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Methodology for determining bottlenecks on the city's street-road network by analyzing GPS track data

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Abstract. Problem. *The article considers the issue of determining the location of "bottlenecks" on the highways of large cities based on the study of the vehicle's driving mode, obtained as a result of GPS data processing and analysis.* ***Purpose.*** *The purpose of this study is to develop and test the methodology for identifying potential "bottlenecks" on the city's freeway by analyzing the GPS track data of the car. The subject of the study is the interrelationship of the characteristics of the sections of the city's street-road network (SRN) with the parameters characterizing the vehicle movement mode in the traffic flow.* ***Methodology.*** *Two experimental routes with the same starting and ending points were chosen to obtain data on traffic conditions on the SRN of the city of Kharkiv, which correspond to typical routes of official movement of personal transport on weekdays. During the movement of the car along the specified routes, GPS tracks were obtained, whose processing made it possible to determine the driving conditions along the entire length of the routes.* ***Results.*** *The work presents a method of researching the vehicle's driving mode by analyzing GPS track data; the determined indicators of the traffic regime, which can be effectively used as criteria for determining potential "bottlenecks" on the city's SRN; the methodology was tested on real traffic routes on the SRN of the city of Kharkiv. For selected routes, the work presents histograms of instantaneous speed distribution, graphs of car movement in "distance - speed" and "time - speed" coordinates. Graphs of changes in specific time in motion, specific idle time, speed gradient, energy gradient, Hermann-Prygozhin criterion were obtained for individual kilometer segments of routes. The specific idle time and the Herman-Prygozhin criterion turned out to be the most effective criteria for the purposes of determining the "bottlenecks" of SRN.* ***Originality.*** *An experimental technique was developed and tested, which allows to determine the potential "bottlenecks" of the city's SRN as a result of conducting short-term and not labor-intensive research. The proposed approach does not require the presence of specialized equipment or software, which makes this method effective when conducting scientific research.* ***Practical value.*** *The possibility of using the proposed method of data processing of GPS tracks to analyze traffic conditions on the city highway and identify potential "bottlenecks" was shown. For the selected routes in Kharkiv, such sections turned out to be Vesnina St. (beyond the intersection with Pushkinska St.); Heroes of Stalingrad Ave. (access to the intersection from Leva Landau Ave.); Gagarina Ave. (access to the intersection with Kashtanova St.)*

Key words*: traffic, street-road network, GPS track, bottlenecks, traffic conditions.*

Introduction

Trouble-free functioning of the street and road network (SRN) of cities is the main condition for effective infrastructure in the state or in a separate region. The high degree of concentration of production and consumption in modern megacities imposes strict requirements for ensuring the logistics of cargo transportation, as well as ensuring the transport mobility of the population.

One of the significant problems of the city transport system manifests itself in traffic jams and their consequences, such as a decrease in the technical and economic indicators of the rolling stock of road transport, a decrease in the efficiency of public transport, etc. In the area of the transport process, congestion usually refers to an excessive number of vehicles on a certain section of the SRN in a certain period of time, which leads to a decrease in the speed of the traffic flow and the occurrence of traffic jams. This usually means a long-term paralysis of movement or movement in the "start - stop" mode. According to some data, a decrease in traffic speeds due to overloading of SRN sections leads to an increase in the cost of transportation by 20-30%, and the growth of the transport component in the final cost of products and services can be approximately 7-10% [1 ,2]. The problem of increasing the carrying capacity of city roads and increasing communication speeds is also relevant for Ukraine.

Sections of the road, where complicated conditions for the movement of the transport flow systematically arise due to their overloading, are called "bottlenecks". The problem of identifying such areas on the SRN of large cities is a separate important area of research.

Analysis of publications

According to the general interpretation of the concept of "bottleneck", it is a phenomenon in which the performance or throughput of the system is limited by one or several components or resources [3]. In the corresponding English term “Bottleneck”, an analogy with the neck of a bottle can be traced. The analogy will be more than obvious if we rely on the hydrodynamic model of traffic flow. The term "constrictions" is also used in literary sources, especially when considering the road's carrying capacity.

Many scientific publications on this problem offer different approaches to the determination of "bottlenecks" on the city's SRN, which can be useful for planning and managing traffic in large cities. The use of various methods and algorithms allows identifying problem areas and developing recommendations for improving traffic conditions in these areas.

To solve the problem of identifying "bottlenecks" in modern conditions, geo-information transport systems and technologies are being widely used, which primarily include navigation and communication technologies with the use of services based on global satellite positioning systems.

