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Land use by transport infrastructure in Tashkent City

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Abstract. Achieving environmental sustainability of transport largely depends on the degree of use of urban land by transport infrastructure. The article studies the indicator "land use" in Tashkent to the target 2030. The following criteria were selected as assessment criteria: the area and degree of filling of public parking lots, the area of transport infrastructure enterprises, as well as the length of roads with two-sided landscaping. Evaluation of indicators was carried out using GIS, by processing satellite maps of Tashkent in the Quantum GIS program, as well as by monitoring online maps of the movement of automobile transport. It was revealed that the existing area of public parking is 33.4% of the required area, while the degree of use of existing parking is only 40-60%. Bilateral landscaping, have only 26.6% of roads. Trends in the development of the Tashkent transport system suggest mainly an increase in the number of private cars (an increase of 1.23 times by 2025), the pace of construction of parking lots and improvements in the road-street network are significantly behind (an increase in the area of parking lots by 1.06 times by 2025). In the current state of development, the stability of transport until 2030 according to the criterion of "land use" is not provided.

1. Introduction

The purpose of this article is to assess indicators of transport sustainability associated with the use of land resources in the conditions of Tashkent (capital of the Republic of Uzbekistan).

In recent years, measures have been taken in the Republic of Uzbekistan aimed at implementing ongoing reforms on sustainable development. The Republic of Uzbekistan adopted 17 national sustainable development goals in 2018. Currently, the main focus of sustainability researchers is on problems in the areas of water use [1, 2], land degradation [3], and greenhouse gas emissions [4]. There are practically no studies on the sustainability of transport systems, although they are one of the main sources of harmful effects in cities. The Decree of the Cabinet of Ministers "On measures to implement national goals and objectives in the field of sustainable development for the period up to 2030" includes the task of providing access to safe, affordable, and environmentally sustainable transport systems by 2030 [5]. First of all, the stability of transport systems should be ensured in large cities, such as the capital of Uzbekistan, Tashkent.

Sustainability of transport is assessed by a number of economic, social, and environmental indicators [6, 7, 8, 9]. Although Uzbekistan has not made a comprehensive assessment of sustainability indicators, there are quite a lot of regional studies (mainly related to Tashkent) devoted

to emissions from vehicles [10, 11], problems of noise exposure (research by the Research Institute of Sanitation, Hygiene and Occupational Diseases of the Ministry Health of the Republic of Uzbekistan), motor vehicle waste [12] and also traffic safety.

One of the biggest problems in the transport system of Tashkent is, in our opinion, the reduction of free space in the city. It has been characteristic of the increase of automobile load, as well as the increase of the territory with high-rise buildings for the city of Tashkent, as well as for many modern cities of the world, in recent years. This leads to an expansion of the road network, an increase in the area of parking lots and other transport infrastructure enterprises, and as a result, a decrease in the free space and green spaces in the city. This state of affairs reduces the ability to achieve sustainability.

Thus, the purpose of this study is to answer the question: does the use of land by transport in Tashkent meet the goals of sustainable development until 2030.

The transport infrastructure of the city of Tashkent is chosen as the object of study, and the indicators of the use of urban territory by transport are the subject of the study.

The use of the city's land space by transport and its infrastructures is one of the environmental indicators of sustainable transport [6]. The following indicators correspond to this goal: 1) area of land intended for vehicles per capita; 2) compact development; 3) preservation of high-quality habitat.

As one of the environmental indicators of sustainable transport, the share of roads with bilateral landscaping is indicated in [7].

Some indicators related to the use of urban areas allow us to determine the economic indicators of transport sustainability. These include the length of roads per capita and the degree of saturation of roads with motor vehicles [7].

Thus, the research objectives to achieve the purpose of the study (assessing the sustainability of transport in Tashkent in terms of land use) are to determine:
- The total area of transport enterprises;
- Area of public parking;
- The total length of roads and streets, as well as the length of roads with bilateral landscaping.

 Information on the magnitude of the above indicators in Tashkent is either completely absent or is fragmentary and controversial. The best way to determine the required indicators is to use GIS.

2. Methods
2.1 General information about the object of research

 The object of study is Tashkent. The total area is 334.8 km², the territory is divided into 11 administrative districts (Table 1). The total number of residents according to statistics for 2019 is 2554.9 thousand people.

