



LABORATORY MANUAL

Sustainable Transportation within the framework of Green Deal

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KIMYO INTERNATIONAL UNIVERSITY IN TASHKENT



Department of Traffic Engineering and Management

COLLECTION OF METHODOLOGICAL MANUALS

for laboratory work in the course of
Traffic engineering and management



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The set of methodological manuals consists of 10 practical tasks. Each task contains theoretical materials on the topic of "Traffic Engineering and Management", the sequence of tasks, and control questions.

This toolkit has been developed within the framework of the SPHERE project of the Erasmus+ programme, funded by the European Union. However, the views and opinions expressed therein are those of the author(s) and do not necessarily reflect the views of the European Union or the European Education and Culture Executive Agency (EACEA). The European Union and the EACEA cannot be held responsible for the content of this material.

Introduction

These methodological guidelines have been developed for the practical classes of the Traffic Engineering and Management course. They are intended to develop students' knowledge and practical skills in analyzing, evaluating, and designing engineering solutions for road traffic operations. With the continuous growth in the number of vehicles, increasing urban traffic congestion, and the growing importance of ensuring road traffic safety, the need for well-qualified specialists in the field of sustainable transportation has become more significant than ever.

The practical sessions include practical assignments and assessment questions. Each assignment focuses on a specific topic related to traffic engineering and management. The guidelines provide theoretical background, step-by-step procedures for completing the practical tasks, the required calculation methods, traffic analysis techniques, and recommendations for evaluating the obtained results. During the practical sessions, students will learn how to analyze traffic flow using real-world data, model traffic operations with the help of an automobile driving simulator, compare different alternatives, and select the most appropriate engineering solutions. Modern approaches, including traffic simulation modeling and transportation system analysis methods, are applied throughout the practical exercises.

These methodological guidelines are intended for undergraduate and graduate students specializing in Traffic Engineering and Management, Transportation Systems, Traffic Organization, and related academic programs, as well as for instructors conducting practical classes. The manual is designed to support the systematic organization of practical sessions, strengthen students' practical competencies, and bridge theoretical knowledge with real-world transportation challenges.

By completing the practical exercises presented in these methodological guidelines, students will develop the ability to independently solve current transportation problems, make scientifically justified decisions in traffic engineering and management, and prepare practical engineering projects based on modern transportation principles.

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Practical exercise 1: Determining and analyzing the speed of traffic flow

1. **Objective:** to study methods for determining and analyzing the instantaneous speed of traffic flow by measuring it.
2. **General information.**

Traffic flow studies the movement of drivers and vehicles between two points, as well as their interaction with each other. Traffic flow analysis is a complex process, since it is not possible to predict the behavior of drivers with 100% accuracy. At the same time, road users, in particular drivers, move in accordance with certain traffic conditions. Therefore, traffic flows have a certain degree of consistency and can be approximately expressed through mathematical calculations.

The indicators characterizing traffic flow change dynamically at different time intervals throughout the day. Traffic flow is a complex system due to its nonlinear properties. Nevertheless, traffic jams can be predicted and controlled to a certain extent. For this, it is important to identify the main variables affecting traffic flow, study their interrelationships, and correctly assess traffic conditions.

Determining and analyzing traffic indicators using various technical means plays an important role in the effective management of the transport system. In particular, by determining indicators such as traffic flow speed, density, intensity, distance between vehicles, delay time and congestion level, it is possible to assess the state of the traffic process. It is also necessary to identify the main factors affecting traffic efficiency and study the relationships between them.

In traffic flow theory, traffic flows in a road network are usually studied in two ways: continuous flow and intermittent flow. In continuous flow, the movement of vehicles is not significantly limited by traffic lights or other mandatory stopping factors. In intermittent flow, the movement of vehicles is periodically stopped or slowed down by traffic lights, pedestrian crossings, intersections, road signs, or other control devices.



Continuous traffic flow



Interrupted traffic flow

A continuous flow is a flow in which the movement of vehicles is mainly determined by the interaction of vehicles, the geometric parameters of the road, the condition of the carriageway, and the traffic conditions. In such a flow, the influence of external control devices, such as traffic lights, is absent or minimal.

Interrupted flow refers to a flow in which the movement of vehicles is regulated by traffic lights, road signs, pedestrian crossings, intersections, and other external control devices. In such a flow, vehicles may stop, slow down, or accelerate periodically.

When measuring the speed of a traffic flow, the speed of vehicles can be determined over time or over a spatial interval. These approaches are called time-averaged speed and spatially averaged speed, respectively. They differ in the method of calculation and may give different results in some cases.

Speed is the ratio of the distance traveled to the time taken. That is:

$$v_o = \frac{\Delta S}{\Delta t}$$

Here, v_o – instantaneous speed, ΔS – distance traveled, Δt – time spent covering the intermediate distance.

Time mean speed is the average speed of vehicles passing a checkpoint on a specified road section during a certain time interval. It is determined by the arithmetic mean of the individual vehicle speeds:

$$\bar{v}_t = \frac{1}{n} \sum_{i=1}^n v_i$$

Here:

$\bar{v}_t$ — average speed over time, km/h;

v_i — i- Instantaneous vehicle speed, km/h;

n — number of vehicles passing through the checkpoint during the monitoring period.

Average speed over distance (Space mean speed) — is the average speed determined by the spatial location of vehicles moving on a specified road section during a certain time interval. This indicator is determined based on the time taken by vehicles to cover a certain distance and is important in assessing the general traffic conditions of the traffic flow.

The average speed over the interval is determined by the following expression:

$$\bar{v}_s = \frac{n}{\sum_{i=1}^n \frac{1}{v_i}}$$

Here:

$\bar{v}_s$ — Average speed over the interval, km/h;

v_i — i- vehicle speed, km/h;

n — number of vehicles being monitored.

The time-averaged velocity and the interval-averaged velocity are related, and the time-averaged velocity is usually greater than or equal to the interval-averaged velocity. Their relationship is expressed as follows::

$$\bar{v}_t = \bar{v}_s + \frac{\sigma_s^2}{\bar{v}_s}$$

Here: σ_s^2 — Interval variance of vehicle speeds.

The time-averaged speed is usually higher than the interval-averaged speed. However, the difference between them depends on the degree of variability of the vehicle speed. In free-flow conditions, that is, when vehicles move at a high and relatively constant speed, the difference between the time-averaged and interval-averaged speeds is not very large. In traffic jams, however,

the speed of vehicles varies sharply, as a result of which the difference between these two indicators increases significantly.

Example: The following instantaneous vehicle speeds were observed on a specified section of the road network:

$$\bar{v}_t = \frac{66 + 62 + 45 + 79 + 32 + 51 + 56 + 60 + 53 + 49}{10} = 55.3 \text{ km/h}$$

$$\bar{v}_s = \frac{n}{\sum_{i=0}^n \frac{1}{v_i}} = \frac{10}{\frac{1}{66} + \frac{1}{62} + \frac{1}{45} + \frac{1}{79} + \frac{1}{32} + \frac{1}{51} + \frac{1}{56} + \frac{1}{60} + \frac{1}{53} + \frac{1}{49}} = 52.4 \text{ km/h}$$

According to the calculation results, the average speed over time was 55.3 km/h, and the average speed over the interval was approximately 52.4 km/h. So, in this example, the average speed over time is higher than the average speed over the interval, and the difference between them is explained by the different speeds of the vehicles.

Median speed (50th percentile speed or 50 percent speed) — This is the speed value in the middle of the speed range when the speed values are arranged in ascending order. The median speed indicates that 50% of the vehicles in the traffic flow are traveling at or below this speed, and the remaining 50% are traveling at a speed greater than this speed.

The given instantaneous speed values are arranged in ascending order as follows: 32, 39, 45, 51, 53, 56, 60, 62, 66 and 79 km/h.

Since the number of observations is even, the median speed is determined by the arithmetic mean of the 5th and 6th values: Median speed = (53 + 56)/2 = 54.5 km/h.

Therefore, the median speed or 50th percentile speed is 54.5 km/h.

The 85th percentile speed is the speed at which 85 percent of the vehicles in a free-moving vehicle speed distribution travel at or below this value. In other words, only 15 percent of the observed vehicles travel at speeds above the 85th percentile speed.

The 85th percentile speed is an important indicator in traffic engineering for assessing speed regimes, determining realistic traffic conditions on a road section, and justifying recommended or permitted speed limits.

After the given speed values are arranged in ascending order, the 85th percentile speed can be determined by the following expression:

$$R = \frac{85}{100} \cdot (n + 1)$$

Here:

R — 85 percentage speed location ordinal number;

n — number of vehicles tracked.

If the speeds in this example are 32, 39, 45, 51, 53, 56, 60, 62, 66, and 79 km/h, then: $R = 0.85(10+1)=9.35$.

The 85th percentile speed is between values 9 and 10. That is, it is interpolated between values 66 km/h and 79 km/h. 9.35 means that the number should start at value 9. 0.35 means that it is 35 percent from value 9 to value 10.

$$V_{85} = 66 + 0.35 \cdot (79 - 66) = 66 + 0.35 \cdot 13 = 70.55 \text{ km/h}$$

So, in this example, the 85th percentile speed is approximately 70.55 km/h.

The speed of vehicles on highways is determined using a simple stopwatch, special radar devices, various speed measuring devices, automatic sensors and detectors, as well as video recording.

Depending on their purpose and objectives, speeds are divided into the following types:

The calculated speed is the maximum speed at which a single vehicle can move in favorable weather conditions, with normal tire contact with the road surface and on sections of the road with the most unfavorable permissible geometric elements. In practical calculations, it is usually taken as the 98th percentile speed.

