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Cyclists movement: The results of assessing the intensity using surveillance cameras

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ABSTRACT

The increase in the number of rides with the use of non-motorized vehicles such as bicycles changes the requirements for urban infrastructure. As a result, there is a growing need for monitoring bicycle traffic. The purpose of this scientific work is to study the traffic intensity of cyclists and users of other non-motorized vehicles and analyse it by type of infrastructure, days of the week, and type of vehicle. For the study, we used data obtained from video surveillance cameras installed on the streets with different types of bicycle infrastructure. A database was formed based on the accounting of the cycle traffic intensity at the counting points. The analysis showed a similarity in the behaviour of cyclists in the conditions of identical infrastructure, which allows us to assess the intensity by the base points for each category of infrastructure.
Keywords: Bicycle traffic; Video monitoring; Urban bike infrastructure; Traffic estimation; Intensity accounting; Non-motorized vehicles.

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INTRODUCTION

In recent decades, more and more residents of large cities have chosen cycling as a means of transportation, which has several advantages over traditional modes of transport. In this regard, the need for monitoring bicycle traffic is growing.

Various methods are used to monitor cycle traffic, allowing us to record bike rides manually or automatically. The traditional and easiest method is manual counting. It is used in the USA (Ryus et al., 2004; Johnstone et al., 2017), in Australia (Bicycle NetWork, 2020), in Calgary (Canada) (Bike Data, 2016), in Scotland (Cycling Scotland, 2016). This method is time-consuming and costly; therefore studies of bike rides are usually limited to a small sample size and have infrequent updates.

Traditional methods of counting also include automatic methods, such as analysis of recordings from CCTV cameras (Kidholm et al., 2017), counting using sensors such as pneumatic tubes or infrared sensors (Tianjun et al., 2017). Calculations obtained by manual and automatic methods have a strong correlation (Tianjun et al., 2017).

The avalanche-like growth in the use of mobile devices (for example, smartphones, tablets, smart watches and bracelets) made it possible to use new methods for monitoring bicycle traffic based on the analysis of GPS data (Lee et al., 2020; Romanillos et al., 2015).

A significant amount of research on cycle traffic in recent years has been carried out using a smartphone application Strava (Lin et al., 2020; Chen et al., 2020).

If there is a rental system in cities, bicycle traffic can be monitored according to bicycle rental data. So, in the city of Krakow (Poland), the analysis of daily cycle traffic was carried out using automatic meters and GPS data received from the bike sharing system Wavelo (Pogodzinska et al., 2020).

Many researchers use both traditional and new methods at the same time. (Chen et al., 2016; Lee et al., 2016; Milne et al., 2019; Rojas et al., 2016; Wang et al., 2018a; Wang et al., 2018b). The data obtained using traditional and using new methods, in particular using the Strava application, have a high correlation (Boss et al., 2018).

Automatic counting methods are also not without drawbacks. These include errors and omissions in the data. The problem of lack of data at automatic counting stations is successfully solved by the method of multiple filling (Esawey, 2018).

Monitoring bicycle traffic in cities allows solving various problems. Firstly, it allows us to evaluate the safety and comfort of the bicycle infrastructure. (Trofimenko et al., 2017; Chen et al., 2020).

Secondly, it allows us to track what changes the creation of new infrastructure leads t. (Pritchard et al., 2019; Heesch et al., 2016; Bernardi et al., 2015).

Thirdly, thanks to the monitoring of bicycle traffic, it is possible to create the optimal layout of docking stations for bicycles. A similar problem was solved in Japan. (Zhang et al., 2019).

Monitoring of bicycling traffic by types of bicycling infrastructure, which is especially relevant for megacities, remains insufficiently studied. In very large cities there are a large number of different types of infrastructure: bike lanes, bicycle paths, shared paths, highways, dedicated lanes for public transport, etc. They differ in the intensity of movement of all participants, as well as safety and comfort of movement.

We studied the traffic intensity of bicyclists and users of other non-motorized vehicles (NMV) in Moscow and analysed it by type of infrastructure, days of the week and type of NMV.

METHOD AND DATA COLLECTION

Intensity assessment using video recording is one of the methods for recording intensity, which allows performing continuous monitoring at the counting points. A limitation of the use of this method is its high labour costs in processing video images.

To reduce labour costs, it is possible to use software that allows us to detect moving road users due to the video (Kidholm et al., 2017, Bahnsen et al., 2014).