The GPS-tracking technology is the most effective and available for automated analysis of traffic conditions on SRN sections [4-12]. Based on the results of the analysis of the tracks of vehicles moving in conditions of steady traffic flow, it is possible to evaluate a wide range of characteristics of the traffic conditions on the SRN sections, such as the average technical speed, connection time, duration of downtime in traffic jams, etc. In [10], the authors proposed an original algorithm for detecting "bottlenecks" based on SRN data. The algorithm was tested on several city streets and the results showed high accuracy of the results.

One of the important approaches when searching for "bottlenecks" of the SRN of cities is the use of data processing with the help of machine learning algorithms and statistical analysis. For example, in work [13], the clustering method was used to identify areas on the road where the speed of cars is the lowest. The authors of the work [14] worked with data on the mode of movement of vehicles in the sections of the SRN of the city and used the clustering algorithm to highlight "bottlenecks".

Searching for "bottlenecks" on city highways using traffic jam frequency analysis is also one of the common methods [15,16]. This approach makes it possible to identify points of overload on the SRN, which can lead to traffic jams and other problems associated with the movement of motor vehicles in urban conditions.

The work [17] used the method of detecting "narrow" roads in an urban environment based on data from video surveillance cameras. The authors proposed using a learning algorithm of deep neural networks to detect "bottlenecks", as well as a system for warning drivers when approaching them.

Purpose and Tasks

Data on the presence and location of "bottlenecks" on the city's SRN are of great importance for both users and owners of highways. Since the size and patterns of distribution of traffic flows on the network are stochastic and determined by a significant number of factors, determining potential bottlenecks at the stage of designing streets and roads is too difficult a task. In most cases, the task of establishing bottlenecks is implemented based on the results of monitoring the work of SRN in real conditions.

A large number of studies on the problem of "bottlenecks" of the SRN have shown that they most often occur in congestion zones, that is, in places where there is a specific interaction between road traffic participants due to a change in traffic directions. Road crossings (crossroads), where the flows of vehicles and pedestrians meet and cross, are particularly typical in this regard.

Identifying the "bottlenecks" of SRN on a city scale is problematic, since classical methods can take a long time to process a large amount of data, especially if it is necessary to identify tens or hundreds of such areas. This can complicate the process of surveying city roads and complicate the introduction of new technologies into the existing transport infrastructure. Therefore, it is urgent to develop and test experimental methods that allow identifying potential problem areas of the SRN of cities as a result of conducting short-term and not labor-intensive studies.

The purpose of this study is to develop and test the methodology for determining potential "bottlenecks" on the city's freeway by analyzing the GPS track data of a car. To achieve the set goal, the following intermediate tasks can be identified:

– to develop a methodology for researching the vehicle's driving mode by analyzing GPS track data;

– determine the effective indicators of the car's driving mode to determine the potential bottlenecks of the SRN;

– to test the methodology on real traffic routes on the SRN of a large city.

The subject of this study is the interrelationship of the characteristics of the city's SRN sections with the parameters characterizing the traffic mode of vehicles.

Description of research methodology

In most cases, the task of establishing the location of "bottlenecks" on the SRN of cities is realized as a result of monitoring the movement of vehicles in real conditions. Currently, several methods can be used to obtain primary information, the most accessible of which is the method of analyzing GPS tracks of vehicles. The absolute advantage of the approach based on the analysis of GPS tracks is the objectivity of the obtained data, since the mode of movement of the car is fixed by automatic means of geo-positioning, and not by a person. Also, it does not require the presence of specialized equipment or software, which makes this method particularly effective when conducting scientific research.

Data collection of GPS tracks obtained from navigation equipment can be carried out by two methods:

- a passive experiment, during which selective data collection is carried out on a set of random traffic routes of cars equipped with on-board GPS navigation systems, with subsequent linking of the tracks to the GIS map of the city;

- an active experiment, in which data collection is carried out by a laboratory car on pre-selected traffic routes along the city's SRN.

In our case, the car-driving laboratory method was used to obtain the characteristics of the speed modes. Also, this method of research is called the method of a "floating" car, that is, a car moving at a speed characteristic of most vehicles in the stream. A typical example of the use of this method is the study of the spatial characteristics of speed along a highway based on continuous automatic recording of speed in the form of GPS tracks. At the same time, the "floating" car must move in a mode typical for the given state of the traffic flow. In this study, a sedan-type car with an engine with a working volume of 1.8 cubic centimeter was used.

