



MINISTRY OF SCIENCE AND HIGHER EDUCATION OF THE RUSSIAN FEDERATION

**FEDERAL STATE BUDGETARY  
EDUCATIONAL INSTITUTION OF HIGHER EDUCATION  
DON STATE TECHNICAL UNIVERSITY  
(DSTU)**

**INTERNATIONAL ACADEMIC COMPETITION  
FOR MASTER'S APPLICANTS «MASTERSIUM»**

**PROGRAM INTELLIGENT TRANSPORT SYSTEMS**

**METHODOLOGICAL RECOMMENDATIONS FOR PREPARATION  
TO THE FINAL STAGE OF THE COMPETITION**

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## FINAL STAGE

The nature and difficulty level of the Competition problems are aimed at achieving the goals of the Competition: identifying and supporting individuals who have demonstrated outstanding abilities; stimulating students' educational, cognitive, and research activities; developing students' intellectual and creative abilities; creating the necessary conditions for developing a high-quality contingent of master's students focused on continuing their academic careers; developing a system of continuous interaction with gifted and talented youth; disseminating and popularizing scientific knowledge; attracting talented youth, including those from foreign countries, to study for a master's degree.

The tasks vary in difficulty and require varying amounts of time to complete a correct and complete solution. The tasks are designed to test participants' intellectual potential, analytical skills, and creative thinking, among other things.

The in-person stage of the Competition is conducted in written form only. Each Competition participant receives a task form with two possible answers. Each answer contains five questions. When completing the tasks, you must have a black or blue pen, a pencil, and a calculator.

When preparing for the Competition, you should review the topics below.

1. On a section of road XY, a traffic engineer standing at point X counted four vehicles passing in front of him in 20 seconds. Their speeds are shown in the figure. Find: intensity; density; average temporal speed; average spatial speed.

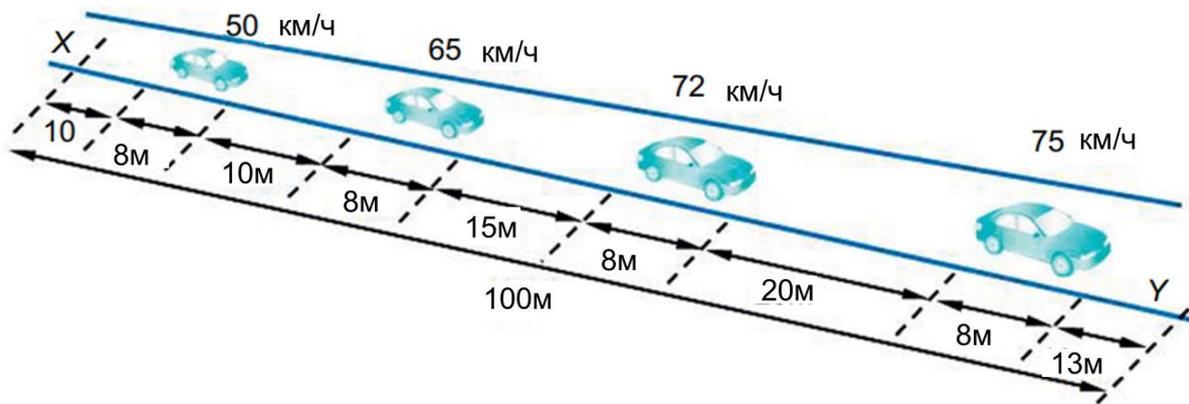


Figure 1

Solution:

Intensity:

$$q = \frac{N}{T}$$

$N$  – the recorded number of vehicles, avt ;

$T$  – data collection period , h

$$q = \frac{N}{T} = \frac{4}{20} = \frac{1}{5} = \frac{1}{\frac{3600}{720}} = 720 \text{ veh/h}$$

Density:

$$k = \frac{N}{L}$$

$N$  - number of vehicles;

$L$  is the length of the observed road section

$$k = \frac{N}{L} = \frac{4}{100} = \frac{1}{25} = \frac{1}{\frac{25}{1000}} = 40 \text{ avt/km}$$

Average time speed:

$$v_t = \frac{1}{N} \sum_{i=1}^N \dot{x}_i$$

( $\dot{x}_i, i = 1, 2, \dots, N$ ) - instantaneous speeds of the vehicle, km/h

$N$  is the number of vehicles

$$v_t = \frac{1}{N} \sum_{i=1}^N \dot{x}_i = \frac{50 + 65 + 72 + 75}{4} = 65,5 \text{ km/h}$$

