Channelization Turning Flows at Controlled Intersections. The Concept of the Local Roadway Widening

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Abstract. Distinct recommendations on the use of the channelization method absent in the normative documentation of the Russian Federation and the specialized literature. Uniform terminology and the using methods of the channelization of traffic flow on the intersection is absent. In this article: analysis of normative documentation and previously works was performed; definition of the local roadway widening is formulated; the formula for calculating the local roadway widening length for left-turn traffic flows is developed. The optimal parameters calculating of local roadway widening is possible on the basis of the obtained mathematical model.

1. Introduction
Ensuring the appropriate capacity of the street road network is become increasingly urgent problem every year in the cities of the Russian Federation. The capacity of the street road network determines the level of transport service and the quality of the population life. The high level of transport service is determined by the speed, timeliness, predictability, rhythm, safety and environmental performance of the transport system.

Full reconstruction of the street road network sections provides methods: the expansion of the roadway, the construction of engineering structures that separate transport, transport and pedestrian flows at different levels and others. Full reconstruction is not always a possible and appropriate variant to improve the traffic management. Less expensive methods can be used to increase the capacity of the road network.

The presence of three bands (minimum) required for the comfortable accumulation of transport recommended at the entrances before the intersection [2]. Allocating a full lane for left-turn, right-turn traffic flows is not an effective variant for using traffic capacity at intersection. Observations show that the intensity of the turning directions is not more than 25% - 30% from the total flow. In such cases, the most rational variant of the traffic management is the arrangement of special relatively short length lines before intersection for the channelization of the traffic flows directions. Sometimes this method is called "speed change lane".

The definition of "speed change lane" are provided in set of rules 34.13330.2012 "Automobiles roads". The speed change lane is a lane arranged to provide acceleration or deceleration of vehicles when vehicles leave or enter from the traffic flow into the traffic flow moving along the main lanes" [3].

Speed change lane design:
- At intersections and adjunctions in the same level in the places of exit on the roads with heavy traffic and places of exit to the buildings and structures located in the roadside zone;
- At road interchange;
- In locations of sites for bus and trolleybus stops;
- Before the entrances to petrol stations and rest areas.

Based on the definition, the main objective of the speed change lane is to reduce or increase the speed to ensure a safe transition of the traffic flow from the secondary direction, and vice versa.

Lines for the channelization of turning streams are designated by signs "the beginning of a line" before intersections from the viewpoint of the traffic management (Figure 1). According to national standard 52289 "Technical means of traffic management" signs are used to indicate the number increase of lanes for movement in this direction, as well as to indicate the lane intended for turning left or turning [4].

![Figure 1. Signs 5.15.3 и 5.15.4 – «the beginning of a line»](image)

Thus, in the conditions of the city, the increase of the lanes number before intersections is not a speed change lane. Extensions of the roadway are intended to divert left-or right-turn traffic flows in the city (Figure 2).

![Figure 2. Use of sign 5.15.3 when increasing the lanes number before crossing](image)

This allows you to increase the crossing capacity. In turn, speed change lanes are intended to increase or decrease the speed of traffic flows. In this case, the increase of the crossing capacity is due to the providing of security conditions. Transport delays are decreasing. Transport delays are caused by the difficulty of entering the flow from a secondary direction into the main flow, and vice versa.

Domestic experience shows that the increase the lanes number before intersection was considered earlier as a means of increasing the crossing capacity. For example, in the book "Urban routes of communication" Professor M. S. Fishelson proposes the use of "broadening" approaches to the intersection for the separation of traffic flows in the directions [2]. The Professor notes that the length of the broadening should be at least 60 m, as shown in figure 3. However, there is no explanation why the broadening should be of such length and the length should be increased in which cases.
Professor G. I. Klinkovstein does not consider the increase of the lanes number as an independent improvement type of the traffic management to increase traffic capacity of the intersection in the textbook "Traffic management". First of all, he describes the use of channelizing island. The increase of the lanes number is described indirectly (number three in Figure 3) [5].

In addition, the Professor J.A. Kremenets recommends to allocate the left-turn traffic flow in a separate regulation phase of traffic light at the intersection or use other methods of traffic management when the value of left-turn traffic flow exceeding 120 cars per hour [6].

A description of this flow channelization method is found in Highway Capacity Manual 2010 [7]. Intersection turn lanes are desirable at selected locations on two-lane highways to reduce delays to through vehicles caused by turning vehicles and to reduce turning accidents (Figure 4). Separate right- and left-turn lanes may be provided, as appropriate, to remove turning vehicles from the through travel lanes. Left-turn lanes, in particular, provide a protected location for turning vehicles to wait for an acceptable gap in the opposing traffic stream.