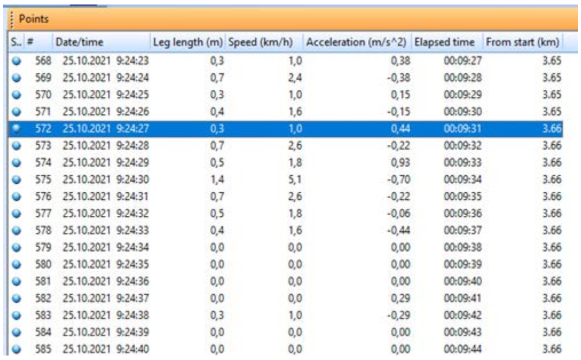
In order to test the method of determining "bottlenecks" on the SRN of the city of Kharkiv, two routes were chosen, the starting and ending points of which were, respectively: the intersection of the district highway and the street of Prospect Heroiv Kharkiv at the entrance to the city, and the Kharkiv National Automobile and Highway University, located in the center of the city (Fig. 1). The length of route No. 1 (blue) was 18.14 km. The length of route No. 2 (green) was 22.06 km.

Fig. 1. Display of GPS tracks of car movement on experimental routes

Research was conducted on weekdays between 09:00 a.m. and 10:00 a.m., which corresponds to the period of maximum loading of the city's SRN. The movement took place in the conditions of the real traffic flow in compliance with all the requirements of the Road Traffic Rules. A mandatory condition was the absence of additional traffic delays due to reasons not related to traffic management (accidents, road works, etc.), which could affect the vehicle's driving mode.

Pioneer 7014 navigator and Navitel navigation application were used to record GPS tracks. Tracks were recorded in the *.gpx format (text format for storing and exchanging GPS data, based on the XML format), which allows you to store information in an arbitrary form, in which only the longitude and latitude of the track points are required. The GPSTrackEditor program was used for the initial processing of tracks and translation of the received traffic characteristics into *.xls format. The array of received data included parameters of the car's movement recorded at one-second intervals, including: time in motion from the moment the recording began; instantaneous movement speed; the distance covered in one step of the record; accumulated distance since the start of recording; linear acceleration. In fig. 2 shows the form of presentation of GPS track data by the GPSTrackEditor program.

As you can see, the step of registration of the car's driving mode is 1 s, which indicates a sufficiently high accuracy and sensitivity of this method.


Points

S..	#	Date/time	Leg length (m)	Speed (km/h)	Acceleration (m/s^2)	Elapsed time	From start (km)
	568	25.10.2021 9:24:23	0,3	1,0	0,38	00:09:27	3.65
	569	25.10.2021 9:24:24	0,7	2,4	-0,38	00:09:28	3.65
	570	25.10.2021 9:24:25	0,3	1,0	0,15	00:09:29	3.65
	571	25.10.2021 9:24:26	0,4	1,6	-0,15	00:09:30	3.65
	572	25.10.2021 9:24:27	0,3	1,0	0,44	00:09:31	3.66
	573	25.10.2021 9:24:28	0,7	2,6	-0,22	00:09:32	3.66
	574	25.10.2021 9:24:29	0,5	1,8	0,93	00:09:33	3.66
	575	25.10.2021 9:24:30	1,4	5,1	-0,70	00:09:34	3.66
	576	25.10.2021 9:24:31	0,7	2,6	-0,22	00:09:35	3.66
	577	25.10.2021 9:24:32	0,5	1,8	-0,06	00:09:36	3.66
	578	25.10.2021 9:24:33	0,4	1,6	-0,44	00:09:37	3.66
	579	25.10.2021 9:24:34	0,0	0,0	0,00	00:09:38	3.66
	580	25.10.2021 9:24:35	0,0	0,0	0,00	00:09:39	3.66
	581	25.10.2021 9:24:36	0,0	0,0	0,00	00:09:40	3.66
	582	25.10.2021 9:24:37	0,0	0,0	0,29	00:09:41	3.66
	583	25.10.2021 9:24:38	0,3	1,0	-0,29	00:09:42	3.66
	584	25.10.2021 9:24:39	0,0	0,0	0,00	00:09:43	3.66
	585	25.10.2021 9:24:40	0,0	0,0	0,00	00:09:44	3.66

Fig. 2. Array of data obtained from GPS track

Research results

Such duration of the interval of fixation of car movement parameters allows obtaining the histograms of the distribution of instantaneous movement speeds during the trip, which are shown in fig. 3 together with the corresponding statistical characteristics.