This study processed videos provided by the Department of Transport and the Development of Road Transport Infrastructure of Moscow (DTDRTIM). The cameras were installed at a sufficiently high altitude in order to monitor the situation in the city; this did not reveal the age and gender characteristics of bicyclists, as well as their protective equipment. The layout of the cameras is shown in Figure 1.

We studied the traffic intensity of bicyclists and users of other non-motorized vehicles (NMV) in Moscow and analysed it by type of infrastructure, days of the week and type of NMV.

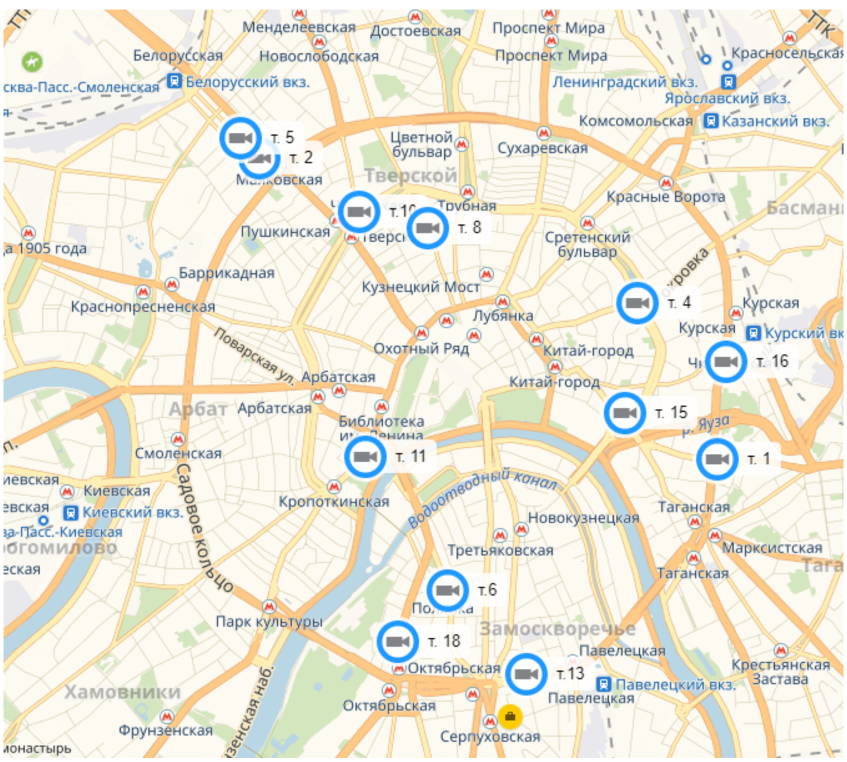

Figure 1. Map with layout of counting points with video recording.

The list of counting points using video recording is presented in Table 1.

Based on the intensity accounting performed at the counting points, a database (DB) was formed by analogy with the Portland database[1]. Saving the data and the result of their analysis in the register allows for comparing the intensity of bicyclist traffic with previous measurement results.

Table 1. Intensity counting points (video recording).

ID Point	Address[2]	Coordinates	Type of infrastructure
IDV_1	Nikolo-Yamskaya St.	55.747188, 37.656467	C
IDV_2	1-ya Brestskaya St. / Gasheka St.	55.770565, 37.592928	C
IDV_4	Pokrovka St. / Pokrovsky Boulevard	55.759223, 37.644636	C
IDV_5	1-ya Brestskaya Street / Fucika St.	55.771839, 37.590853	C
IDV_6	B. Polyanka St.	55.736083, 37.619468	C
IDV_8	Petrovka St.	55.764712, 37.616711	C
IDV_10	Pushkinskaya Sq. (Malaya Dmitrovka)	55.766186, 37.606805	C
IDV_11	Volkhonka St. / Lenivka St.	55.747386, 37.607730	A
IDV_13	Valovaya St.	55.730383, 37.630061	C
IDV_15	Yauzsky Boulevard	55.750760, 37.643233	D
IDV_16	Zemlyanoy Val St.	55.755351, 37.657446	C
IDV_18	B. Yakimanka St.	55.732871, 37.612230	C

In accordance with the objectives of the study, the intensity was accounted in the context of road sections, including one or several traffic ways, as well as tram tracks, sidewalks, curbs and dividing lanes, if available, according to the average value of intensity at the following dates: 05.06.18 to 12.06.18. The period under consideration includes working days of the week from Tuesday to Friday, and also Saturday, Sunday and public holidays, Monday (11.06.18) and Tuesday (12.06.18). Significant precipitation was observed at 8.06.18.