However, the Highway Capacity Manual does not provide recommendations for calculating the optimal parameters for turn lanes at intersections.

Material about the waiting area was found in the current of the study of previous studies (Figure 5) [8]. The Waiting area is a part of the left-turn line after the stop line. The authors give a formula to estimate the traffic capacity of the left-turn lane with the waiting area. However, the left-turn lane before the stop line is not considered. The authors do not specify what this lane should have characteristics in particular, the characteristics of the length.
2. The local roadway widening

Thus, the clear definition and methods of use are not available for method involving an increase of the lanes number before intersection in professional literature and regulatory documents.

Based on the above, the definition can be formulated:

Local roadway widening – additional lane before the intersection, allocated special protective structures or road markings, designed to separate right-turn or left-turn traffic flows from the flow of the vehicle moving in the forward direction.

The optimal parameters of the local roadway widening must be defined because:

- the insufficient length of the local roadway widening will not allow to effectively distribute the traffic flow, because the left-turn (right-turn) flow will create a queue at the beginning of the local roadway widening occupying a lane for traffic in the forward direction;
- Excessive the local roadway widening leads to budget overruns
- Excessive the local roadway widening reduces the efficiency of the urban space using;
- The separation of traffic flow into traffic directions will improve traffic capacity and traffic safety at the intersection.

The calculation of the local roadway widening for the left-turn flow moving in the phase of the traffic light cycle together with the flow of the opposite direction is considered (Figure 6).

![Figure 6. Scheme of traffic flows in the phase of traffic light control.](image-url)

Working hypothesis is formulated. The average number of cars accumulated per cycle is calculated knowing the number of traffic light control cycles.
The dynamic gauge of the vehicle is calculated by the formula (1) [5]:

\[ L_D = l_a + v_a t_p + l_0 \]  

(1)

Where: \( L_D \) – dynamic gauge, m; \( v_a \) – vehicle speed, m/s; \( t_p \) – the reaction time of the driver, s; \( l_a \) – average vehicle length, m; \( l_0 \) – the gap before the stopped car, m.

Since the vehicle speed is zero, the formula (1) takes the form:

\[ L_D = l_a + l_0 \]  

(2)

Thus, the formula (3) for the calculation of the local roadway widening takes the form:

\[ L_{LRW} = \frac{N_{lf}}{n_c} (l_a + l_0); m \]  

(3)

Where: \( L_{LRW} \) – length of the local roadway widening, m; \( N_{lf} \) – intensity of left-turn traffic flow, veh/h; \( t_p \) – the number of traffic regulation cycles for the hour.

3. Example of the local roadway widening calculation

The length calculating of the local roadway widening will make for crossing the street Melnikayte – street Taymyrskaya, Tyumen.

The high intensity of the left-turn flow from Taymyrskaya street combined with the counter flow leads to significant traffic congestion on Taymyrskaya street. The risk of car accident increases during rush hours.

The local roadway widening is proposed to organize on Taymyrskaya street towards the street Melnikayte for left turn due to lane for the opposite direction. The incoming flows move only on one lane from the intersection on the street Taymyrskaya. Tangible interference from the narrowing of the roadway designed to move in this direction is not predicted. At the same time, vehicles will be able to make a left turn from two lanes, a right turn on the allocated right lane and move directly along the middle lane on the Taymyrskaya street (Figure 7).

![Figure 7. Schemes of the traffic management at the intersection of the street Melnikayte – street Taymyrskaya.](image)

The optimal length of the local roadway widening is calculated by the formula (3). The intensity of the left-turn flow is 390 veh/h (distributed into two bands). The cycle time is 146 seconds.
The average length of the car is 4 meters. The gap is equal to 3 meters before the stopped car. The optimal length of the local roadway widening is 55 meters.

Thus, the length of the local roadway widening is 55 meters for the left-turn flow on the Taymyrskaya street. The method of simulation modeling in the PTV Vissim software package is used to substantiate the effectiveness of the calculated length project solution for the local roadway widening.

4. Simulation modelling

The simulation model of the current situation was created in the PTV Vissim software package. The simulation model of the Melnikayte and Taymyrskaya streets intersection is shown in figure 8.

**Figure 8.** The simulation model of the Melnikayte and Taymyrskaya streets intersection, the current situation.

Evaluation of the changes effectiveness in the traffic management can be made on the basis of the developed model:
- Changes in the geometric parameters of the road;
- Changes in traffic regulation;
- Changes of traffic parameters.