As we see in fig. 3, the largest relative number of second intervals falls on zero or near-zero values of the car's instantaneous speeds, i.e., the car did not move during these periods. However, such a large number of idle intervals does not yet indicate the presence of "bottlenecks" on the selected routes, as it may be associated with delays as a result of traffic regulation at intersections. For "bottlenecks" movement with a minimum speed in the "start-stop" mode is more characteristic, so a relatively large number of corresponding intervals on the histogram of the instantaneous speed distribution can be a sign of the presence of potential "bottlenecks". In fig. 3, you can see that such a phenomenon occurs for route No. 1. Also, an increase in the relative frequency is observed near the speed values of 60 km/h. These intervals correspond to sections of the routes where free traffic conditions were observed and the traffic flow moved at maximum speed. In general, the presence of speed values at intervals greater than 50 km/h indicates that the speed of the traffic flow on certain sections of the SRN exceeded the speed limit for populated areas established by the Road Traffic Rules. But most drivers take advantage of the 20 km/h speeding tolerance established in Ukraine.

Looking at the overall distribution of the vehicle's instantaneous speed, the driving conditions on Route 2 can be called more differentiated, whereas on Route 1, large periods of driving time were either for driving in free conditions, or, conversely, for driving in very dense traffic flow.

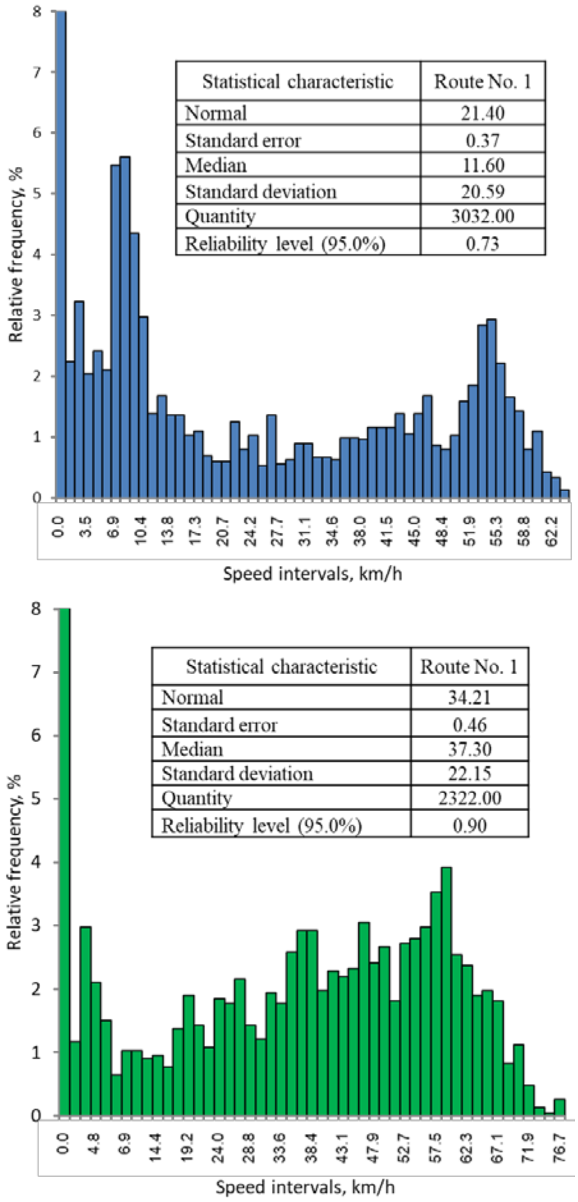


Fig. 3. Histograms of distribution of instantaneous speed values

Since the recording of the track took place at an interval of 1 s, the "Quantity" parameter in fig. 3 corresponds to the travel time on the routes, and "average" corresponds to the value of the average technical speed.

As mentioned above, as a result of processing the GPS track, such characteristics of the car's driving mode as speed and distance traveled were obtained. Thanks to this, it is possible to directly conduct an initial assessment of the route sections, in particular, graphs of the car's movement can be built in the "distance-speed" and "time-speed" coordinates (Figs. 4, 5).

