Methodology for determining the required length and number of traffic lanes, other parameters, taking into account the passenger city transport motion

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Abstract. The article presents methods for determining the maximum severity and speed, high-speed and regulated roads, as well as other parameters taking into account the movement of passenger urban transport. The introduction of meta-dynamics will reduce conflict situations to 35–40 %, and, accordingly, the number of places in cities and between them. The lack of published methods for determining the necessary length and number of movements and the principles of their development adversely affects road traffic in cities, in particular, the establishment of the causes of congestion. Traffic safety cannot be ensured without decision making.

Zones resulting from traffic shortages, as well as secondary streets, due to the mismatch of traffic sizes to the number of lanes, primarily the construction of roads [1]. For each car, it is necessary to calculate the interval between the front bumpers (\( \gamma = 1000 \frac{V_{\text{max}}}{\lambda} \)) in terms of ensuring road safety; at the place of residence for night and day storage; for short-term storage (markets, stations, stadiums, hospitals, shops, etc.) [2–4]. Due to the lack of the necessary space for short-term (daily) car storage outside these areas, drivers are forced to use half sons for these purposes, including at least a 50 percent lane deficit in cities and creating this necessary road safety [1, 2, 4].

Road traffic is made possible by calculation and estimation methods. This means that the tools cannot be implemented in a timely manner with the aim of assessing the existing length of the lane, including in the case of highways, and in general in cities, places, regions and the Russian Federation. For each car (on average), 320 square meters (80x4 square meters) of lane are required, 35 square meters – for night garage storage and 25 square meters for short-term storage outside the carriageway, i.e. only 380 sq.m. The proposed methods for calculating and assessing the sufficiency, insufficiency of movement in the territorial formations of cities, with study [1, 3], have the form:

- express roads (highways):
  \[ L_{\text{CD}} = (N_{z. \text{avl.}} + N_{\text{Transz}}) \cdot L_d \cdot h_{\text{TG}} \cdot h_a \cdot K_{\text{TO}} / 1000, \text{km/city}; \]

- adjustable roads:
  \[ L_{\text{MRD}} = (N_{z. \text{avl.}} + N_{\text{Transz}}) \cdot V_a \cdot \tau_j \cdot C \cdot h_{\text{TG}} \cdot h_a \cdot K_{\text{TO}} / t_{\text{zel}} 1000. \]

In particular, methods for operational use are presented.

\[ L_{\text{MRD}} = (N_{z. \text{avl.}} + N_{\text{Transz}}) \cdot V_a \cdot \tau_j \cdot C \cdot h_{\text{TG}} \cdot h_{\text{TO}} / t_{\text{zel}} 3600. \]
For any situations in the object of study:

\[ L = (N_{z,\text{avl}} + N_{\text{trans}}) \cdot V_a \cdot h_{\text{TG}} \cdot h_b \cdot K_{\text{TOL}} \cdot \lambda, \text{ km/citi.} \]  

(4)

Knowing that \( \lambda = q \cdot V_a \) [5], we obtain:

\[ L = (N_{z,\text{avl}} + N_{\text{trans}}) \cdot h_{\text{TG}} \cdot h_b \cdot K_{\text{TOL}} / q, \text{ km/city.} \]

(5)

The spatial interval between the front bumpers of the vehicle is \( \gamma = 1000V/\lambda \) and \( \lambda = 1000V/\gamma \), we obtain

\[ L = (N_{z,\text{avl}} + N_{\text{trans}}) \cdot \gamma \cdot h_{\text{TG}} \cdot h_b \cdot K_{\text{TOL}} / 1000, \text{ km/city,} \]

(6)

where \( N_{\text{avl}} \) – the number of registered vehicle fleet in the control object (OU), TE/mountains; \( N_{\text{trans}} \) – the number of transit fleet daily (on average), TE / city; \( L_d \) is the length of the dynamic longitudinal dimension [6], m/ TE; – traffic intensity (average for OU), TE/h:

\[ \bar{\lambda} = \sum_{j=1}^4 \sum_{k=1}^K \sum_{n=1}^M (\lambda_{jnk} / 4 \cdot K \cdot M), \]

(7)

\( \lambda_{\text{max}} = 3600 \cdot t_{\text{rel}} / (t_{\gamma} - C) \) – lane potential, TE / h; \( j = 1, 2, 3, 4, (1, 3 – \text{odd}), (2, 4 – \text{clear}) \) – traffic numbers of traffic flows (TP); \( k = 1, 2, ..., K \) – lane numbers in directions, \( j \) – through; \( m = 1, 2, ..., M \) – numbers of roads (streets) in the OU, in the directions.