Instantaneous speed is the actual speed of movement of a vehicle over a certain short distance or at a certain point in real road conditions. It represents the speed of a single vehicle or

traffic flow over a specified short distance. Such a distance is usually set at 50, 100, 150 or 200 meters. Instantaneous speed is widely used in organizing traffic on certain road sections and assessing the speed regime.

Communication speed is the average speed of a vehicle along a certain route, taking into account various delays. Such delays occur as a result of the interaction of vehicles in the traffic flow at level crossings, railway crossings, uneven sections of the road surface and the interaction of vehicles with each other. The communication speed is determined by taking measurements several times along the route using a mobile laboratory. This indicator is one of the main indicators of how well the road works as a transport structure.

The design speed of a vehicle is the maximum speed that a vehicle of a certain design can technically achieve. This indicator depends largely on the type of vehicle. For example, the design speed of medium and large passenger cars can be 200–260 km/h, for small passenger cars it can be 150–200 km/h, and for small trucks it can be around 100–120 km/h.

Technical speed is the speed of movement along a given route, without taking into account delays. Its value depends mainly on the geometric dimensions of the highway, road conditions, the condition of the carriageway, and the composition of the traffic flow.

The maximum design speed of a car (V_{max}) depends on its engine power. Observations show that drivers drive at V_{max} only in some cases and for a short time. Under good road conditions, the speed of vehicles is usually in the range $(0.7–0.85V_{max})$. Such a speed is observed mainly in vehicles moving alone, on horizontal and straight road sections.

In practical conditions, the road may consist of various ups and downs, small-radius curvatures in the plan, sections with a visibility distance below the norm, and vertical curvatures. In addition, the difference in the volume and composition of the traffic flow also directly affects the instantaneous speed value.

One of the simplest and most convenient tools for studying the speed of movement is a stopwatch. Therefore, it is widely used to measure speed. For this, a control section with a length of 50–100 m is marked on the carriageway. In order to accurately determine the time of entry and

exit of vehicles into the observation area, indicator sticks are installed on the roadside or transverse marking lines are drawn on the carriageway.

Observers measuring the speed of movement are located on the side of the road, approximately 10–15 m from the carriageway. The stopwatch is started when the vehicle enters the measurement area, and stopped when the vehicle leaves this area. The results obtained are entered into a specially prepared table.

The initial data on the speed of movement are analyzed using mathematical statistical methods. To do this, first of all, the speed values determined as a result of the observation are divided into categories, i.e., ranges. After that, the speed data corresponding to each category are calculated and the frequency is determined.

Frequency is the number of vehicles that fall into a certain speed range, that is, a category. Based on the frequency, the relative frequency is determined. The relative frequency is the ratio of the frequency value in each category to the sum of the total frequencies, usually expressed as a percentage.

The cumulative **relative frequency** is also determined. It consists of the sequential sum of the relative frequencies for each category. The calculated values are entered into a table. Based on this table, the distribution curve of speeds and the cumulative distribution curve are plotted. Then, using the obtained graphs, the speed indicators of the transport flow are analyzed.

Using the distribution curve, the most frequent speed, that is, the modal speed, is determined. Using the cumulative distribution curve, the 15th, 50th, 85th and 95th percentile speeds are determined. Figure 1 shows the relative frequency distribution by vehicle speed. The horizontal axis shows the speed of vehicles, expressed in km/h, and the vertical axis shows the relative frequency corresponding to this speed range, expressed in percent. Figure 2 shows the distribution of vehicle speeds by cumulative relative frequency. The horizontal axis shows the speed of vehicles, expressed in km/h, and the vertical axis shows the cumulative frequency, expressed in percent.

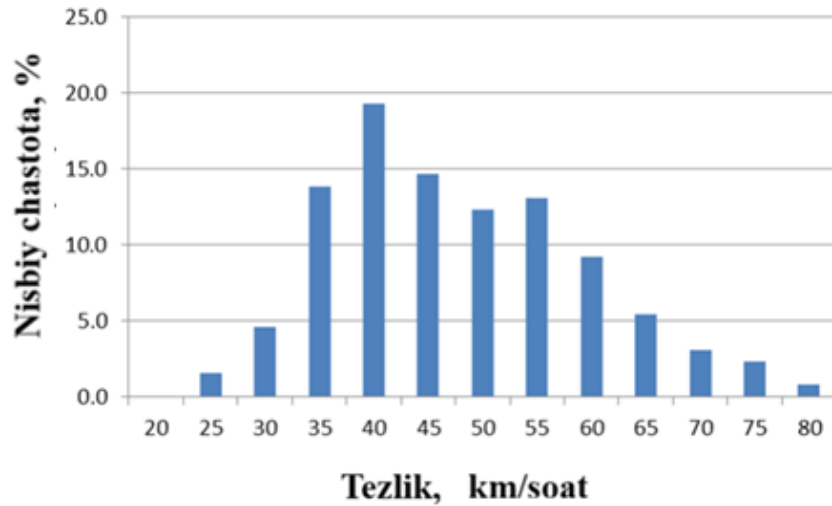


Figure 1. Distribution of transport flow speeds

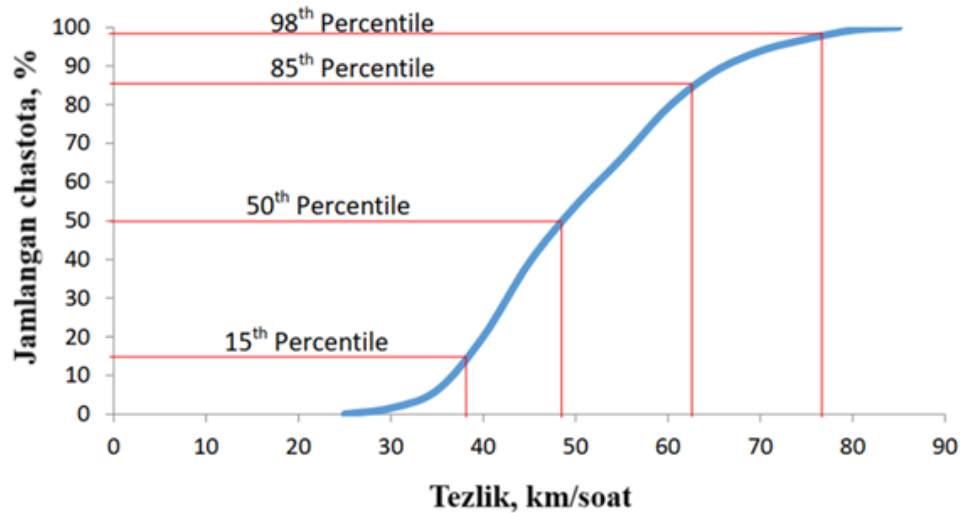


Figure 2. Cumulative distribution curve of movement speeds

The speed indicators determined on the basis of the cumulative distribution curve can be analyzed as follows. In this case, the 15th percentile speed is used to assess the lower speed limit in the organization of traffic. Using this indicator, the minimum speed limit is based and, if necessary, a road sign 4.7 “Minimum speed” can be installed.

The speed at 50 percent coverage represents the median speed. That is, 50 percent of the cars in the traffic flow move at a speed lower than or equal to this speed, and the remaining 50 percent at a speed higher than it. Therefore, this indicator characterizes the central value of the speeds in the traffic flow.

The speed at 85 percent coverage is one of the important indicators in traffic engineering. Road signs, road markings, recommended speed regimes and other measures aimed at ensuring traffic safety are based on this speed value.

The speed at 98 percent coverage is considered an indicator close to the calculated speed. This value is used to calculate the geometric elements of the road, assess the traffic conditions of the road section, and justify design solutions.

The reliability of the results of the speed measurement depends primarily on the number of measurements taken. The greater the number of measurements, the higher the reliability of the determined speed indicators. The number of measurements, in turn, depends on the volume of traffic flow and its degree of variability. The number of measurements required depending on the change in the volume of traffic is given in Table 1.

Table 1.

One-way traffic volume, vehicles/hour	50 va kam	50–100	100–200	200 va ko‘p
Number of measurements, units.	150	100	50	30

3. Procedure for performing the work.

In the process of studying the speed of traffic flow in real road conditions, students perform the following actions:

1. According to the instructions, a designated section of the street is selected and the distance between the inspection points is determined. Students determine the length of the longitudinal section of the street in real road conditions according to the option (Figure 3). During the specified observation period, each student analyzes a 15-minute video recording according to their option.

2. Using the provided video, the observer uses a stopwatch to measure the time taken by vehicles passing along the road section of the inspection point X1(A) and X2(B) for a given period. When the front of the vehicle crosses the line, the stopwatch starts the counter, and when the observer there crosses the second line, he stops the stopwatch. The observer takes the time traveled between the two lines.

3. Vehicles moving in each lane are recorded separately. When entering the instantaneous speed study data, the travel time is recorded in Table 1.

4. Using the specified study length and the time it takes for the vehicles to travel the distance, the instantaneous speed of the vehicle is calculated using $v_o = \Delta S / \Delta t$ and the calculation results are recorded in Table 1..