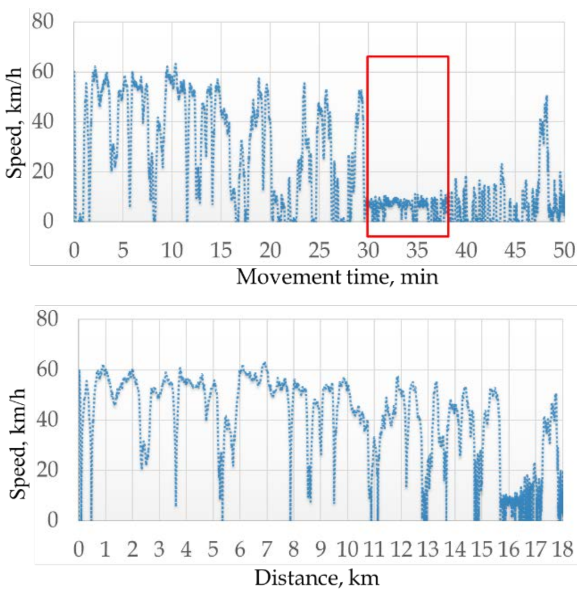


Fig. 4. Car traffic schedules for route No. 1

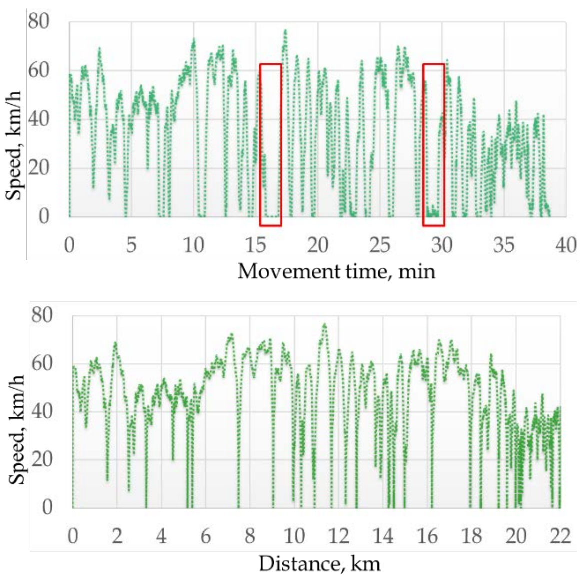


Fig. 5. Car traffic schedules for route No. 2

In the given graphs, you can see that during the movement of the car on the selected routes, there are significant fluctuations in the speed of traffic, which is associated with a large number of intersections, pedestrian crossings and other places where there was a reduction in speed or stops related to traffic regulation.

Relatively long periods of idleness or movement at a minimum speed in the "start-stop" mode, characteristic of "narrow places", can be visually determined on the graphs in the "time-speed" coordinates. Then, by collating the array of GPS track data, they can be tied to specific sections of the route. But such a technique will be quite time-consuming, and its automation will require the creation of special algorithms for computer data processing and software.

Therefore, it is urgent to search for quantitative criteria for traffic flow conditions on SRN sections that will be sensitive enough to determine potential "bottlenecks". To do this, we will divide the experimental routes into separate sections, 1 km long, and in the future we will calculate the corresponding indicators for individual kilometer sections of the routes.

An important technical and economic indicator of the efficiency of the transport process in road transport is the average technical speed, which is the ratio of the length of the traveled route to the time the vehicle is in motion. Derivatives of the average technical speed, such as the specific time in motion T_r, min/km, and the specific idle time T_S, min/km, can be used as criteria for evaluating the vehicle's driving mode on the route sections:

$$T_r = \frac{60}{V_r}, \qquad (1)$$

where V_r – the average speed in motion (for intervals where the speed was at least 5 km/h), km/h.

$$T_S = \frac{\sum t_S}{L_м}, \qquad (2)$$

where $\sum t_S$ – the total duration of idle intervals, min; $L_м$ – route length, km.

In work [18], it is recommended to use energy criteria of the traffic flow state to assess the quality and stability of traffic conditions. Speed gradient and energy gradient are the most effective indicators for analyzing the quality of the city's transport system. Since these indicators characterize the stability of the movement mode due to the change in instantaneous speed, they can be calculated using GPS track data.

Since the speed gradient G_V is the ratio of the acceleration noise to the average technical speed, for a separate kilometer segment of the route, it can be obtained as:

$$G_V = \frac{\sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} j_i^2}}{V_T}, \quad (3)$$

where j_t – the acceleration value in the i-th measurement interval, m/s^2; n – the number of measurement intervals; V_T – average technical speed for the section, km/h.

The energy gradient G_E can be defined as:

$$G_E = \frac{\sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} \left(j_i \cdot V_i - \overline{j_i \cdot V_i} \right)^2}}{V_T}, \quad (4)$$

where $j_i \cdot V_i$ – the product of acceleration and velocity at the ith measurement interval, m^2/sec^3; $\overline{j_i \cdot V}$ - the average value of the product of acceleration and speed for the kilometer section of the route.