Average spatial velocity:

$$v_s = \frac{1}{\frac{1}{N} \sum_{i=1}^N \frac{1}{\dot{x}_i}}$$

( $\dot{x}_i, i = 1, 2, \dots, N$ ) - instantaneous speeds of the vehicle, km/h

$N$  is the number of vehicles

$$v_s = \frac{1}{\frac{1}{N} \sum_{i=1}^N \frac{1}{\dot{x}_i}} = \frac{4}{\frac{1}{50} + \frac{1}{65} + \frac{1}{72} + \frac{1}{75}} = 63,891 \text{ km/h}$$

Answer: intensity 720 *veh/h*; density 40 vehicles/km; average temporal speed 65,5 *km/h*;  
average spatial speed 63,891 *km/h*.

2. When designing information systems for a non-urban road, a transportation engineer must determine the distance  $L$  from the preliminary direction sign to the beginning of the exit (branch). This distance should provide the driver with sufficient time to perceive the information, make a decision, and safely execute the lane change.

Initial data for calculation:

Speed of movement when approaching the exit:  $V_1 = 50 \text{ km/h}$ .

Speed of movement on the exit:  $V_2 = 30 \text{ km/h}$ .

The width of the roadway minus the leftmost lane:  $B = 3.75 \text{ m}$ .

Average lane width:  $b = 3.75 \text{ m}$ .

Distance from the left edge of the sign to the edge of the roadway (for lateral placement):

$b_y = 2 \text{ m}$ .

Sign width:  $b_{\text{sign}} = 2.5 \text{ m}$ .

Sign installation height (lower edge above the road, for over-the-road placement):  $h_y = 4.5 \text{ m}$ .

Driver's eye height:  $h_{gl} = 1.2 \text{ m}$ .

Total height of the sign:  $h_{\text{sign}} = 5.1 \text{ m}$ .

Correction factor:  $k = 0.3$ .

Solution:

The distance of the sign from the exit to ensure sufficient distance when performing a lane change maneuver is determined as follows:

$$L_y = 0.5 V_1 + 0.02 (V_1^2 - V_2^2) - 3.5 l_o;$$

where  $V_1$  is the speed of the vehicle when approaching the exit, km/h;

$V_2$  - speed of movement on the exit, km/h;

$l_o$  - the distance of the right edge of the sign from the straight-line trajectory of a vehicle moving in the leftmost lane of a given direction, m.

If the sign is installed to the right of the road, then the value of  $l_o$  is determined as follows:

$$l_o = B = kb + b_y + b_{\text{zn}},$$

where  $B$  is the width of the roadway minus the leftmost lane, m;

$k$  is the correction factor;  $k = 0.3$

$b$  - average width of traffic lane, m;

$b_y$  - distance from the left edge of the sign to the edge of the roadway, m;

$b_{\text{sign}}$  - sign width, m.

In case of installation of a sign above the roadway, the value of  $l_o$  is determined as follows:

$$l_o = h_y - h_{\text{gl}} + h_{\text{zn}},$$

where  $h_y$  is the distance from the lower edge of the sign to the road surface, m;

$h_{\text{gl}}$  - height of the driver's eyes, m;

$h_{\text{sign}}$  - total height of the sign, m.

### **Example.**

$$V_1 = 50 \text{ км/ч}$$

$$b_y = 2 \text{ м}$$

$$V_2 = 30 \text{ км/ч}$$

$$b_{\text{sign}} = 2.5 \text{ м}$$

$$B = 3.75 \text{ м}$$

$$h_y = 4.5 \text{ м}$$

$$b = 3.75 \text{ м}$$

$$h_{\text{gl}} = 1.2 \text{ м}$$

$$k = 0.3$$

$$h_{\text{zn}} = 5.1 \text{ м}$$

1. The sign is located on the right:

$$l_o = B = kb + b_y + b_{\text{sign}};$$

$$l_o = 3.75 + 0.3 \cdot 3.75 + 2 + 2.5 = 9.4 \text{ м};$$

$$L_y = 0.5 V_1 + 0.02 (V_1^2 - V_2^2) - 3.5 l_o;$$

$$L_y = 0.5 \cdot 60 + 0.02 (60^2 - 30^2) - 3.5 \cdot 9.4 = 51.1 \text{ м};$$

2. The sign is located above the roadway:

$$l_o = 4.5 - 1.2 + 5.1 = 8.4 \text{ м};$$

$$L_y = 0.5 \cdot 60 + 0.02 (60^2 - 30^2) - 3.5 \cdot 8.4 = 54.6 \text{ м}.$$

3. Determine the distribution of traffic along two routes in accordance with the Wardrop equilibrium condition .

Efficiency function for route **a** :