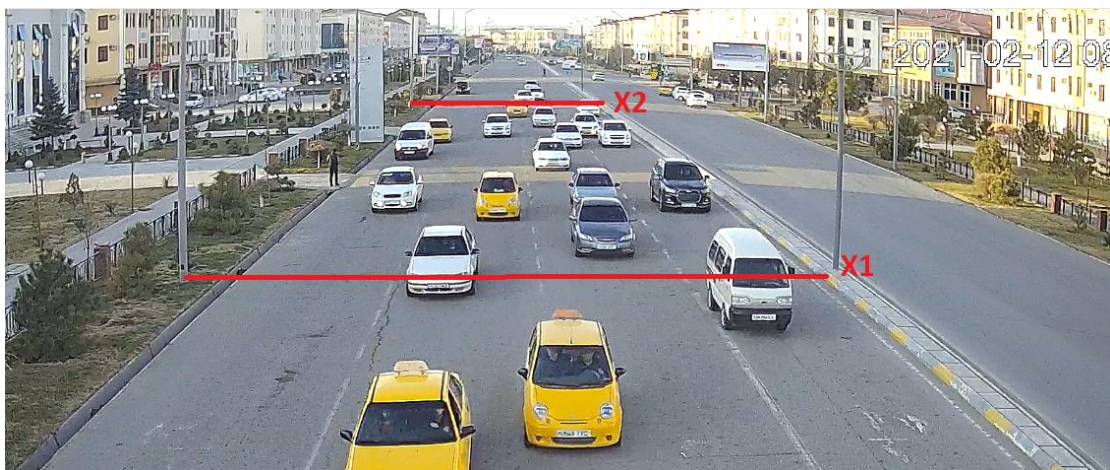
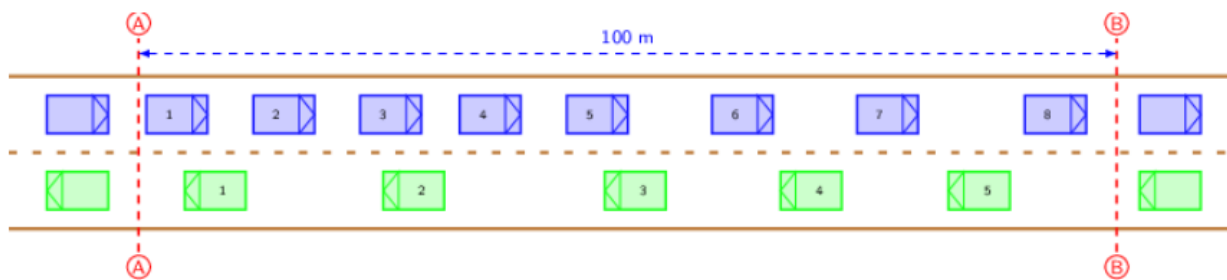


Figure 1. Determining the length of a street-road longitudinal section

Vehicle registration	Traversal time (s)	Instantaneous speed (m/s)
1		
2		
3		
...		

6. Using the determined instantaneous speed values, the average, standard deviation, median, mode, and 85% speed values are found using statistical data.

7. By grouping the speeds of the studied vehicles in 5 km/h intervals, speed distribution graphs are constructed.

8. The calculations are recorded in Table 2 for all the examined vehicles and, based on the results obtained, the speeds are plotted in terms of cumulative (accumulated) frequencies. A frequency distribution curve and a cumulative frequency distribution curve are created.

Table 2.

Rate interval	Average value	Frequency	Cumulative frequency	%frequency	% cumulative frequency
1					
2					
3					
...					

4. Conclusion

This work considers the procedure for studying and analyzing the speed of traffic flow in real road conditions. In the process of observation, a specified road section is selected, the time taken

by vehicles to travel this section is determined, and their speed is calculated based on the data obtained.

During the work, students will master the methods of determining the instantaneous speed of the traffic flow, calculating the average speed over time, the average speed over the interval, the median speed, the 85th percentile and other provided speeds. Also, the speed regime of the traffic flow is evaluated based on the speed distribution curve and the cumulative distribution curve. The results obtained allow assessing the traffic conditions of vehicles, the variability of speeds on the road section, and the general state of the traffic flow. By analyzing speed indicators, practical conclusions can be drawn on the organization of traffic, ensuring safe traffic conditions, substantiating road signs and markings, and effectively managing traffic flow.

Control questions

1. What is meant by traffic flow?
2. What is the speed of traffic flow considered as an indicator?
3. What is the main purpose of studying traffic speed?
4. What is meant by instantaneous speed of traffic flow?
5. How is the average speed over time determined?
6. How is the average speed over an interval determined?
7. What is the difference between the average speed over time and the average speed over an interval?
8. What technical means are used to measure the speed of vehicles?
9. How is the procedure for determining the speed of movement using a stopwatch carried out?
10. How is a road section selected for measuring speed?
11. How is the distance between observation points determined?
12. What is meant by modal speed?
13. What does median speed or 50th percentile speed mean?
14. For what purposes is the 85th percentile speed used?

15. What speed is the 98th percentile speed considered to be?
16. What indicators are determined using the speed distribution curve?
17. What speed values are found using the cumulative distribution curve?
18. What do the concepts of frequency and relative frequency mean?
19. What factors affect the speed of the transport flow?
20. What is the practical significance of analyzing the speed of the transport flow in the organization of traffic?

Practical exercise 2: Measuring instantaneous speed using a Bushnell device

1. **Purpose of work:** To study the working principle of the Bushnell device and use it to determine the speed of vehicles at a selected point on a city street and analyze the speed characteristics of the traffic flow..
2. **Equipment Required:** The following equipment is required to complete this lab:
 - Bushnell Velocity Speed Gun
 - A sheet of paper to record
 - Pen or pencil
 - Safety vest
3. **3. General information:** The Bushnell Velocity Speed Gun works on the principle of sending and receiving signals. When the trigger (button) is pressed, the device sends an electromagnetic signal to a moving object. This signal returns from the vehicle. Based on the difference between the frequencies of the transmitted and returned signals, the device determines the instantaneous speed of the object and displays the result on its digital display. The change in the returned frequency (phase difference) indicates the radial speed of the object relative to the radar. If the device is directed at a large angle to the direction of movement of the object, the measured speed may be lower than the actual speed. Therefore, the device should be directed as close as possible to the direction of movement of the vehicle. Also, the researcher should take precautions not to enter the roadway, use it in a safe place, and avoid confusion when recording the results. Speed determination is carried out for the following purposes:
 - • identify speed trends on a road section;
 - • set speed limits;
 - • assess the need for speed control;
 - • analyze accident hotspots;
 - • study driver behavior;

- justify decisions on road geometry and vehicle control.

In practice, the Bushnell device documentation states that the accuracy of instantaneous speed measurement is approximately ± 2 km/h. It is also stated that, depending on the target and conditions, it can work up to a distance of about 25 m for a baseball, and up to 450 m for a race car. One important limitation is that if the device is directed at an angle to the direction of travel of the vehicle, the indicated speed will be lower than the actual speed. Therefore, the manuals recommend holding the device as parallel to the direction of travel of the object as possible or very close to it.



Bushnell device



The principle of operation of the device

Advantages	Disadvantages
• easy and convenient to measure; • the distance is not measured separately; • the result is immediately visible on the screen; • the possibility of application in practical research; • has almost no impact on traffic flow.	• if the device is aimed at the wrong angle, the speed will be lower; • in a dense traffic flow, it will be difficult to determine exactly which vehicle is being measured; • The driver can reduce his speed in advance by seeing the radar.

4. 4. Procedure for performing work:

1. A straight and well-visible section of the street is selected for the study.
2. The researcher is placed in a safe place.
3. The Bushnell device is brought into working condition.
4. The device is directed at a moving vehicle.

5. The trigger is pressed and the device sends a radar signal.
6. The speed value shown on the display is recorded.
7. The speed is recorded separately for each vehicle.
8. Observation is carried out for at least 30–50 vehicles.
9. The data obtained are recorded in a table and the results are analyzed.
10. The calculated speeds are divided into appropriate interval groups, for example, 10 km/h intervals.
11. A speed distribution histogram, frequency curve, and cumulative frequency curve are drawn.
12. The average speed, median speed, mode speed, 15th percentile speed, 85th percentile speed, and speed range are determined.

Table 1. Recording table

Surname, name		
Date		
Street name		
Direction	From _____	To _____
Motor transport t/r	Type of transport	Measured speed, km/h
1		
2		
3		
4		
5		
...		

When processing the results, all speed values are summed up according to the results obtained and the average speed ($\bar{V}$) is determined based on the following formula:

$$\bar{V} = \frac{\sum V}{n}$$

Here, $\sum V$ – is the sum of all observed speeds and n – is the number of observed vehicles.

Also, the obtained speed values are grouped by interval and a speed frequency table is created. If necessary, the median speed, mode speed, 15th percentile speed and 85th percentile speed can also be determined.

Main speed indicators:

- Arithmetic mean speed — the average of all observed speeds.
- Median speed — the speed at which 50% of vehicles travel at a speed below this value.
- Mode speed — the most frequently occurring speed.
- 85th percentile speed — the speed at which 85% of vehicles travel at a speed below this value.
- 15th percentile speed — the speed at which 15% of vehicles travel at a speed below this value.
- Speed range — the 10 km/h speed interval with the highest concentration of vehicles.

5. Conclusion. During the student's laboratory work, the principle of operation of the Bushnell Velocity Speed Gun device was studied. With its help, the instantaneous speed of vehicles was measured. Based on the results obtained, it was found that it is possible to evaluate the speed characteristics of the traffic flow.