In some scientific publications, the German-Prygozhin model is used to assess the quality of traffic management on city roads [19-21]. From these works, it can be concluded that the Herman-Prygozhin criterion can be effectively used to assess the quality of traffic management on city roads.

In the Hermann-Prygozhin two-parameter traffic flow state model, the parameter T_m characterizes the minimum specific time spent on movement in free conditions, that is, at a very low level of network loading, in which there is no interaction between vehicles in the flow, and the parameter n reflects the influence of the road load level on the actual movement speed. Studies have shown that the parameter n varies in the range from 0.8 to 3.0, while smaller values indicate better functioning of the SRN section.

For a separate kilometer segment of the route, the value of the criterion n can be obtained as:

$$n = \frac{\ln T_m + \ln T}{\ln T_r} - 1, \quad (5)$$

where T_m – the minimum value of the speed of movement, on the SRN section, min/km; T - current speed value, min/km; T_r - the average pace of movement in the section, min./km.

As a result of the calculation of the specified indicators of traffic conditions, it is possible to construct graphs of changes in these parameters along the sections of two experimental routes.

In fig. 6 shows the graphs for specific time in motion and specific idle time. From the analysis of the graphs, it is possible to ascertain the presence of a tendency to increase the specific time in motion when approaching the central part of the city, although in general this indicator was not sensitive to changes in traffic conditions. On the graphs of changes in the specific idle time, you can highlight areas that, according to the value of this parameter, are out of the general trend. For route No. 1, these are sections 13, 15 and 17; for route No. 2 – 11 and 15. These sections can be considered as potential "bottlenecks" of the SRN.

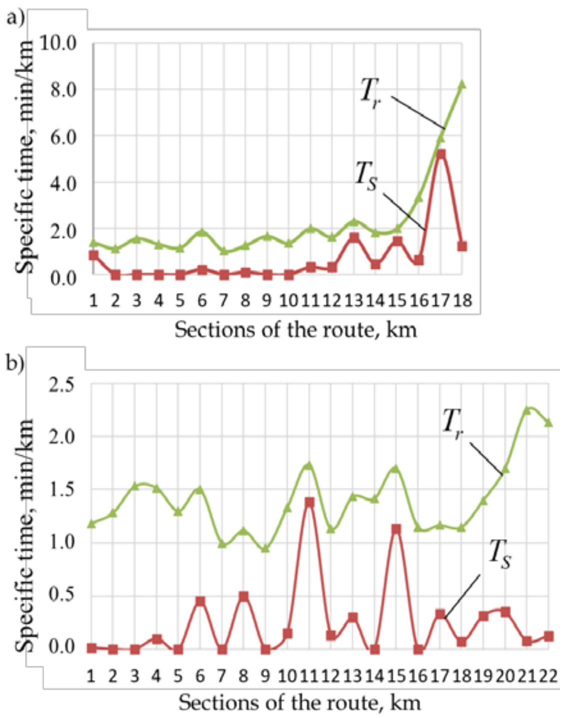


Fig. 6. Schedules of changes in time characteristics of traffic: a) for route No. 1; b) for route No. 2

The change in the values of the energy criteria of driving conditions along individual kilometer sections on the experimental routes are shown in fig. 7.

The reason for the discrepancy in the values of the speed gradient and energy gradient indicators on individual sections of the routes may be the result of the location of regulated intersections with main streets on them. The significant duration of traffic light regulation cycles at such intersections could cause increased traffic delays in the event that a car stopped at a traffic light prohibiting signal. On section 17 of route No. 1, there is a significant deterioration of both indicators, which may be a confirmation of the earlier assumption about the presence of a "bottleneck" on this section. However, in general, it can be noted that the indicated energy criteria are not sufficiently sensitive to traffic flow conditions, so it is not advisable to use them to diagnose the "bottlenecks" of SRN.

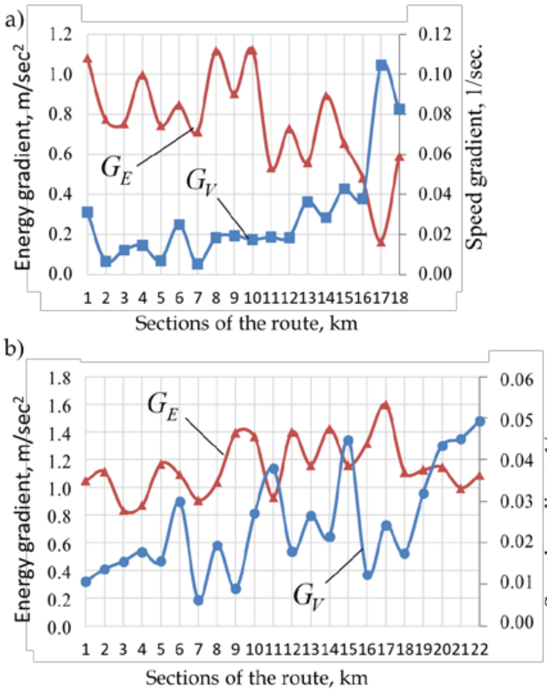


Fig. 7. Graphs of changes in speed gradient and energy gradient: a) for route 1; a) for route No. 1; b) for route No. 2