$$S_a = 5 + 2 \cdot Q_a .$$

For route **b** :

$$S_b = 10 + Q_b .$$

The total flow between departure points 1 and destination 2 is 1000 vehicles ( $Q_1 = Q_2 = 1000$ ).

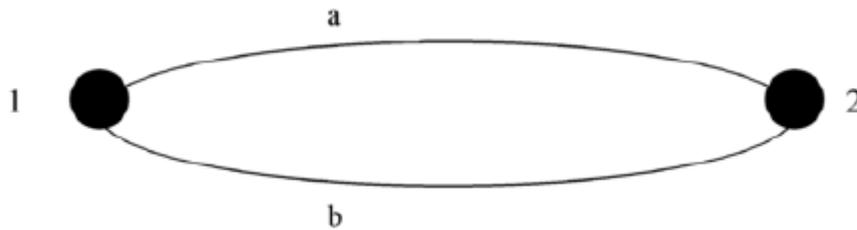


Figure 2 – Dual-route transport network

Solution : The time costs in accordance with the equilibrium condition must be the same for both routes, i.e.  $S_a = S_b$  .

From the condition of preserving the traffic flow (as many as depart from 1 must arrive at 2), it follows:

$$Q_a + Q_b = Q_1 = Q_2 = 1000,$$

Then

$$5 + 2(1000 - Q_b) = 10 + Q_b .$$

Where

$$Q_b = 665 \text{ cars}; Q_a = 335 \text{ auto.}$$

Time costs

$$S_a = 5 + 2 * 335 = S_b = 10 + 665 = 675 \text{ units of time.}$$

4. Figure 1 shows diagrams of the street and road network (solid lines) and the bus route network (dashed lines). All key and necessary geometric parameters are shown on the diagrams. The road width is 15 m.

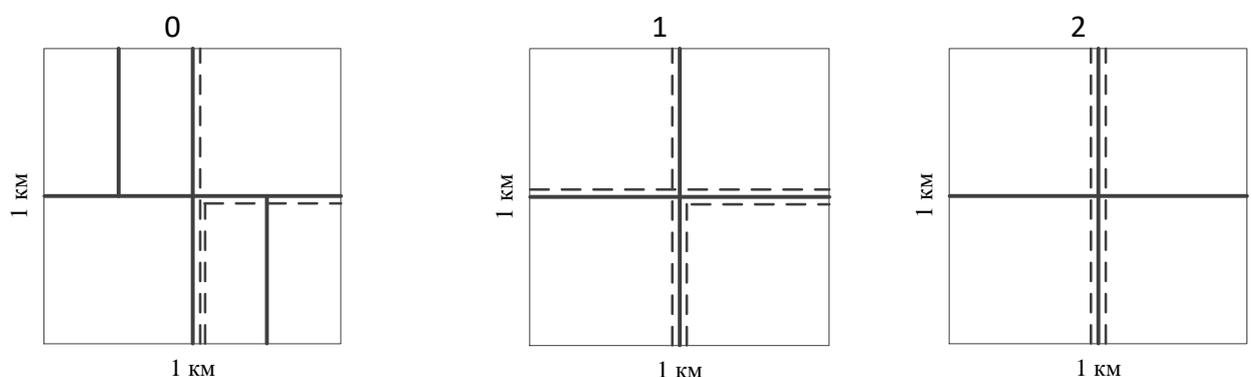


Figure 1 - Schemes of the street-road network and the route network of buses in accordance with the option number

Without performing written or electronic calculations, use the diagram to determine and correctly record the results of the parameter calculations in Table 1.