RESULTS

The share of bicyclists in the total flow of those who moving using NMV is 75% (Figure 2).

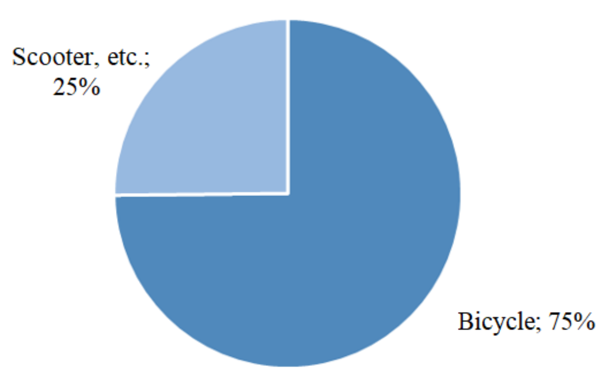

Figure 2. Types of non-motorized vehicles.

[1] *Portland Bureau of Transportation. (2018). Retrieved from https://docs.google.com/spreadsheets/d/1urP-ZA0Pd25_JZZ18hkGPlDEUQusBp49XmLzwpZ-2ag/edit#gid=0.*

[2] *The address must be in atomic form when a single value is stored, and the data is neither a list nor a set of values.*

The share of bicyclists using their own bicycle is 76% (Figure 3). The remaining 24% use bicycle sharing systems in Moscow (Velobike).

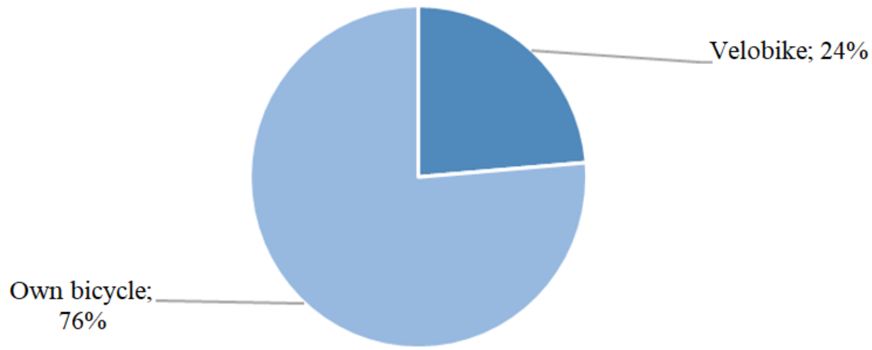

Figure 3. Proportion of bicyclists using Velobike system and own bicycles.

At the point IDV_1 (Nikoloyamskaya St.), there is a sharp difference in the number of people using the Velobike, which may be due to the inadequate bicycle rental system on the outside of the Garden Ring Road (Figure 4).

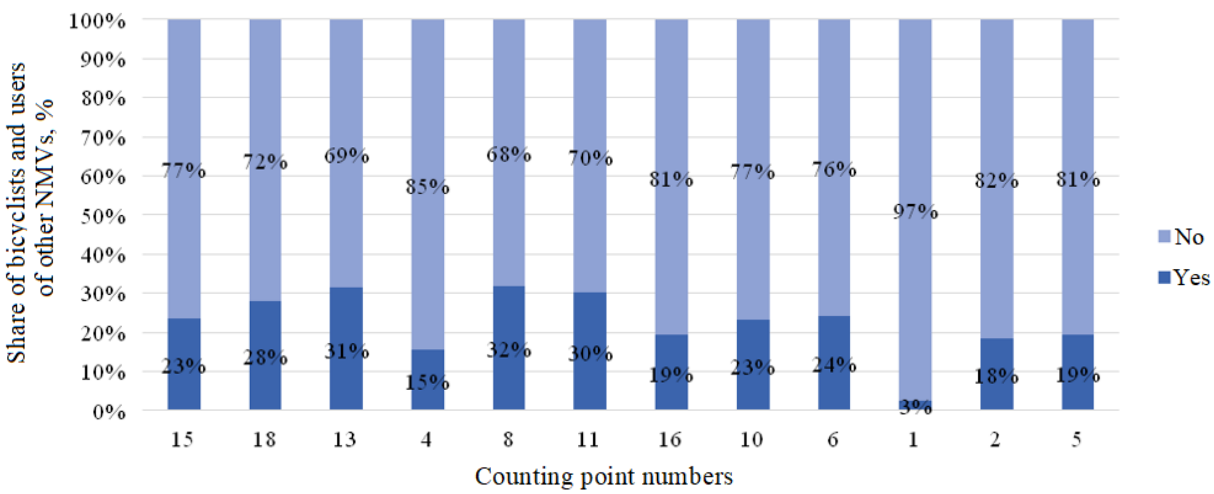

Figure 4. Share of bicyclists using Velobike in the counting points, %.

