perm}), km/h	Recommended lane width, m
1	11.03	2	5.51	2.94	50	80	distribution	60 (50)	3.00–3.25
2	11.08	2	5.54	2.92	50	70	distribution	60 (50)	3.00–3.25
3	9.18	2	3.77	–	70	100	flow	80 (70)	3.5
4	9.20	2	3.69	–	50	100	flow	80 (70)	3.5
5	14.03	2	6.96	2.50	50	80	distribution	60 (50)	3.00–3.25
6	9.60	2	4.75	–	50	80	flow	80 (70)	3.5
7	14.10	4	3.40	2.0	70	80	flow	80 (70)	3.5
8	11.50	2	5.70	1.53	50	70	distribution	60 (50)	3.00–3.25
9	14.43	2	7.21	1.52	50	70	distribution	60 (50)	3.00–3.25
10	9.15	2	4.52	1.95	50	80	flow	80 (70)	3.5
…									
28	10.90	2	4.55	–	90	100	flow	90 (80)	3.5
29	8.92	2	4.46	2.15	50	70	distribution	60 (50)	3.00–3.25
30	11.10	2	4.70	–	70	100	flow	90 (80)	3.5

urban network and that the applied geometrical street dimensions are obviously inadequate. Depending on different traffic conditions the max permitted driving speed on arterial streets mostly is 50 km/h, but the streets themselves according to Table 2 were designed with V_{design} = 70 km/h or even V_{design} = 80 km/h which required inadequately high street geometrical parametres. Based on good practice examples for the planning of urban street network the author in Columns 8, 9 and 10 of Table 4 has made his proposals what could be the function of a specific street, what are the recommended design speed and max permitted driving speed, and what is the recommended width of driving lanes.

Thus inefficient and expensive infrastructure is created that has negative impact on traffic safety because too wide driving lanes contribute to the exceeding of max permitted driving speed. The speed is more accurately estimated in peripheral sight, but underestimated in central sight. The studies revealed the impact of the perception of speed based on the available sphere of sight and they explain why drivers underestimate the speed on wide roads, because there are fewer points of reference. To conclude, the maintenance of such infrastructure also in future may not be feasible.

In addition to that, there are no grounds to specify design speed higher than 60 km/h for regulated city highways, as max permitted driving speed on regulated city highways may not exceed 50 km/h because traffic is regulated with traffic lights and in any case driving speed before traffic lights has to be reduced to 50 km/h.

4. Conclusions

1. It is obvious that the existing legislation on the design of street network in urban areas has to be revised with special attention paid to built-up areas. Appropriate V_{design} has to be applied with respect to urban traffic conditions;

2. When drafting norms under Latvian conditions for the sections of urban streets, the good practice of developed countries should be taken as a basis for the standardisation of street functions with special emphasis of self-explaining roads. It is proposed to use the following main road functions in the planning of urban road network: traffic flow, traffic distribution and access functions, with contribution to simplified understanding and proper use of these functions;

3. Together with the revision of norms the road owners should review the actual functions of streets with respect to traffic conditions in the whole length of the street, as well as, the desired driving speed. Only after that road engineers should choose respective geometrical parametres in their plans and designs;

4. All the above mentioned should serve as pre-condition for the creation of such road infrastructure where drivers acquire knowledge on road environment based on their experience and they themselves organise roads into categories, wherewith a number of additional traffic organisation measures, monitoring and control of traffic flow would become unnecessary.

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