Table 1 – Results of parameter calculations

Parameter	Size	Parameter	Size
Length of the street and road network, km	3	Bus route network density, km/km <sup>2</sup>	2
Density of the street and road network, km/km <sup>2</sup>	3	Route coefficient	1.33
Dubelier coefficient	0.045	Network coverage ratio	0.5

**Solution:**

Let's solve the problem for option "0".

a) The length of the street and road network on the diagram is 3 km.

b) The density of the street and road network is determined by the ratio of its length to the area of the territory, accordingly the density value is 3 km/km<sup>2</sup>;

c) The Dubelier coefficient is calculated by the ratio of the area of the street and road network to the area of the territory. With the width of the roadway of all roads being 15 m and the length of the street and road network being 3 km, the value of the coefficient will be:  $(3000 \text{ m} \cdot 15\text{m})/1 \text{ million m}^2 = 0.045$ .

d) Route network density is determined by the ratio of the total length of all routes to the area of the territory. The length of bus routes, indicated by dotted lines on the diagram, is 2 km. The bus route network density is 2 km/ km<sup>2</sup>.

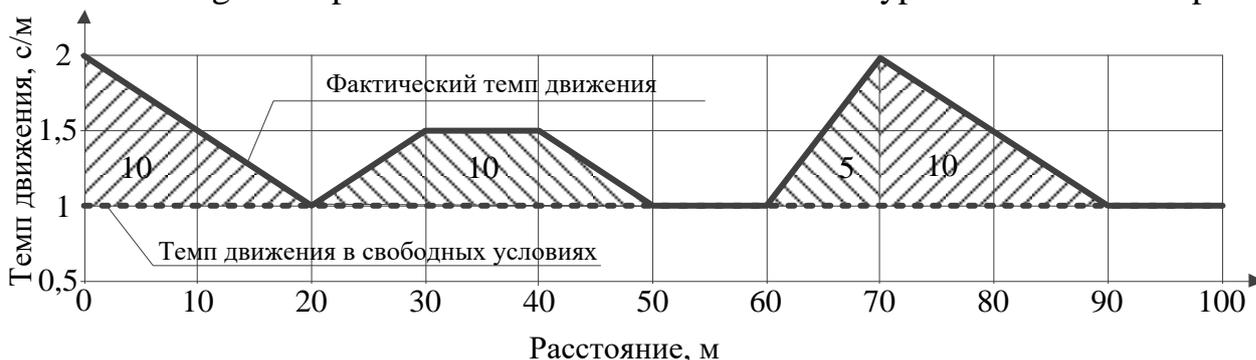
d) Route coefficient – the ratio of the total length of all routes to the length of the street and road network occupied by bus routes. Bus routes occupy 1.5 km of the street and road network. The route coefficient value is:  $2 \text{ km} / 1.5 \text{ km} = 1.33$ .

e) Network coverage coefficient – the ratio of the length of the street and road network occupied by routes to its total length:  $1.5/3 = 0.5$ .

5. On a linear section of pedestrian infrastructure with a length of 100 m, the actual pace of pedestrian movement and the pace of movement in free conditions are set (Figure 1).

Without performing written calculations, determine the pedestrian delay time along a given segment of the route. When determining the delay time, use a geometric method, indicating the delay time directly at each characteristic segment of the given pedestrian route and its overall value directly on the graph.

We'll calculate pedestrian delay time geometrically, defining it as the sum of the areas of simple figures formed by the actual walking pace lines and the walking pace under normal conditions. The height of the figures represents the difference in walking pace values, and the bases of the figures represent the distance traveled over a typical section of the path.



The delay time for a pedestrian moving along a 100m long section with a change in the pace of movement according to the option is 35 s.

#### Literature for preparation

- 1 Andronov, S.A., Fetisov, V.A. Intelligent transport systems textbook Moscow: IPR Media 2021, 260 pages <https://www.iprbookshop.ru/116679.html>
- 2 Fundamentals of Automation of Intelligent Transport Systems Textbook Kapskiy Denis Vasilievich, Kot Evgeniy Nikolaevich Vologda: Infra-Engineering 2022 412 p. <https://znanium.com/catalog/document?id=417411>
- 3 Architecture of intelligent transport systems = Intelligent Transport Systems ` Architecture textbook [for English language learners] Zyryanov, V.V., Feofilova , A.A. Rostov n / D: IC DSTU 202376 p. <https://ntb.donstu.ru/content/intelligent-transport-systems>