Graphical dependences of changes in parameters of the Herman - Prygozhin model for experimental routes are shown in Fig. 8.

As can be seen from fig. 8, parameter n of Herman - Prigozhin shows a high sensitivity to the conditions of car movement on certain sections of the routes, which characterizes its high suitability as a criterion for determining "bottlenecks" on the SRN of cities. The analysis of the graphs confirms the assumption about the presence of potential "bottlenecks" on the SRN sections of the studied routes. For route No. 1, this is segment 17, for route No. 2 – segments 11 and 15.

The function of displaying the GPS track on the city map allows you to localize the location of problem areas of the SRN of the city of Kharkiv within the studied routes (Fig. 9).

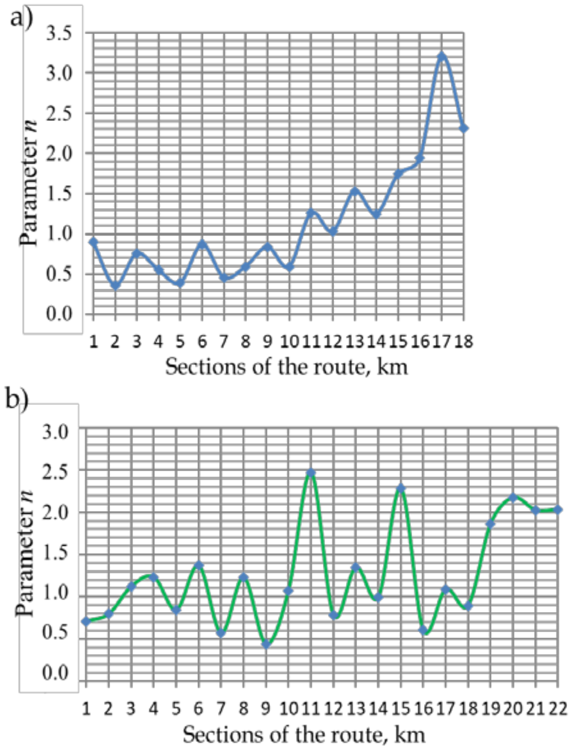


Fig. 8. Graphs of changes in parameter n of the Herman - Prygozhin model: a) for route 1; a) for route No. 1; b) for route No. 2

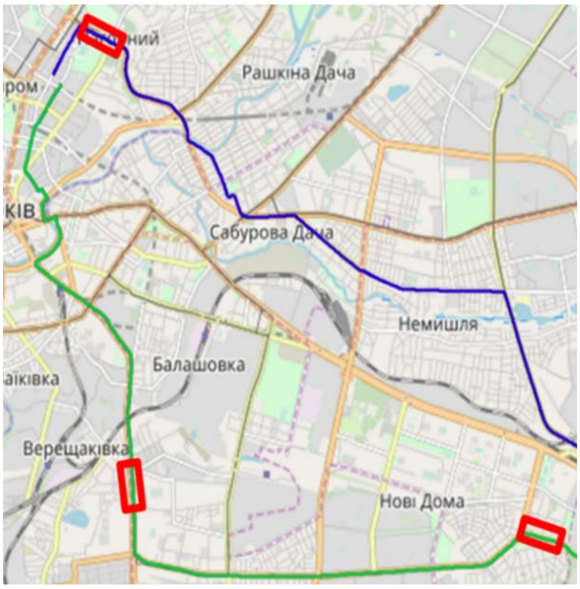


Fig. 9. Location of "bottlenecks" on the sections of the investigated routes

The following areas can be considered as such places: for route No. 1 - st. Vesnina, (beyond the intersection with Pushkinska St.); for route No. 2 - Ave. Heroes of Stalingrad (approach to the intersection from Leva Landau Ave.) and Ave. Gagarina (approach to the intersection with Kashtanova St.).