The organization of local roadway widening in the simulation model of the intersection is shown in Figure 9.

**Figure 9.** The simulation model of the Melnikayte and Taymyrskaya streets intersection with the local roadway widening for left-turn traffic flow.

Experimental studies were carried out to solve the sets problems with using the developed simulation model. The length of the local roadway widening was changed from 25 to 65 meters during the experiment. Also, the whole traffic lane for the left-turn traffic flow was modelled as the maximum possible variant. The results of experimental studies are presented in table 1.
Table 1. The simulation modeling results of the intersection with different lengths of the local roadway widening.

| Parameter                              | Existing road traffic management | The length of the local roadway widening, m | whole traffic lane |
|----------------------------------------|----------------------------------|-------------------------------------------|-------------------|
|                                        | 25                               | 50 | 55 | 60 | 65 |                     |
| Average number of stops                | 1,72                             | 1,71 | 1,68 | 1,65 | 1,66 | 1,68 | 1,52 |
| Average speed of traffic flow, km/h    | 12,99                            | 13,9 | 14,26 | 14,58 | 14,57 | 14,59 | 14,68 |
| Average delay time of one vehicle in the traffic flow, s | 66,93                            | 62,87 | 61,24 | 59,93 | 59,94 | 59,92 | 59,51 |
| Comparative delay time, %              | 100                              | 94 | 91 | 90 | 90 | 89 |                      |

Analysis of the experimental studies results showed that the optimal value of the local roadway widening length is 55 meters. The deterioration of the indicators occurs with a decrease of length (compared with the optimal length):
- Delay time is increased by 2% - 5%;
- The speed of the traffic flow is reduced by 2% - 5%;
- The comparative delay time is increased by 1% - 4%.

Significant changes are not observed when increasing the length of local roadway widening.

The creation of the local roadway widening at the Melnikayte and Taymyrskaya street intersection will decrease delays and increase the speed of traffic flow by 10%. The calculated length corresponds to the simulation results.

Additional studies were conducted to test the working hypothesis. The length calculation of the local roadway widening were conducted to the intersection of Pervomayskaya street, Tyumen. The calculated length parameters are estimated by simulation modeling. The results of calculations and simulation modeling are presented in the table 2.

Table 2. The length of the widening for the intersections of Pervomayskaya St, Tyumen.

| Intersections                                   | The length of the local roadway widening | Intensity of left-turn flow | Cycle time, s |
|------------------------------------------------|------------------------------------------|-----------------------------|---------------|
| Street Pervomayskaya – street Gercena (from Smolenskaya street) | 14,0 | 14,0 | 48 | 150 |
| Street Pervomayskaya – street Respubliki       | 54,8 | 55,0 | 176 | 160 |
| Street Pervomayskaya – street Lenina           | 44,0 | 44,0 | 138 | 164 |
| Street Pervomayskaya – street Gercena (from Lenina street) | 25,2 | 25,0 | 81 | 160 |
| Street Pervomayskaya – street Hohryakova       | 16,0 | 15,6 | 80 | 100 |

Collection of initial data produced for the creation of simulation models and the optimal length calculation of the local roadway widening at intersections street Pervomayskaya – street Gercena, street Pervomayskaya – street Lenina, street Pervomayskaya – street Respubliki, street Pervomayskaya – street Hohryakova. Initial data include:
- Information on the number of lanes on the directions;
- Information on the Existing road traffic management at the intersection;
- Traffic flow intensity.
Simulation modeling and the effective length justification of local roadway widening at the intersections of Pervomayskaya street is performed by the example of the Melnikayte and Taymyrskaya street intersection study.

5. Conclusion
The calculated length of local roadway widening coincide with the optimal lengths obtained by simulation modeling results (Figure 10).

![Figure 10. The parameters of the local roadway widening, obtained by calculations and by simulation modelling.](image)

Thus, the theoretical length value of the local roadway widening is confirmed by experimental data. Studies have shown that the channelization of traffic flows in the directions (channelization left-turn flow) has a positive impact on the intersection capacity. The channelization of the left-turn traffic flow from the forward direction traffic flow allows to reduce probability of situations occurrence at which the vehicles following in the forward direction need to go round the cars expecting opportunity to carry out left turn on the crossing. The road safety increases.

The optimal parameters calculating of local roadway widening is possible on the basis of the obtained mathematical model. This is necessary for developing variants of traffic management at the development stage.

6. References
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