Control questions

1. What is Point (Instantaneous) Speed?
2. Why is a speed survey conducted?
3. What is the difference between point speed and travel speed?
4. What is the 85th percentile speed?
5. Why is the 85th percentile speed important in road engineering?
6. What is the speed range?
7. What are the main methods of measuring speed?
8. Why should the survey be conducted in free-motion conditions?
9. What is the difference between average speed and median speed?
10. On what principle does the Bushnell Velocity Speed Gun work?
11. Why is the speed measured with the Bushnell considered instantaneous speed?
12. Why is it important to orient the device in accordance with the direction of movement of the vehicle?

13. What are the disadvantages of this method?
14. What requirements are taken into account when choosing an observation site?
15. Why should observation be carried out from a safe point?
16. What is the formula used to calculate the average speed?
17. What is the purpose of statistical processing of observed speed data?
18. What is the difference between median speed and mode speed?

Practical exercise 3: Determining and assessing driver reaction time

1. **Purpose of work:** It consists of determining the time that elapses from the moment the driver receives an external influence or signal until he begins to respond, and assessing the importance of this indicator in road safety.
2. **Required Equipment:** The following equipment is required to perform this laboratory work:
 - special reaction measurement test program on a computer device, simulator device;
 - stopwatch or electronic timer;
 - a sheet for recording results;
 - pen or pencil.

3. **General information:**

Reaction time is the time it takes for a driver to notice a change in the road situation, understand it and initiate a response. For example: a traffic light changing from red to green; a car in front brakes sharply; a pedestrian stepping onto the road; a suddenly appearing dangerous situation or obstacle. In this process, the driver: 1-sees or hears the signal; 2-understands it; 3-makes a decision and 4- initiates the appropriate action. Therefore, reaction time is an important indicator in assessing road safety.

The driver's reaction time usually includes the following stages:

- perception time — receiving a signal;
- perception time — understanding the situation;
- decision time — choosing how to act;
- response time — initiating braking or other control action.

In practice, the sum of these stages is taken as the total reaction time.

Many factors affect the driver's reaction time: age; experience; fatigue; lack of sleep; impaired concentration; stress; the influence of alcohol or drugs; weather and vision conditions.

If a driver is driving at a speed of 60 km/h, he will cover a certain distance during the reaction time even before pressing the brakes. Therefore, reaction time is taken into account in road safety calculations. Reaction time is of great importance in transport safety. Reaction time is important in calculating the stopping distance, assessing the braking process, determining the safe distance, and assessing the readiness of drivers.

Several methods are used to determine the driver's reaction time:

Simple signal method - The participant in the experiment is given a certain signal. He must press a button or move his hand when the signal appears. The reaction time is the interval from the moment the signal appears to the moment the response action begins.

Computer test method - A light or color signal appears on the computer screen at random times. The participant presses a button when he sees the signal. The program automatically records the reaction time.

Simulator method - The road situation is simulated in a driving simulator. The time elapsed before the start of braking, turning or other response action is measured. This method gives results closer to real driving conditions.



4. Procedure for performing work:

1. The participant is placed in a comfortable position.
2. The content of the experiment is explained to him.

3. The participant is told that he must immediately perform a response action when the signal appears.
4. The signal is given several times at random times.
5. The reaction time for each attempt is recorded.
6. The experiment is usually repeated 5–10 times.
7. An average value is calculated for each participant.
8. The results are tabulated and analyzed.

O/n	1- attempmt	2- attempmt	3- attempmt	4- attempmt	5- attempmt	Average reaction time, s
1	0.72	0.69	0.75	0.71	0.70	0.71
2						
3						
...	...	...	...	...	...	...

The average reaction time ($\bar{t}$) is determined by the following formula::

$$\bar{t} = \frac{t_1 + t_2 + \dots + t_n}{n}$$

where, $t_1, t_2, \dots, t_n$ are the times recorded for individual attempts and n is the number of attempts.

5. Introduction. Measuring driver reaction time is an important method for assessing road safety. This method determines the time it takes for a driver to react from the moment they receive a signal to the moment they begin to react. The results are used to assess stopping distances, braking processes, and driver safety.

Control questions

1. What is meant by reaction time?
2. Why is driver reaction time important in road safety?
3. What are the main stages of driver reaction time?

4. What is perception time?
5. What is perception time?
6. What is decision-making time?
7. How is the overall reaction time determined?
8. What is the main purpose of measuring driver reaction time?
9. What equipment is used to measure reaction time?
10. How is the light signal reaction time measurement method performed?
11. What is the advantage of the simulator method?
12. Why may the reaction time obtained in laboratory conditions differ from real driving conditions?
13. What formula is used to calculate the average reaction time?
14. How does age affect reaction time?
15. How does driving experience affect reaction time?
16. How does fatigue affect reaction time?
17. How does sleep deprivation affect reaction time?
18. How does stress affect a driver's reaction time?
19. How does impaired attention affect reaction time?
20. How do alcohol and certain drugs affect reaction time?
21. Why do complex road conditions increase reaction time?
22. What is the relationship between reaction time and stopping distance?
23. Why is reaction time even more important at high speeds?
24. How are reaction time measurements used in traffic safety analysis?
25. What is the importance of studying driver reaction time in road infrastructure design?

Practical exercise 4: Studying the degree of slipperiness of the road surface

1. **Purpose of work:** The purpose of this study is to determine the wet skid resistance of the road surface using a British pendulum skid resistance meter, assess the safety level of the pavement surface based on the measurement results, and draw conclusions about the microtexture of the road surface.
2. **Required equipment:** The following equipment is required to perform this lab:
 - British Pendulum Slip Resistance Tester;
 - Rubber Slider;
 - Water (for wet condition test) and Thermometer (if necessary);
 - Pen or pencil and safety vest.
3. **General information:** The British Pendulum is a type of device that measures the energy loss when a rubber slider slides over a road surface. The device is mainly used on flat surfaces, in laboratory and field conditions. The British Pendulum method is used to evaluate the frictional properties of roads and other moving surfaces. It is especially widely used to evaluate the skid resistance of a road surface due to its microtexture. The Federal Highway Administration (FHWA) and other sources note that the results of the British Pendulum Tester are usually reported as the skid resistance index of the road surface, BPN (British Pendulum Number) or SRV (Skid Resistance Value). These indicators are not a direct substitute for stopping distance or other high-speed indicators, but they are a good indicator of the relative frictional properties of the surface. The device has a special rubber slider attached to the end of the pendulum. The pendulum is released from a certain height, and the slider slides along a certain length, touching the test surface. Energy is lost during the slide. A scale reading is obtained based on the amount of energy lost. The famous device measures the energy loss that occurs when the rubber slider moves along the surface.

In short:

- the rougher and more frictional the surface, the more energy the pendulum loses;
- the higher the reading;
- the smoother and more slippery the surface, the lower the reading.



Figure 1. British Pendulum Skid Resistance Tester device

The following factors affect the measurement results: surface microtexture; dirty or clean state of the surface; degree of wear of the slider; amount of water; air and water temperature; correct adjustment of the device by the operator; number of repeated attempts at the same point. In practice, in some projects, the required values are given separately. For example, one of the FHWA documents notes that a wet skid resistance requirement of 60 BPN is used for some surfaces. However, the regulatory acceptance criterion always depends on the project, standard or customer requirements.

Advantages	Disadvantages
• portable and convenient;	• does not fully reflect realistic wheel-surface interactions at high speeds;

• used in both field and laboratory conditions; • characterizes microtexture well; • allows for rapid determination of relative slip resistance.	• results are not directly interchangeable with other friction methods; • temperature and slider position have a significant effect; • measurement becomes difficult if the surface is uneven.
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4. Procedure for performing work:

1. The tested road section is cleaned (dust, sand), the surface must be flat and undamaged, if the wet condition is checked, the surface is evenly moistened with water;
2. The device is installed on a flat surface and the pendulum is brought to a horizontal position and the 0 indicator is checked (calibrated);
3. The pendulum is raised to a certain height and released freely;
4. The rubber touches the road surface three times;
5. The value shown by the device (BPN - British Pendulum Number) is recorded;
6. At least 5 measurements are taken at each point;
7. The average value is calculated and the results are compared. In this:
 - 0 – 24 → Very slippery (dangerous)
 - 25 – 34 → Low resistance
 - 35 – 44 → Satisfactory
 - 45 – 54 → Good
 - 55 and above → Very good (safe)

Table 1. Recording table

Test point coordinates (latitude, longitude):						
O/n	1-attempt	2- attempt	3- attempt	4- attempt	5- attempt	Average value
1						

2						
3						
4						
5						

The average pendulum index ($\bar{t}$) is determined by the following formula:

$$\bar{t} = \frac{t_1 + t_2 + \dots + t_n}{n}$$

here, $\bar{t}$ – average slip resistance value; $t_1, t_2, \dots, t_n$ – individual measurement results and n-number of attempts.

If multiple points are measured, a separate average value is taken for each point, and then, if necessary, a general average is calculated.

5. Conclusion. During the student's laboratory work, the level of skid resistance of the road surface is determined using the British Pendulum Skid Resistance Tester. This method is effective in assessing the friction properties of the road surface, especially in wet conditions. The results obtained are important for analyzing road safety, comparing coatings, and assessing the operational condition of the surface. Road safety is assessed based on the BPN value obtained. The need for repair or resurfacing is also determined.

Control questions

1. What is the purpose of the British Pendulum Skid Resistance Tester?
2. What physical principle does this device operate on?
3. Which surface property does the British Pendulum Tester best describe?
4. What is the function of the rubber slider?
5. Why is the surface tested in a wet state?
6. Why is the device horizontal before measuring?
7. How is the average SRV calculated?
8. How does the microtexture of the surface affect the result?
9. How does surface contamination affect the measurement?