Each street will be counted twice, since on each street there are no clear values; \( V_a \) is the speed of movement (in formula (2) in m/s) in the rest of the equations of a single measurement, km/h; \( \tau_i \) is the time interval between the front bumpers of vehicles when driving, stop lines with a traffic-resolution signal, s/TE; \( C \) is the duration of the traffic light control cycle [1, 3], s/cycle; \( q, r \) – dynamic characteristics (harmonic grand ranks) of traffic flows in odd, clear directions, and other maneuvers, respectively [1, 3];

\[ t_{\text{rel}} = a \cdot (C - T_a) = q / (q + r) \cdot (C - T_a), \quad t_{\gamma} = (1 - a) \cdot (C - T_a), \text{ s/cycle;} \]

1000 – the number of meters per kilometer, m/km; 3600 – number of seconds per hour, s/h;

\( q \) – electric traffic, TE/km; \( \alpha \) is the share of the enabling measure in the sum of the main measures (allowing, prohibiting); \( h_{\text{TG}} \) – coefficient of technical efficiency of the fleet; \( h_b \) in – probability of departure, i.e. receive vehicles to the lanes of the road network, [1, 5];

\( K_{\text{TOL}} \) is the coefficient of transport hazard, \( K_{\text{TOL}} = 1.15 \ldots 1.3 [4] \);

\( t_r \) – reaction of the first car of the queue to \( t_{\text{rel}} \) [1];

4 – the number of directions of movement.

For the operational solution of problems of assessing the sufficiency or insufficiency of the length and number of lanes in key and other directions of traffic flows, the most acceptable formulas are (3)–(7).

The calculations in cycles and main measures, adequate traffic intensities are taken \( \lambda_j, \lambda_{j+1}, \lambda_{j+2} \) and \( \lambda_{j+3} \), t. e. \( q = r, (0.46 + 0.46 = 0.92) \). Inequalities:

\[ 0 \leq \lambda_{j+1} \leq \lambda_{j+2} \leq \lambda_{j+3}, \quad 0 \leq \max (\lambda_j, \tau_j, \lambda_{j+2}, \tau_{j+2}) + \max (\lambda_{j+1}, \tau_{j+1}, \lambda_{j+3}, \tau_{j+3}) \leq 1, \quad \text{charcterizing the rational operation of traffic light control modes, can take place in real conditions:} \]

\[ \max (\lambda_j, \lambda_{j+2}) + \max (\lambda_{j+1}, \lambda_{j+3}) \leq 1656 \text{ TE/h,} \]

(8)

where the terms can have dimensions:

\[ 0 \leq \max (\lambda_j, \lambda_{j+2}) \leq 1656 \text{ TE/h,} \quad 0 \leq \max (\lambda_{j+1}, \lambda_{j+3}) \leq 1656 \text{ TE/h,} \]

(9)

but in total, the intersecting flow directions should not go beyond 1656 TE/h;

The duration of the intermediate ticks is calculated according to the method described in [1], which allows one to obtain optimal traffic light control modes.

Determination of the number of lanes in the meridional \( l_m \) and latitudinal \( l_n \) measurements are carried out by the following expressions:

\[ K_{M} = L_{M\text{MRD}} / (l_M + l_{\text{CB}}), \quad \text{bands/merid;} \]

(11)

\[ K_{Ch} = L_{Ch\text{MRD}} / (l_{Ch} + l_{\text{CB}}), \quad \text{bands/latitudes.} \]

(12)

In large cities and in inter-city traffic – between large cities it is advisable to build a hundred-year-long perspective – 16-lane motorways with eight lanes in each direction:

\( M_M = K_M / 16, \quad \text{motorway/merid.} ; \quad M_{Ch} = K_{Ch} / 16, \quad \text{motorway/lat.} \)

Determination of the area Smag occupied by lanes (highways) is carried out by the following equations:
\[ S_{PDG} = L_{MRD} \cdot B_p, \text{ sq. km /city}, \]  

(13)

where \( B_p \) and \( L_{MRD} \) are measured in km.