In the absence of bicycle paths, most bicyclists (from 80% to 90%) move along the sidewalks, the rest move along the roadway.

The results of assessing the intensity of traffic of bicyclists and users of other NMV are presented in Table 2 and Table 3.

The intensity of traffic of bicyclists at counting points differs on weekdays and weekends. On weekdays, the most active traffic of bicyclists and users of other NMVs were recorded at the points of Bolshaya Yakimanka St., Yauzsky Boulevard, Petrovka St. (Table 8.10), on weekends and holidays - at the counting points of Valovaya St., Yauzsky Boulevard, Pokrovka St. / Pokrovsky Boulevard (Table 4).

Table 2. Evaluation indicators based on the results of video recording the intensity with the use of manual processing.

Indicators	IDV_1	IDV_18	Average value
Share of men in the flow of bicyclists and users of other NMVs	-	-	
Share of women in the flow of bicyclists and users of other NMVs	-	-	
Percentage of bicyclists in the total flow moving using NMV	74%	67%	74%
Percentage of users of other NMVs in the total flow of those moving with the use of NMVs	26%	33%	26%
Percentage of bicyclists and users of other NMVs who do not have safety helmets	-	-	
Percentage of bicyclists and users of other NMVs moving along sidewalks	69%	90%	73%
Percentage of bicyclists and users of other NMVs traveling along traffic ways	31%	10%	25%
Percentage of bicyclists and users of other NMVs traveling along bicycle ways	-	-	
Percentage of bicyclists and users of other NMVs traveling on a rental NMV	4%	28%	24%
Percentage of bicyclists and users of other NMVs traveling on their own NMV	96%	72%	76%
Share of bicyclists and users of other NMVs of middle and youngest age group	-	-	
Share of bicyclists and users of other NMVs of older age group	-	-	

Table 3. Traffic intensity assessment for bicyclists and Users of Other NMVs.

ID	Point	Section	Monday	Sunday	Max	Time	Day of week _мах
1	IDV 1	Section 1	6	11	20	18.00-18.59	Thursday
2	IDV 1	Section 2	3	4	21	18.00-18.59	Thursday
3	IDV 2	Section 1	4	4	18	18.00-18.59	Wednesday
4	IDV 2	Section 2	3	2	7	18.00-19.59	Thursday
5	IDV 4	Section 1	9	20	44	17.00-17.59	Monday PP
6	IDV 4	Section 2	14	19	42	16.00-16.59	Monday PP
7	IDV 5	Section 1	1	2	8	17.00-17.59	Monday PP
8	IDV 5	Section 2	3	2	10	17.00-17.59	Saturday
9	IDV 6	Section 1	5	11	28	15.00-15.59	Monday PP
10	IDV 6	Section 2	7	9	27	17.00-17.59	Monday PP
11	IDV 8	Section 1	5	9	24	19.00-19.59	Saturday
12	IDV 8	Section 2	15	12	27	18.00-18.59	Saturday
13	IDV10	Section 1	5	9	24	19.00-19.59	Saturday
14	IDV 10	Section 2	15	12	27	18.00-18.59	Saturday
15	IDV 13	Section 1	3	23	44	16.00-16.59	Monday PP
16	IDV 13	Section 2	7	19	38	18.00-18.59	Monday PP
17	IDV 15	Section 1	4	9	23	14.00-14.59	Monday PP
18	IDV 15	Section 2	8	13	33	16.00-16.59	Monday PP
19	IDV 16	Section 1	6	8	25	18.00-18.59	Saturday
20	IDV 16	Section 2	11	6	23	18.00-18.59	Saturday

21	IDV 18	Section 1	9	15	29	12.00-12.59	Tuesday P
22	IDV `18	Section 2	12	9	32	12.00-12.59	Tuesday P
23	IDV 11	Section 1	3	12	27	16.00-16.59	Monday PP
24	IDV 11	Section 2	4	11	25	17.00-17.59	Monday PP
25	IDV 11	Section 3	2	7	29	16.00-16.59	Monday PP

Table 4. Activity of bicyclists at counting points on weekdays.