10. How can the result change if the slider is worn?
11. Why are multiple attempts made at one point?
12. What is the difference between field and laboratory measurements?
13. What are the advantages of the British Pendulum Tester?
14. What are the disadvantages of this method?
15. Why is this method not directly comparable to other friction methods?
16. Why are design requirements important in interpreting results?
17. How are British Pendulum Tester results used in road safety?
18. Why is the slip resistance of a road surface important in road safety?
19. What is the principle of operation of the British Pendulum Tester device?
20. How is energy loss generated in this pendulum-type device, and what measurement result is this loss converted into?
21. What is meant by the microtexture of the road surface and how does it affect slip resistance?
22. Why are British Pendulum Tester tests often conducted in wet conditions?
23. What is the significance of wet slip resistance measurement results for practical operating conditions?
24. Why is it necessary to bring the device to a horizontal position before testing?
25. What errors can occur in the measurement results if the device is installed incorrectly or deviates from the horizontal position?
26. Why are several repeated attempts made at one point using the British Pendulum Tester?
27. Why is the result of the first attempt in some cases not taken into account or considered as an “adaptive” attempt?
28. How do factors such as temperature, water content and slider wear affect the test results?
29. What are the differences between field measurements using the British Pendulum Tester and measurements on laboratory samples?
30. What are the advantages of this method and why is it widely used in practice?

31. What are the limitations of the British Pendulum Tester method and why does it not fully reflect the real wheel-surface interaction at high speeds?
32. Why is it not always correct to directly compare the results of the British Pendulum Tester with the results of other friction testing methods?
33. How are the results obtained using this method used to assess the technical condition of the road surface?
34. How can dangerous sections of the road be identified based on the results of the British Pendulum Tester?
35. What is the significance of the results of determining the skid resistance indicators in making decisions on road repair, resurfacing or surface treatment?
36. What safety rules should be followed when measuring with the British Pendulum Tester?
37. What is the significance of regular monitoring of the level of skid resistance of the road surface for traffic safety and long-term operation of the road infrastructure?

Practical exercise 5: Determining the braking and deceleration performance of vehicles

1. **Purpose of work:** It consists of studying the characteristics of the vehicle's behavior during braking, determining the braking distance, braking time, and average deceleration value, and assessing the significance of these indicators in road safety.
2. **Required Equipment:** The following equipment is required to perform this laboratory work:
 - stopwatch or electronic timer;
 - calculator;
 - score sheet;
 - pen or pencil;
 - special braking distance measuring device, if necessary, with an electric scooter.
3. **General information:** When the braking system is activated while a vehicle is moving, its speed decreases. An increase in speed per unit of time is called acceleration. A decrease in speed per unit of time is called deceleration. If a vehicle slows down from motion to a stop under the influence of brakes, this process is called braking.

The factors affecting braking and deceleration are as follows:

- type of vehicle and load level;
- technical condition of the brake system;
- condition and pressure of the tire tread;
- type and humidity of the road surface;
- longitudinal slope of the road;
- driver reaction;
- weather conditions.

The main indicators during the braking process are:

Braking distance - The distance from the point where the braking is initiated to the point where the vehicle comes to a complete stop.

Braking time - The time elapsed from the point where the braking is initiated until the vehicle comes to a complete stop.

Deceleration - The rate of decrease in the vehicle's speed. The average deceleration (a) is determined by the following formula:

$$a = \frac{V_0 - V_1}{t}$$

where: a- average deceleration, m/s²; V₀- initial velocity, m/s; V₁- final velocity, m/s; t- braking time, s.

If the vehicle comes to a complete stop, V₁=0, then:

$$a = \frac{V_0}{t}$$

Slowdown can also be determined by braking distance:

$$a = \frac{V_0^2 - V_1^2}{2 \cdot S}$$

If the vehicle comes to a complete stop:

$$a = \frac{V_0^2}{2 \cdot S}$$

here: S — braking distance, m.

There are several methods for measuring the braking and deceleration of vehicles. They are:

- By distance and time - in this case, the initial speed of the vehicle, the braking distance and the braking time are determined. Then the deceleration is calculated using formulas.
- By brake track - If a brake track is formed on the road surface, its length is measured and the initial speed or deceleration is estimated. This method is more often used in the analysis of road accidents.
- Using an accelerometer - A special device directly records the negative acceleration of the vehicle. This method provides high accuracy.

4. Procedure for performing work:

1. A section of road on which the experiment will be conducted is selected. It must be flat, dry, safe and free of traffic.
2. The vehicle is checked for technical condition.
3. The starting point of the road for braking is determined.
4. The vehicle is driven at a predetermined speed, for example, 10 km/h.
5. When the designated point is reached, the driver presses the brake pedal.
6. The time from the moment the brake is applied to a complete stop is measured using a stopwatch.
7. The distance from the point where the brake is applied to the stopping point is determined using a measuring tape.
8. The experiment is repeated several times.
9. The results obtained are entered into a table.
10. The average deceleration is calculated using formulas.

Table 1. Recording table

T/r	Initial speed, km/h	Initial velocity, m/s	Braking time, s	Braking distance, m	Average slowdown, m/s ²
1					
2					
...					

The vehicle reaches a predetermined speed. At a specified point, the driver applies the brakes. The distance and time from the point where the brakes are applied to the point where the vehicle comes to a complete stop are recorded. Based on this data, the average deceleration is calculated. If the experiment is repeated several times, the average deceleration ($\bar{a}$) is determined as follows:

$$\bar{a} = \frac{a_1 + a_2 + \dots + a_n}{n}$$

5. Conclusion. The braking and deceleration measurement method of vehicles determines the braking efficiency, stopping distance, and average deceleration of a vehicle. These indicators are important in assessing road safety, checking the technical condition of vehicles, and substantiating design calculations.

Control questions

1. What is meant by braking?
2. What is deceleration?
3. What is the difference between braking and deceleration?
4. How is the braking distance determined?
5. What is the braking time?
6. What is the formula for calculating the average deceleration?
7. Why is the initial speed converted to m/s?
8. How does the braking distance change when the initial speed increases?
9. How does the road surface affect the braking results?
10. How does the condition of the brake system affect the result?
11. How does the condition of the tires affect braking?
12. What is the difference between wet and dry road surfaces?
13. What are the methods for measuring braking?
14. What is the advantage of measuring using an accelerometer?
15. In what cases is the brake track method used?
16. Why are braking performance important in road safety?
17. What does the safe stopping distance depend on?
18. How many times is it advisable to repeat the experiment?
19. How is the average deceleration determined?
20. What qualities of a vehicle do braking performance help to assess?
21. Why does the braking distance increase sharply with an increase in initial speed?
22. How does the type of road surface affect the braking efficiency of a vehicle?
23. How do braking performance change on dry, wet and slippery road surfaces?
24. How does the technical condition of the brake system affect the deceleration value?
25. How do the tread, pressure and general condition of the tires affect the braking distance?
26. How does the vehicle load affect the braking and deceleration results?
27. How does the longitudinal slope of the road affect the braking process?
28. To what extent does the driver's method of pressing the brake pedal affect the results?

29. What are the advantages and disadvantages of the distance and time method in measuring braking?
30. In what cases is the brake track method used and what is its practical significance?
31. What is the main advantage of measuring braking using an accelerometer?
32. Why is it advisable to repeat the experiment several times?
33. How can the average deceleration value be determined based on the results of several experiments?

Practical exercise 6: Studying the variation of braking distance depending on vehicle speed using a passenger car simulator

- 1. Purpose of work:** The aim of the study is to observe the braking process of a car at different speeds using a car simulator, determine how the braking distance changes with increasing speed, and analyze the results from a traffic safety perspective.
- 2. Required equipment:** The following equipment is required to perform this laboratory work:
 - a car simulator;
 - a monitor or visualization screen;
 - a score sheet and calculator;
 - a pen or pencil.
- 3. General information:** The greater the speed of a vehicle when it is moving, the greater the distance required to stop when the brakes are applied. The braking distance depends on the initial speed of the vehicle, the condition of the road surface, the effectiveness of the braking system, the condition of the tires, and the driver's steering action. Theoretically, under the same conditions, the braking distance increases in proportion to the square of the vehicle's speed. That is, if the speed doubles, the braking distance can increase by about four times.

The average braking distance is determined by the following formula::

$$\bar{S} = \frac{S_1 + S_2 + \dots + S_n}{n}$$

where: S_i — braking distance, m; n — average deceleration, m/s^2 .

In the simulator, the car is accelerated to a certain speed and the brake pedal is pressed at a certain point. The software records the distance the car travels from the point of braking until it comes to a complete stop. In this way, braking distances are obtained for different speeds and compared with each other.



Figure 1. Passenger car simulator

Advantages	Disadvantages
• the experiment is conducted in safe conditions; • different speeds can be easily modeled; • does not pose a hazard on a real road; • the results are demonstrable and understandable; • clearly shows the effect of speed on braking distance.	• the simulator may not fully reflect real road conditions; • the psychological state of the driver differs from that of the real situation; • the model results depend on the program parameters; - not all technical factors in real vehicles may be fully reflected.

4. Procedure for performing work:

1. The simulator is brought into working condition.
2. The virtual road section on which the experiment will be conducted is selected.
3. The car is accelerated to the first set speed, for example, 50 km/h.
4. When the set point is reached, the brake pedal is pressed.
5. The distance traveled by the car from the point where the brakes were applied until it came to a complete stop is recorded.
6. The experiment is repeated in this order for speeds of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 km/h.
7. The experiment is performed at least 3 times for each speed.