The density coefficient of motorways (lanes) is determined by the following expression:

\[ K_{PPDG} = S_{PDG} / S_G, \text{ harmonic quantity}; \]  

(14)

\[ K_{PPDG} = \left( S_{PDG} / S_{cit.} \right) 100, \% \]. \hspace{1cm} (15)

There is a linear relationship between the coefficient of transport hazard and the product of the speed and density of movement, and the proportional dependence is inverse between the intensity of movement, etc.:

\[ K_{to} = V \cdot q / \lambda \cdot h \approx 1,315; \]  

(16)

\[ K_{to} = q \cdot \gamma / 1000 \cdot V \cdot h \approx 1,315; \]  

(17)

\[ K_{to} = \lambda \cdot \gamma / 1000 \cdot V \cdot h \approx 1,315, \]  

(18)

where \( \approx 0.76; \lambda = 0.23 \text{ TE/s}; T = 6.3 \text{ s/TE}; \gamma = 1000 \cdot V / \lambda; \) after substituting \( \gamma \) into formula (18), we obtain:

\[ K_{to} = 1 / h = 1 / 0.76 = 1.315. \]

The traffic safety coefficient is the ratio of the product of the density and speed \((q \cdot V)\) to the product of the coefficient of transport hazard and the traffic intensity \((K_{TO} \cdot \lambda)\) or the product of the density of traffic and the space interval between the front bumpers of vehicles \((q \cdot \gamma)\) the product of the coefficient of transport hazard multiplied by 1000 \((K_{TO} \cdot 1000)\), and finally, the inverse of the coefficient of transport hazard:

\[ K_{BDD} = (q \cdot V) / (K_{to} \cdot \lambda), \text{ relative value}. \]  

(19)

Check: \((\text{TE km/h km/h h/r-TE}) = 1; \) the formula is correct.

\[ K_{BDD} = (q \cdot \gamma) / (K_{to} \cdot 1000), \text{ relative value}. \]  

(20)

Check: \((\text{TE m/km/km TE/h/r-m}) = 1; \) the formula is correct.

\[ K_{BDD} = (\lambda \cdot V) / (V K_{to} \cdot \lambda) = 1 / K_{to} \approx 0.76 \text{ on average}. \]  

(21)

**Figure.** The dynamics of the road safety coefficient
Conclusion
In conclusion, the following should be noted:

- The new formulas presented in the article to determine the necessary length, unlike [3], taking into account the coefficient of transport hazard and the probable size of the traffic and the number of lanes, will allow us to estimate the size of the provision of urban and rural lanes educational institutions not only in districts, territories, regions and republics, but also, integrally, in the whole of the Russian Federation.

- The use of the transport hazard coefficient increases the length of lanes by about 26%, but at the same time helps to create conditions for ensuring traffic safety by at least 30–35%, relative to the existing state of traffic [4, 7].

- Before reconstructing regulated road networks, it is necessary to assess the degree of provision of street-road networks with lanes, then, if not only sufficient, but also if there is a reserve of 30–40%, you can engage in the implementation of modern adaptive traffic light control tools for sequentially skipping flows (this is one of the last options for improving O and UDD on networks at the same level).

- At the same time, it should be borne in mind that 3- and 4-phase hard traffic lights regulation, as well as the passage of left-hand traffic or pedestrian flows according to the cycles allowed for movement in cycles, significantly increase delays [1–3], which are adequate in time – the maintenance of a motor vehicle depot in 406 cars (only at one 4-way intersection with two lanes in each direction, 828 TE/h in each lane) during the year [1, 3]. This is, in fact, an economic justification for the construction of multi-level interchanges for the passage of both traffic and pedestrian flows, linearly related to ensuring safety, both road traffic and environmental traffic, due to a sharp increase in the speed of communication of the public transit passenger transport and bandwidth lanes.

- Road safety depends on the intensity of the conflict between traffic and pedestrian flows, the latter on the frequency, size and complexity of hazardous areas, the density of the information field, and on the isolation of flows in maneuvers and directions, including pedestrian flows and ultimately as a result, from the costs of eliminating these dangerous sections and creating traffic isolation.

- There is a linear relationship between road safety and the cost of creating a road environment that excludes conflict situations not only at intersections, but also on road sections. The quicker the safe road conditions are created, the faster the moment of trouble-free operation of vehicles will come.

- The construction of 16-lane motorways and express roads with the specialization of lanes for passengers, freight and other vehicles will significantly increase the throughput and speed relative to existing regulated road networks, and eliminates conflicting traffic situations, which means creating safe conditions for traffic and pedestrian flows.

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