ID	Counting point	The number of recorded NMV users on weekdays
IDV_18	B. Yakimanka St.	932
IDV_15	Yauzsky Boulevard	918
IDV_8	Petrovka St.	801
IDV_4	Pokrovka St. / Pokrovsky Boulevard	793

Table 5. Activity of bicyclists at the counting points on weekdays.

ID	Counting point	The number of recorded NMV users on weekdays
IDV_13	Valovaya St.	1465
IDV_15	Yauzsky Boulevard	1449
IDV_4	Pokrovka St. / Pokrovsky Boulevard	1085
IDV_18	B. Yakimanka St.	998
IDV_11	Volkhonka St. / Lenivka St.	933

For the analysis of bicycle traffic, it is important to consider the traffic intensity in the context of the type of bicycle infrastructure.

The collector street (counting points ID_2 and ID_5)

The points are on the same street. There are data gaps in the database at the point ID_5.

1. The share of bicyclists at the counting points of those moving along the sidewalks and roadways differs by no more than 2%, which corresponds to a statistical error (Table 6).

Table 6. Comparative analysis of preferences for bicyclists.

Counting point	Roadway	Sidewalks	Total
IDV_2	22.3%	77.7%	100%
IDV_5	19.7%	80.3%	100%

2. The share of bicyclists and users of scooters and other NMVs differs by 4%, which is due to a gap in the data on accounting for intensity in IDV_5 (Table 7).

Table 7. Comparative analysis of NMV users.

Counting point	Bicycles	Scooters etc.	Total
IDV_2	72%	28%	100%
IDV_5	76%	24%	100%

1. The main traffic flow of NMV users is directed from the centre (for IDV_2 - direction 2, for IDV_5 - direction 1) and is about 60% (Table 8).

Table 8. Direction of movement.

Counting point	Share of NMV users
IDV_2	100.0%
Section 1	66.9%
Section 2	33.1%
IDV_5	100.0%
Section 1	40.7%
Section 2	59.3%

Primary distributor road of class I (counting points ID_13 and IDV_16)

Points are located on the Garden Ring with 8 lane traffic.

1. The share of bicyclists at the counting points, moving along the sidewalk and roadway differs by no more than 1%, which corresponds to a statistical error (Table 9).

Table 9. Comparative analysis of NMV users.

Counting point	Roadway	Sidewalk
IDV_13	4.0%	96.0%
IDV_16	5.0%	95.0%

2. The share of bicyclists and users of scooters, and other NMVs differs in the considered points by 2%, which corresponds to the statistical error (Table 10).

Table 10. Comparative analysis of NMV users.

Counting point	Bicycles	Scooters and others	Total
IDV_13	77%	23%	100%
IDV_16	75%	25%	100%

3. The main traffic flow of NMV users is distributed almost evenly with a difference of 10% less on the inner side of the Ring (Table 11).

Table 11. Comparative analysis of NMV users.

Counting point	Share of NMV users
IDV_13	100.00%
1	54.2%
2	45.8%
IDV_16	100.00%
1	54.2%
2	45.8%

The analysis showed a similarity in the behaviour of bicyclists in the conditions of identical infrastructure, which allows us to assess the intensity of the base points in each category of infrastructure.

It is proposed to classify bicycle infrastructure into ten types, listed in Table 12. The classification is based on the type of design (bicycle lane, bicycle path, shared path, etc.), the method of organizing traffic (one-way or two-way) and the location on the road network (detached, combined with car traffic, etc.).

Table 12 presents the option of permanent target counting points for their inclusion in the number of points required for annual monitoring.

Table 12. Counting points for the formation of a system for monitoring the level of development of bicycle transport infrastructure.

Counting point	Type of infrastructure	Counting points
1	Bicycle lane combined with car traffic. Same-direction traffic lane for bicycles	Mytnaya St. 55.719788, 37.618066
2	One-way bicycle path	Olof Palme Street 55.719001, 37.511326
3	Combined bicycle walking path	Borovskoye highway 55.660350, 37.418102 Bolshaya Academicheskaya St. 55.819976, 37.525056 Vernadtskogo Prospect 55.681507, 37.515558
4	Detached bi-directional traffic bicycle lane	Beskudnikovsky Boulevard (green part) 55.868651, 37.557011 Guryanova St. 55.688480, 37.717188
5	Roadway Collector street	1-ya Brestskaya St. 55.771839, 37.590853 Krasnogo Mayaka St. 55.611771, 37.598299
6	Dedicated lane for public transport	Bolshaya Polyanka St. 55.736083, 37.619468
7	Shared path with combined traffic and oncoming bicycle lane, two way bicycle lane	Nikitskykh Vorot Square 55.757402, 37.597520
8	Shared path with combined oncoming lane	Bolshaya Ordynka St. 55.730911, 37.624083
9	Shared path with combined traffic, Same-direction traffic lane for bicycles, one-way lane for bicycles	Yauzsky Boulevard 55.750760, 37.643233
10	Primary distributor road of class I	Valovaya St. 55.730383, 37.630061 Zemlyanoy val St. 55.755351, 37.657446