8. The results obtained are entered into a table.
9. The average braking distance is determined for each speed.
10. The relationship between speed and braking distance is represented in a graph.
11. Finally, the results are analyzed and a conclusion is drawn.

Table 1. Recording table

O/n	Speed, km/h	1-attempt, m	2-attempt, m	3-attempt, m	Average braking distance, m
1	10				
2	20				
3	30				
4	40				
5	50				
6	60				
7	70				
8	80				
9	90				
10	100				

The graph shows that as the speed of the car increases, the braking distance also increases. This change is not linear, but occurs according to a law close to the square of the speed. This means that when a vehicle is moving at high speed, a much greater distance is required to stop it. This situation indicates the need to maintain a moderate speed from the point of view of road safety.

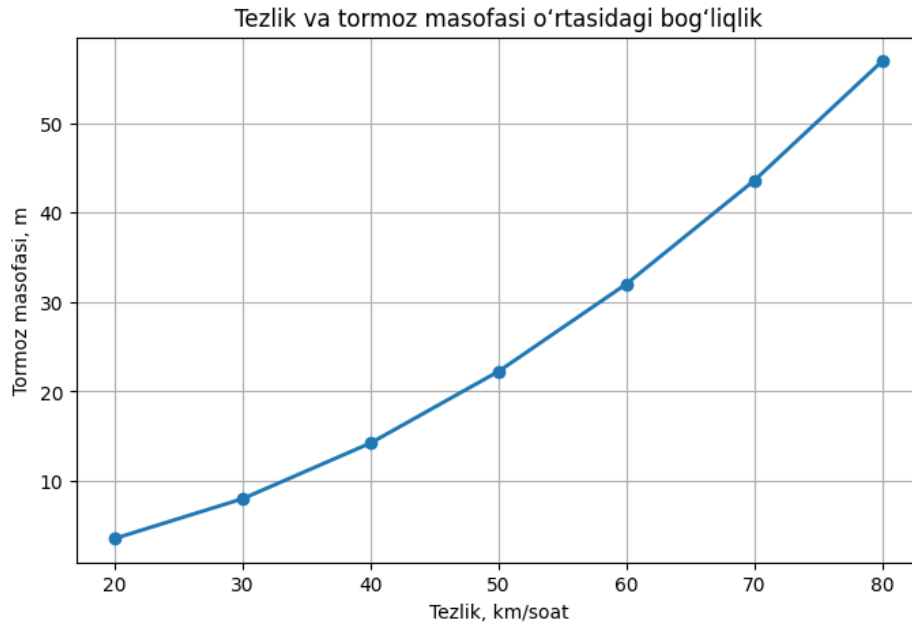


Figure 2. Graphical representation of the relationship between speed and braking distance

5. Conclusion. An experiment using a passenger car simulator revealed that the braking distance increases significantly with increasing vehicle speed. The experimental results showed that the braking distance varies in close proportion to the square of the speed. This confirms the importance of maintaining a moderate speed from a traffic safety perspective.

Control questions

1. What is meant by braking distance?
2. What factors does braking distance depend on?
3. Why does braking distance increase sharply with increasing speed?
4. What is the theoretical relationship between braking distance and speed?
5. What is the advantage of conducting experiments using a simulator?
6. What is the purpose of conducting experiments at different speeds under the same conditions?
7. How is the average braking distance determined?
8. Why is speed converted from km/h to m/s?
9. How does road surface affect braking distance?

10. How does tire condition affect braking distance?
11. What is the difference between a wet road and a dry road?
12. Why does high speed reduce road safety?
13. How do simulator results relate to real life?
14. Why is it necessary to repeat the experiment several times?
15. What does a graphical analysis of braking distance show?
16. Why is braking distance important in traffic safety?
17. How does driver behavior affect the result?
18. What parameters should be kept constant in the simulator?
19. How does vehicle loading affect braking distance?
20. Why is braking distance important when choosing speed?

Practical exercise 7: Studying the effect of road surface on slippage using a passenger car simulator

1. **Purpose of work:** The purpose of the study is to study the driving characteristics of a passenger car on various road surfaces using a simulator, and to determine how the slippery nature of the road surface affects the vehicle's handling, braking distance, and safety performance.
2. **Required equipment:** The following equipment is required to perform this laboratory work:
 - car simulator;
 - monitor or visualization screen;
 - score sheet and calculator;
 - pen or pencil
3. **General information:** The interaction of a car with the road largely depends on the adhesion force between the wheels and the road surface. If the adhesion properties of the road surface are high, the car moves stably, brakes effectively and is well controlled. On the contrary, if the slipperiness of the road surface increases, the adhesion between the wheels and the road decreases, as a result of which the braking distance increases, the lateral slip of the car increases, the controllability deteriorates when cornering, and it becomes difficult to stop and maintain direction.

The effect of the road surface on slippage is mainly evident in the following cases:

- dry asphalt;
- wet asphalt;
- snowy road;
- icy road;
- surface covered with dust or mud.

Theoretically, as the coefficient of friction decreases, it becomes more difficult for a car to move safely. In the simulator, different road surfaces are modeled under the same vehicle,

the same speed, and the same driving conditions. The driver drives at a certain speed and brakes or maneuvers at a certain point. The program records the braking distance, the degree of deviation, the side slip, and the stopping position of the car. In this way, the effect of the road surface on slip is determined.



Figure 1. Passenger car simulator

Advantages	Disadvantages
• the experiment is conducted in safe conditions; • it does not pose a risk on a real road; • it is possible to compare different road surfaces under the same conditions; • the results are demonstrable and understandable; • it clearly shows the impact of the road surface on safety.	• the simulator may not fully reflect real road conditions; • the psychological feeling of the driver differs from the real situation; • the results depend on the program model; • not all factors of real weather and road surface may be fully reflected.

4. Procedure for performing work:

1. The simulator is brought into working condition.
2. The same road section is selected for the experiment.
3. Initially, dry asphalt conditions are selected.

4. The car is accelerated to a specified speed, for example, 60 km/h.
5. At a specified point, the brakes are applied or a turning maneuver is performed.
6. The braking distance, stopping time and slippage are recorded.
7. The same experiment is repeated under wet asphalt conditions.
8. Then the experiment is repeated under snowy or icy road conditions.
9. The experiment is performed at least 3 times for each condition.
10. The results obtained are entered into a table.
11. Average values corresponding to each road surface are calculated.
12. The results are analyzed and a conclusion is drawn.

Table 1. Recording table

T/r	Road surface condition	Speed, km/h	1st attempt braking distance, m	2nd attempt, m	3rd attempt, m	Average braking distance, m	Slip situation
1	Dry asphalt	60					
2	Wet asphalt	60					
3	Snowy road	60					
4	Frozen road	60					

The results obtained for different road surfaces are compared. The longest braking distance and the most severe slippage indicate the most dangerous road conditions. When analyzing the results, the following are taken into account:

- dry asphalt provides the best grip;
- increased braking distance on wet roads;
- sharp increase in slip on snowy and icy roads;
- the negative impact of the road surface increases with increasing speed;
- reduced controllability and parking safety on slippery roads.

For example, when comparing dry and icy roads at the same speed, the braking distance on icy roads can be several times longer. This shows that driving in high-slip conditions is much more dangerous.

5. Conclusion. As a result of experiments conducted using a passenger car simulator, it was found that the slipperiness of the road surface has a significant impact on the safety of motor vehicles. As the slipperiness of the road surface increases, the braking distance increases, the controllability deteriorates, and the lateral deviation of the vehicle increases. Therefore, it is necessary to reduce speed and use cautious driving techniques in slippery road conditions.

Control questions

1. What is meant by road slippage and how does this condition affect the safety of vehicle movement?
2. What is the friction force between the wheel and the road surface and what role does it play in the movement process?
3. What is meant by the coefficient of friction and how do the vehicle's driving characteristics change when it decreases?
4. Why is the controllability of a vehicle higher on dry asphalt and lower on slippery surfaces?
5. Why does the braking distance of a vehicle increase on wet asphalt compared to dry asphalt?
6. How do the braking and steering characteristics of a vehicle change on a snowy road?
7. Why does the lateral sliding of a vehicle increase on an icy road?
8. How does the slipperiness of the road surface affect the stopping distance of a vehicle?
9. Why does the level of danger on a slippery road increase with increasing speed?
10. What scientific conclusion can be drawn from comparing the results obtained on dry, wet, snowy and icy surfaces at the same speed?
11. How is the road surface modeled in a simulator?
12. Why should the type of vehicle, speed and braking point be kept the same in the experiment?
13. What is the purpose of changing only the road surface during the experiment?
14. What are the main indicators recorded during braking in a simulator?
15. How do the braking distance, stopping time and lateral deviation indicators express the degree of slipperiness of the road surface?
16. What is the formula for determining the average braking distance and what does this indicator mean?
17. How is the coefficient of variation determined and how does it show the difference between road surfaces?

18. What is the basis for the assessment of “slip condition” as low, medium or high in the simulator results?
19. How does the slip of the road surface affect the behavior of the car when cornering?
20. What causes the car to deviate from the course on a slippery road?
21. How can the technical condition of the tires and the tread depth increase or decrease the effect of the road surface on slip?
22. How does the efficiency of the brake system affect the level of safety on a slippery road?
23. To what extent do the driver’s braking method and steering movements affect the test results?
24. How do the results obtained in the simulator relate to real road conditions?
25. What are the advantages of conducting experiments using a simulator compared to real road tests?
26. What are the limitations of this methodology and why may the simulator not fully reflect real conditions?
27. What is the importance of studying the effect of road surface slippage in the process of training drivers?
28. What practical recommendations on road safety can the results of this experiment help to develop?
29. How is the need to reduce speed and drive carefully on slippery roads justified by the results of the experiment?
30. What is the importance of studying the degree of slippage of the road surface in the fields of transport engineering, driver training, and road operation?