**INTERNATIONAL ACADEMIC COMPETITION  
FOR MASTER'S APPLICANTS «MASTERSIUM»**

Program 23.04.01 program Intelligent Transport Systems

Assessment criteria

Option for the final stage of the Competition on 23.04.01 program INTELLIGENT TRANSPORT SYSTEMS. The program includes five different types of tasks. Each task is worth from 0 to 20 points. The maximum total score that can be awarded for all questions in the Competition version, provided there are no errors, incorrect, incomplete, or inaccurate answers, is 100. Incorrect answers are worth 0 points. Partial points may be awarded for incomplete answers to tasks. An incomplete answer is defined as an answer that does not contain correct answers to all questions. In this case, only a portion of the points awarded for correct answers is equal to a percentage of the maximum possible score. The final score for the task is calculated by summing the points awarded for each question.

Problem 1. On road section XY, a traffic engineer standing at point X counted four vehicles passing in front of him in 20 seconds. Their speeds are shown in the figure. Find: intensity; density; average temporal speed; average spatial speed.

Total: 20 points .

Assessment criteria

Criterion	Score
Incorrect answer given/no answer available	0
Traffic intensity was calculated incorrectly	0
The traffic intensity is calculated correctly	2
Traffic density was calculated incorrectly	0
The traffic density is calculated correctly	2
The average time speed was calculated incorrectly.	0
The average time speed is calculated correctly	6
The average spatial velocity was calculated incorrectly.	0
The average spatial velocity is calculated correctly	8
The correct answer is given on all points.	20

Problem 2. When designing information support for a non-urban road, a transportation engineer must determine the distance  $L$  from the preliminary direction sign to the beginning of the exit (branch). This distance should provide the driver with sufficient time to perceive the information, make a decision, and safely execute the lane change.

Total: 20 points.

Assessment criteria

Criterion	Score
Incorrect answer given/no answer available	0
The distance of the right edge of the sign from the straight-line trajectory of the vehicle's movement was calculated incorrectly.	0
The distance of the right edge of the sign from the straight-line trajectory of the vehicle has been calculated correctly.	10
The distance from the edge of the sign to the roadway was calculated incorrectly.	0
The distance from the edge of the sign to the roadway is calculated correctly.	10
The correct answer is given on all points.	20

Task 3. Determine the distribution of traffic along two routes in accordance with the Wardrop equilibrium condition.

Total: 20 points.

Assessment criteria

Criterion	Score
Incorrect answer given/no answer available	0
The condition for maintaining traffic flow was calculated incorrectly.	0
The condition for maintaining traffic flow has been calculated correctly	10
Time costs were calculated incorrectly	0
Time costs are calculated correctly	10
The correct answer is given on all points.	20

Task 4. Without performing written or electronic calculations, use the diagram to determine and correctly record the results of the parameter calculations in Table 1.

Table 1 – Results of parameter calculations

Parameter	Size	Parameter	Size
Length of the street and road network, km	3	Bus route network density, km/km <sup>2</sup>	2
Density of the street and road network, km/km <sup>2</sup>	3	Route coefficient	1.33
Dubelier coefficient	0.045	Network coverage ratio	0.5

Total: 20 points.

Assessment criteria

Criterion	Score
Incorrect answer given/no answer available	0
The length of the road network was determined incorrectly	0
The length of the road network has been correctly determined	2
The density of the street and road network is incorrectly determined	0
The density of the street and road network has been correctly determined	2
Incorrectly defined Dubelier coefficient	0
Dubelier Coefficient is determined correctly	4
Incorrectly defined density bus route network	0
The density of the bus route network has been correctly determined	4
The route coefficient is incorrectly defined	0
The route coefficient is determined correctly	4
The network coverage ratio is incorrectly determined.	0
The network coverage ratio is determined correctly	4
The correct answer is given on all points.	20

Problem 5. On a 100-meter-long linear section of pedestrian infrastructure, the actual pedestrian traffic rate and the traffic rate under unconstrained conditions are specified. Without performing written calculations, determine the pedestrian delay time along this segment. To determine the delay time, use a geometric method, indicating the delay time directly at each characteristic segment of the given pedestrian path and its overall value directly on the graph.

Total: 20 points.

### Assessment criteria

Criterion	Score
Incorrect answer given/no answer available	0
The pedestrian delay time was determined incorrectly	0
The pedestrian delay time was determined correctly	20
The correct answer has been given	20