Conclusion

Identification and elimination of "bottlenecks" on the SRN of cities is one of the main areas of increasing the efficiency of traffic management. However, the use of integral criteria for the quality of traffic organization to determine "bottlenecks" on the SRN of cities may turn out to be ineffective, since such an approach requires the availability of data on the degree of traffic congestion of sections of the SRN.

It is possible to use the analysis of the spatio-temporal characteristics of the speed regime as an objective method for operational evaluation of the efficiency of the traffic organization, which can be obtained from the data of experimental studies by the running laboratory method.

The necessary characteristics of the mode of movement of cars in the traffic flow can be obtained from the results of the analysis of GPS tracks, which will allow the use of this data to find "bottlenecks" on the SRN sections. Although the presence of problem areas can be visually assessed by graphs of the car's movement in "time-speed" coordinates, the automation of this process will require special computer data processing algorithms and appropriate software.

Another approach is the use of certain indicators of traffic conditions for individual sections of the route, which can be obtained as a result of data processing of car GPS tracks and will characterize the level of quality of traffic management in the relevant sections of the city's SRN. The criterion for the potential presence of a "bottleneck" on this or that section of the route will not be so much the absolute value of traffic quality indicators as their relative deviation from the averaged trend.

One of these indicators can be the specific idle time of the car. Energy criteria of the state of the traffic flow, such as the speed gradient and the energy gradient showed insufficient sensitivity to the "bottlenecks" of the SRN, so their use can be considered inappropriate. Parameter *n* of the German - Prygozhin transport flow model showed high efficiency for solving the task of finding potential "bottlenecks" of the SRN of cities.

An important advantage of the presented method of searching for bottlenecks on the city's SRN is the possibility of automating the analysis process and creating a special computer program, since all its stages can be described by simple mathematical algorithms.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Методика визначення вузьких місць на вулично-дорожній мережі міста шляхом аналізу даних GPS-треків

Анотація. Проблема. *В статті розглядається питання визначення розташування «вузьких місць» на вулично-дорожній мережі (ВДМ) великих міст на основі дослідження режиму руху автомобіля, що отримуються в результаті обробки та аналізу даних GPS.* ***Мета.*** *Метою даного дослідження є розробка та апробація методики визначення потенційних «вузьких місць» на ВДМ міста шляхом аналізу даних GPS-треку автомобіля. Предметом дослідження є взаємозв'язок характеристик ділянок ВДМ міста з параметрами, що характеризують режим руху автомобіля в транспортному потоці.* ***Методика.*** *Для отримання даних про умови руху на ВДМ міста Харкова були обрані два експериментальні маршрути з однаковими початковими та кінцевими пунктами, які відповідають типовим маршрутам службового переміщення особистого транспорту в будні дні тижня. Під час руху автомобіля за означеними маршрутами були отримані GPS-треки, обробка яких дозволила визначити умови руху по всій довжині маршрутів.* ***Результати.*** *В роботі представлена методика дослідження режиму руху автомобіля шляхом аналізу даних GPS-треку; визначені показники режиму руху, що можуть бути ефективно використані як критерії визначення потенційних «вузьких місць» на ВДМ міста; проведена апробацію методики на реальних маршрутах руху на ВДМ міста Харкова. Для обраних маршрутів в роботі представлено гістограми розподілу миттєвої швидкості, графіки руху автомобіля в координатах «відстань – швидкість» та «час – швидкість». Для окремих кілометрових відрізків маршрутів отримані графіки зміни питомого часу у русі, питомого часу простою, градієнту швидкості, градієнту енергії, критерій Германа – Пригожина. Найбільш ефективними критеріями для цілей визначення «вузьких місць» ВДМ виявилися питомий час простою та критерій Германа – Пригожина.* ***Оригінальність.*** *Була розроблена та перевірена експериментальна методика, які дозоляє визначати потенційні «вузькі місця» ВДМ міста в результаті проведення нетривалих та нетрудомістких досліджень. Запропонований підхід не вимагає наявності спеціалізованого обладнання або програмного забезпечення, що робить даний метод ефективним при проведенні наукових досліджень.* ***Практичне значення.*** *Було показано можливість використання запропонованої методики обробки даних GPS-треків для аналізу умов руху на ВДМ міста та виявлення потенційних «вузьких місць». Для обраних маршрутів в м. Харкові такими ділянками виявилися вул. Весніна (за перехрестям з вул. Пушкінською); просп. Героїв Сталінграду (підхід до перехрестя з просп. Льва Ландау); просп. Гагаріна (підхід до перехрестя з вул. Каштановою).*

Ключові слова: *дорожній рух, вулично-дорожня мережа, GPS-треку, вузькі місця, умови руху.*

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