Practical exercise 8: Determining air quality and environmental safety indicators in the street area

1. **Purpose of work:** It consists of measuring atmospheric air quality indicators in street and roadside areas, assessing the impact of traffic flow on the environment, and determining the level of environmental safety.
2. **Required equipment:** The following equipment is required to perform this laboratory work:
 - portable air quality analyzer, or gas analyzers or dust meter;
 - traffic flow monitoring sheet;
 - pen or pencil, calculator;
 - mobile applications and safety vest as needed
3. **General information:** The deterioration of air quality on city streets is mainly associated with motor transport, dust, construction work, fuel combustion and other anthropogenic factors. The concentration of harmful substances in the atmospheric air increases, especially on highways with dense traffic. Street air quality is understood as the amount of harmful substances in the atmospheric air that affect human health and the environment. Ecological safety means the state of these indicators being within the regulatory limits and not posing a threat to the population and the natural environment. When assessing street air quality and ecological safety, the following indicators are determined:
 - a. **Concentration of harmful substances** - The amount of pollutants in the ambient air in mg/m^3 , $\mu\text{g}/\text{m}^3$ or ppm.
 - b. **The amount of dust particles** - Especially the PM_{10} and $\text{PM}_{2.5}$ fractions are important for human health.
 - c. **The amount of gaseous pollutants** - the concentration of CO , NO_2 , SO_2 and other gases is determined.

d. Meteorological indicators - air temperature; relative humidity; wind speed and wind direction.

e. Transport indicators - transport intensity; transport composition; traffic speed; traffic congestion level.

The measurement point is selected based on the following criteria:

- near a street or intersection with high traffic flow;
- in an area close to residential and pedestrian areas;
- where the measuring device is installed at a safe distance from the roadside;
- taking into account the wind and street configuration;
- if comparison is required, at several points with different loads.

Measurement methods;

- Direct instrumental method - The concentration of harmful substances in the air is directly measured using a gas analyzer and a dust meter.
- Sampling method - An air sample is taken and then chemically analyzed in a laboratory.
- Observation and traffic analysis method - The intensity, composition and level of traffic flow are observed and analyzed in relation to air pollution.
- Comparison method - Results are compared for different streets, different time periods or in traffic and free flow conditions.
- The simplest laboratory method - A convenient method in laboratory or field conditions is the use of a portable air quality meter and transport monitoring.

The concentration of the main pollutants in the air is measured at a selected point for a certain period of time. At the same time, the intensity and composition of the transport flow are monitored. Based on the data obtained, the state of air quality and the level of environmental safety are assessed.

Factors affecting air quality

- traffic flow intensity;

- share of diesel and gasoline transport;
- traffic congestion and stop-and-go traffic;
- street width and building spacing;
- availability of green areas;
- seasonal and meteorological conditions;
- dust emission;
- road surface condition.

4. Procedure for performing work:

1. A street or roadside area where the study will be conducted is selected.
2. A measurement point is determined in a safe place.
3. Air quality measuring devices are brought into working condition.
4. The measurement height is usually set close to the human breathing zone, approximately 1.5–2.0 m above the ground.
5. Air quality parameters are measured at a specified time interval, for example, 15, 30 or 60 minutes.
6. During this time, the number, type and flow characteristics of vehicles are recorded.
7. Meteorological indicators are recorded.
8. The obtained data are entered into a table.
9. The results are compared with standard values.
10. A conclusion is drawn on the level of ecological safety.

Table 1. Recording table

[illegible]

3									
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The measured value for each pollutant is compared with the corresponding permissible standard value.

$$K = \frac{C_{measured}}{C_{standard}}$$

here:

- K — excess coefficient;
- $C_{measured}$ — actual measured concentration;
- $C_{standard}$ — standard concentration.

If $K > 1$, it is determined that the pollution is above the norm.

5. Conclusion. During the student's laboratory work, the methodology for determining air quality and environmental safety indicators on the street is of great importance in assessing the impact of traffic flow on atmospheric air. With the help of this methodology, the relationship between the concentration of the main pollutants in street areas, traffic load and meteorological conditions is determined. The results obtained are used in the development of measures to ensure environmental safety, transport management and environmental protection.

Control questions

1. What is meant by street air quality and why is it important in assessing the urban environment?
2. How is the concept of ecological safety explained and how is it related to public health?
3. What are the main factors leading to atmospheric air pollution on city streets?
4. How do vehicles affect urban air pollution?
5. Why can air quality on highways be worse than on inner streets?
6. What is the relationship between traffic flow intensity and the concentration of harmful substances in the air?
7. Why does atmospheric air pollution increase in traffic jams?

8. What are the main harmful substances emitted by road transport and what is their impact on human health?
9. What danger does carbon monoxide (CO) pose when it increases in the air?
10. What is the ecological and sanitary danger of nitrogen dioxide (NO₂) and other nitrogen oxides?
11. What do PM_{2.5} and PM₁₀ particles mean and why are they considered a particularly important indicator?
12. For which population groups is a high concentration of dust particles considered particularly dangerous?
13. What are the main indicators measured in determining air quality and environmental safety?
14. What equipment is used to determine the concentration of gaseous pollutants?
15. What instruments are used to determine the amount of dust and what information do they provide?
16. Why are meteorological indicators also recorded in air quality studies?
17. How do wind speed and direction affect the spread of air pollution?
18. How can air temperature and relative humidity change the results of street air quality?
19. Why are the geometric features of the street and surrounding buildings taken into account when choosing a measurement point?
20. What is the purpose of choosing a measurement height close to the human respiratory zone in roadside areas?
21. What is the main difference between the direct instrumental method and the sampling method?
22. What scientific conclusions can be drawn from the combined analysis of traffic flow and air quality results?
23. What formula is used to determine the average concentration and what does this indicator mean?
24. How is the relative increase coefficient calculated and how is it used to assess the ecological state?
25. In what cases do the measured indicators indicate the presence of an ecological hazard?
26. How do green areas and landscaping have a positive effect on street air quality?
27. How do diesel and gasoline vehicles affect air quality differently?
28. How are the results obtained on street air quality used in transport management and urban planning?

29. What practical measures can be recommended based on the results of the air quality and environmental safety assessment?
30. What is the environmental and social significance of regularly organizing air quality monitoring in street areas?

Practical exercise 9: Studying the change in fuel consumption depending on driving mode using a passenger car simulator

- 1. Purpose of work:** Using a passenger car simulator, it is possible to determine the fuel consumption of a car in various driving modes, evaluate the impact of driving speed and mode on fuel economy, and draw economic and environmental conclusions based on the results obtained.
- 2. Required equipment:** The following equipment is required to perform this laboratory work:
 - a car simulator;
 - a monitor or visualization screen;
 - a score sheet and calculator;
 - a pen or pencil.
- 3. General information:** Fuel consumption depends on the technical condition of the vehicle, engine type, speed, road conditions, load level and driver's driving style. In particular, the driving mode has a significant impact on fuel consumption. Fuel consumption usually varies in the following driving modes:
 - steady driving — the most stable and relatively economical mode;
 - frequent acceleration and deceleration — increases fuel consumption;
 - traffic jams — consumption increases due to stop-and-go driving;
 - high-speed driving — consumption increases due to aerodynamic resistance;
 - low-speed, but continuous driving — can be moderately economical in some cases.

Theoretically, to minimize fuel consumption, the vehicle should be driven at a steady speed, without excessive acceleration or sudden braking.

Fuel consumption is often expressed as:

$$Q = \frac{q}{L} \times 100$$

here: Q — fuel consumption per 100 km, l/100 km; q — amount of fuel consumed, l and L — distance traveled, km.

The following factors affect fuel consumption:

- driving mode;
- average speed;
- acceleration intensity;
- number of braking;
- driver's control method;
- vehicle mass;
- road profile;
- parameters in the simulator program.

In the simulator, the same car is driven in different driving modes. The program calculates or records fuel consumption based on the car's speed, duration of travel, acceleration-deceleration mode, and distance traveled. Fuel consumption is recorded separately for each mode and compared with each other.



Figure 1. Passenger car simulator

Advantages	Disadvantages
• experiments are conducted in safe conditions; • different driving modes can be modeled; • there is no need to conduct experiments on a real road; • it is convenient to explain economical management methods; • it allows for economic and environmental evaluation.	• the simulator may not fully reflect the real fuel system; • the results will depend on the program model; • real weather, road resistance and all engine characteristics may not be fully reflected; • psychological factors in real traffic flow may not be taken into account.

4. Procedure for performing work:

1. The simulator is put into operation.
2. A virtual road section or route on which the experiment will be conducted is selected.
3. Initially, a single-speed driving mode is selected.
4. The car is driven at a constant speed for a certain distance, for example, 3 km or 5 km.
5. The distance traveled and the amount of fuel consumed are recorded.
6. Then the same route is driven in frequent acceleration and deceleration modes.
7. Then a traffic jam or stop-and-go mode is modeled.
8. If necessary, a high-speed driving mode is also tested.
9. The experiment is repeated at least 3 times for each mode.
10. The results obtained are entered into a table.
11. The average fuel consumption is calculated for each mode.
12. Finally, it is determined in which mode the fuel consumption is lower or higher.