CONCLUSIONS

When creating a new infrastructure, research should be carried out on the ways of moving bicyclists in the proposed zone for organizing new infrastructure, even if the movement of bicyclists is not intense. To ensure the coherence of the actions of the organizers to create a new infrastructure, public discussions or a survey of residents of the district should be conducted in order to identify their preferences. When planning a bicycle transport infrastructure, it is necessary to analyse alternative routes to ensure maximum safety conditions for all traffic participants.

Modernization of the bicycle transport infrastructure involves the improvement of existing sections for the movement of bicyclists. In this regard, traffic intensity is an important indicator for on-going changes which involve replacing the cover of bicycle paths, expanding or converting them to the bicycle path of another type, etc. To modernize the bicycle transport infrastructure, it is necessary to study the territory to assess the possibility of expanding the bicycle path or allocating it to a separate infrastructure with the separation of traffic of pedestrians, transport means and bicyclists.

Modernization of the urban bicycle transport infrastructure at the modern level of its development should be local in nature (within districts and regions) and contribute to ensuring the accessibility and safety of the movement of citizens to social facilities: schools, kindergartens, government agencies, and entertainment and recreation centres, other centres of attraction, including a transport hub. When upgrading the intensity of traffic of bicyclists and users of other NMVs, it should be performed in terms of gender and age of bicyclists, the availability of protective equipment, and identifying violations of the rules of the road when changing its location.

In order to organize the transit movement of bicyclists from their place of residence to the transfer hub or stops of another, more high-speed transport, it is necessary to be guided by the principle of minimizing the risks of a traffic accident involving bicyclists. This approach requires taking into account the traffic intensity of all participants: bicyclists, vehicles and pedestrians. Taking into account the age and gender characteristics of bicyclists in this case is not mandatory, however, their preferences when moving to the purpose of the trip are significant.

The basic principle for the development of bicycle infrastructure should be the principle of maximum safety for road users. In this regard, an intensity assessment should be made at the points where bicyclist accidents occur regularly. In this situation, it is mandatory not only to record the intensity of bicyclists' traffic, but also to inspect the existing infrastructure (availability of information for bicyclists, the quality of coverage of bicycle paths, assessments of visibility for all participants in the movement).

In order to monitor the level of development of the bicycle transport infrastructure and to identify the increase in the number of bicyclists through the cross section of the road, the main condition is the choice of permanent places for recording and the formation of a database of regular observations, similar to the database of Portland[3].

Counting points should include all types of bicycle infrastructure, which are listed in Table 12. They should be located in different areas of the city.

Intensity accounting should be carried out at selected points using one accounting method. The measurement period should be 1 week per month in the warm season and not include holidays and public events in the city. The main result of regular intensity accounting is the determination of the dynamics of growth in the number of bicyclists at the counting points.

[3] Portland Bureau of Transportation. (2018). Retrieved from https://docs.google.com/spreadsheets/d/1urP-ZA0Pd25_JZZ18hkGPlDEUQusBp49XmLzwpZ-2ag/edit#gid=0.

The accounting of intensity carried out within the framework of this study showed a high level of labour costs, both for processing video images of cameras, and a high level of labour costs with manual accounting of intensity. The decoding of the video images revealed that changing the shooting angle does not allow a portrait of a bicyclist moving in the city conditions to be made with a high degree of accuracy. The use of manual accounting at these points also limits the amount of information observed.

In the future, it is necessary to consider the possibility of installing CCTV cameras at a height that provides the possibility of recognizing bicyclists and users of other NMVs in the flow of pedestrians and cars.

Automation of processes for assessing the traffic intensity of NMV users is mandatory for decision-making on the development of bicycling infrastructure.

DISCLOSURE STATEMENT

The authors have no financial interest or benefit arising from the direct application of this research.

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