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T/r	Traffic mode	Distance, km	Consumed fuel, l	Consumption per 100 km, l/100 km
1	Movement in a rhythm	5.0		
2	Frequent acceleration and deceleration	5.0		
3	Traffic jam mode	5.0		
4	High-speed movement	5.0		
5	Continuous movement at low speed	5.0		

When analyzing the results, attention is paid to the following:

- relatively low fuel consumption in a single-speed driving mode;
- frequent acceleration and braking increase fuel consumption;
- the highest consumption in traffic jams;
- increased consumption due to aerodynamic resistance at high speeds;
- the advantage of smooth and stable movement as an economical control method.

For example, in traffic jams, a car works in low gear or idle for a long time, often stops and drives. Because of this, fuel consumption increases significantly.

5. Conclusion. As a result of the experiment conducted using a passenger car simulator, it was found that the driving mode has a significant impact on fuel consumption. While a steady and smooth movement is relatively economical, fuel consumption increases in frequent acceleration, deceleration and traffic jams. Therefore, it is important to choose a stable and careful driving method for economical driving.

Control questions

1. What is meant by fuel consumption?

2. How does the driving mode affect fuel consumption?
3. Why is driving at a constant speed considered economical?
4. Why does frequent acceleration and deceleration increase fuel consumption?
5. Why is fuel consumption higher in traffic jams?
6. What is the formula for determining fuel consumption?
7. Why is fuel consumption per 100 km calculated?
8. How is average fuel consumption determined?
9. How does high speed affect fuel consumption?
10. In what cases can continuous driving at low speed be economical?
11. How does the driver's control method affect the result?
12. What is the advantage of conducting experiments in a simulator?
13. What is the purpose of comparing different driving modes?
14. What is the relationship between fuel consumption and environmental safety?
15. In which mode can fuel consumption be the highest?
16. In which mode can fuel consumption be the lowest?
17. Why is it necessary to repeat the experiment several times?
18. What is the difference between real and simulator results?
19. What control method is recommended to reduce fuel consumption?
20. What is the practical significance of this laboratory work?
21. Why can fuel consumption differ even if the average speed is the same in different driving modes?
22. How does engine idling in traffic jams affect overall fuel consumption?
23. How can the results of fuel consumption studies be used to train drivers in economical and safe driving?
24. What is the practical significance of the results of this laboratory work in transport operations and motor transport enterprises?
25. What is the significance of the study of fuel consumption depending on the driving mode in the fields of transport engineering, ecology and automobile operations?

Practical exercise 10: **Determining the stability of a car in cornering using a passenger car simulator**

1. **Purpose of work:** Using a car simulator, it is intended to study the characteristics of a car's behavior during cornering, assess its stability at different speeds and road conditions, and identify dangerous situations that arise during cornering.
2. **Required equipment:** The following equipment is required to complete this lab:
 - a car simulator;
 - a monitor or visualization screen;
 - a score sheet and calculator;
 - a pen or pencil.
3. **General information:** When a car goes through a turn, it needs a centripetal force to maintain its centripetal motion. This force is created by the friction between the wheels and the road. If the friction is insufficient or the speed is too high, the car may lose stability in the turn. The following factors affect cornering stability:
 - vehicle speed;
 - turning radius;
 - road surface condition;
 - wheel-to-road friction coefficient;
 - vehicle center of gravity height;
 - tire condition;
 - steering accuracy.

Theoretically, as speed increases, the centrifugal force acting on the car increases. As a result:

- the vehicle will drift to the outside;
- the risk of sideslip increases;
- the possibility of leaving the turning trajectory increases;

- there may be a risk of rollover.

The basic relationship for rotational motion is expressed as follows:

$$a = \frac{V^2}{R}$$

where: a - lateral acceleration, m/s²; V - vehicle speed, m/s and R - turning radius, m.

From this formula it can be seen that with increasing speed, the lateral effect increases sharply, and with decreasing radius, stability deteriorates even more.



Figure 1. Passenger car simulator

In the simulator, a car is driven into a corner at a certain speed. The program records the car's trajectory, directional deviation, lateral movement, response to braking or steering, and stability. Based on this, the car's safety in cornering is assessed.

Advantages	Disadvantages
• the test is conducted in a safe environment; • various hazardous situations can be modeled;	• the simulator may not fully reproduce the feeling of real driving; • the results will depend on the software model;

• factors affecting stability can be accurately observed; • does not pose a hazard on a real road; • the results are demonstrable and understandable.	• not all dynamic characteristics of a real car may be fully reflected; • the psychological pressure of the driver will differ from that in real conditions.
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4. Procedure for performing work:

1. The simulator is brought into working condition.
2. A turning area is selected for the experiment.
3. Initially, a turn with a certain radius, for example, 50 m, is determined.
4. The car is accelerated to the first speed, for example, 20 km/h.
5. The car is driven through the turn and its movement is observed.
6. Deviation from the direction, lateral displacement and steering position are recorded.
7. The same experiment is repeated at speeds of 30, 40, 50, 60 km/h and higher.
8. If necessary, the experiment is also performed on turns with other radii or on other road surfaces.
9. The experiment is carried out at least 3 times for each condition.
10. The results obtained are entered into a table.
11. The average results are determined for each speed and condition.
12. Finally, a conclusion is drawn on the stability of the car in turns.

When analyzing the results, attention is paid to the following:

- decrease in stability with increasing speed;
- increase in risk as the turning radius decreases;
- increase in lateral deviation on a slippery road surface;
- the possibility of the car leaving the turning trajectory after a certain speed;
- the possibility of the driver's steering actions restoring stability to a certain extent.

For example, in a 50 m radius turn, a car may be stable at a speed of 20–30 km/h, but at 50–60 km/h it may slip sideways or go off the trajectory.

Table 1. Recording table

#	V, km/h	R, m	1st attempt	2nd attempt	3rd attempt	Average evaluation
1	10	50				
2	20					
3	30					
4	40					
5	50					
6	60					
7	70					
8	80					
9	90					
10	100					

5. Conclusion. As a result of an experiment using a passenger car simulator, it was found that the stability of a car in a turn is directly dependent on speed, road surface condition, and turning radius. As speed increases and traction decreases, the risk of the car slipping sideways, deviating from the course, and deviating from the trajectory increases sharply. Therefore, it is important to choose a safe speed when turning and take into account road conditions.

Control questions

1. What is meant by fuel consumption?
2. How does the driving mode affect fuel consumption?
3. Why is driving at a constant speed considered economical?
4. Why does frequent acceleration and deceleration increase fuel consumption?
5. Why is fuel consumption higher in traffic jams?
6. What is the formula for determining fuel consumption?
7. Why is fuel consumption per 100 km calculated?

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References

1. Азизов К.Х. // Шаҳар йўлларида ҳаракат хавфсизлигини ташкил этиш, Тошкент. «Транспорт» 2021 й – 227б.
2. Азизов Қ.Х., Поспелов П.И., Ўроқов А.Х.. Йўл шароити ва ҳаракат хавфсизлиги. Олий ўқув юртлари учун даслик. –Т.: ТАЙЛҚЭИ, 2018. –208 б.
3. Азизов К.Х. // «Ҳаракат хавфсизлигини ташкил этиш асослари» Тошкент. «Фан ва технология» 2009 й – 242б.
4. Азизов К.Х.// Основы организации безопасности движения: Учебник для вузов. –Ташкент: «Fan va texnologiya», 2012. –272 стр.
5. Азизов К.Х., Ураков А.Х. // Безопасность дорожного движения. Учебник для вузов. – Ташкент: «ТИПС и ЭАД», 2017.–320с.
6. Азизов К.Х., Дарабов М., Сайфутдинова Р.А. // Обеспечения безопасности движения на городских улицах. -Т.: ТАДИ, 2009.-132 с.
7. Сильянов В.В., Домке Э.Р.// Транспортно-эксплуатационные качества автомобильных дорог и городских улиц. М.: Издательский центр “Академия”, 2008. – 352 с.
8. Сильянов В.В. // Теория транспортных потоков в проектировании дорог и организации движения. М.: Транспорт, 1977. - 303 с
9. Victor L. Knoop // Introduction to Traffic Flow Theory: An Introduction with exercises, 2021, 267 pages.
10. Femke Kessels // Traffic Flow Modelling: Introduction to Traffic Flow Theory Through a Genealogy of Models, Springer International Publishing, 2019, 139 pages.
11. ШНҚ 2.07.01-23 «Аҳоли пунктларининг ҳудудларини ривожлантириш ва қуришни шаҳарсозлик жиҳатидан режалаштириш» шаҳарсозлик нормалари ва қоидалари, 2024 й – 111 б.
12. ШНҚ 2.07.06-24 «Шаҳар кўча-йўллари. Лойиҳалаш талаблари» шаҳарсозлик нормалари ва қоидалари, 2024 й – 39 б.
13. ГОСТ 52289-2004 «Йўл белгилари, чизиклар, тўсиқлар ва светофорларни ўрнатиш қоидалари бўйича асосий ҳужжат» (расмий манба: Основной документ, описывающий правила размещения дорожных знаков, разметки, ограждений и светофоров).
14. <https://traffic-simulation.de/>
15. <https://www.eclipse.org/sumo/>
16. https://www.webpages.uidaho.edu/niatt_labmanual/index.htm
17. <https://mintrans.uz/>
18. <https://nrm.uz/>