Table 1. Administrative unit of the city of Tashkent

Name of the district	Area, ha	Population, thousand people
Almazar district	3378	364.9
Bektemir district	2138	33.6
Mirabad district	1672	139.4
Mirzo-Ulugbek district	3617	279.9
Sergeli district	4893	179.45
Uchtepa district	2820	272.5
Chilanzar district	3043	238.4
Shaykhantakhur district	2717	340.9
Yunusabad district	4106	336.9
Yakkasaray district	1400	122.9
Yashnabad district	3715	235.2

Tashkent city	33500	2554.9

The total length of Tashkent city roads according to Uzavtoyul JSC (Uzbek Highways) is 2.380 km (excluding intra-quarter streets and driveways).

The norms of greening cities depend on the presence of industrial enterprises in them. If the city has the status of a metropolis and the number of environmentally hazardous industrial production in it is limited, the area of green spaces should be 50-60% of the city [13]. Thus, for the city of Tashkent with an area of 334.8 km², 16.74 thousand hectares of green space is required. Currently, this indicator is considered equal to 11.7 thousand ha, i.e. 35% of the area of the city [14].

Recently, the construction of car parking in Tashkent, as never before, is becoming more and more relevant and does not stand still. According to statistics for 2015, there were more than 140 open and closed parking lots in the city with a total capacity of more than 27.400 cars [4]. Consequently, the provision of public parking for 2015 was only 6.9%.

In 2017, according to the General Directorate of Architecture and Construction of Tashkent, it was planned to build about 20 high-rise parking lots by demolishing private garages with a total area of 25.6 hectares and a capacity of 8470 cars. Partial demolition of garages was carried out; however, the construction of high-rise parks has not yet been fully implemented [15].

2.2. Research methods

The methods of this study are based on the assessment of transport sustainability indicators. Various authors propose different lists of stability indicators and their determination both by means of quantitative assessment [7, 8, 9, 16] and by means of calculation according to empirical formulas [17]. We have chosen the approach to the determination of some indicators of environmental sustainability of transport, proposed by the OECD in 1999 [18, 19]. Among these quantitative criteria for ensuring the environmental sustainability of transport in the target year 2030, in particular, the use of land is indicated: in comparison with the 1990 levels, it is necessary to reduce the share of land intended for transport [19].

As the main indicators for the assessment were adopted according to [7]: per capita road length; public parking space per 1000 vehicle; % of the road having plantation on both sides. The indicators [7] Vehicles per road length, Vehicles per 1000 population, Average speed of transport were evaluated as additional criteria for obtaining a more complete picture.

The recent assessment of territorial changes in environmental studies is usually done using GIS [20]. Therefore, to evaluate indicators such as the area of public parking lots and the length of roads with two-sided landscaping, we used the Quantum GIS program, which allows you to digitize, analyze, and create maps [9]. At the first stage, to create a database for this work, a map was created in the QGIS program with the coordinate system WGS 84 ID with the source EPSG: 4326. Using the Quick map service module, a Google Satellite map was selected based on Landsat 8 Copernicus images, and the border of the city of Tashkent, including all areas, was outlined. On the layers of each region, the road was digitized and their total length was calculated. After this calculation, a road with bilateral landscaping was digitized and the total length was also calculated. The length of the streets was determined in the attribute data table using the field calculator and the $ length function. Then, open parking lots were found and digitized throughout the area and their total area was calculated in the attribute data table on the field calculator by the $ area function. At the end of this work, a map layout was created, its legend was added, and a scale of 1: 23000 was chosen. The result of the work is a set of maps with real geographic coordinates, completely linked together.

An observational method was used to assess the extent of filling existing parking lots. The total number and location of parking lots (Figure 1) were previously determined using the maps of the public service 2gis.uz/tashkent. (https://2gis.uz/tashkent/). On these cards there are indications of the type of parking (public, corporate, closed, etc.), as well as the number of parking spaces (from 6 to 650). The total number of parking lots of various sizes is 4168.

To determine the sample size, 100 parking lots were preliminarily examined at different times of the day and the coefficient of their filling with cars was determined.

The dispersion was determined by the Dixon method [21]:

$$\sigma = W \cdot C_f \qquad (1)$$

where W is the range of variability, $W = X_{max} - X_{min}$; C_f is the Dixon conversion factor.

Figure 1. The location of public parking in Tashkent
(data from the site https://2gis.uz/tashkent/search/)

The results of preliminary studies are given in Table. 2.

Next, the sample size was determined by the formula

$$N = \frac{\sigma^2 \cdot t^2}{d_{abs}^2} \qquad (2)$$

Where N is the desired sample size; σ is the variance of the sign, the expected average deviation of the obtained results from the expected average value; t is the value of Student's criterion, taken $t = 2$ for a confidence probability of 0.954; d is the accuracy level for this factor (absolute measurement error). The absolute measurement error d was set $d = 0.03$ (5% of the average degree of filling parking lots).

The results of preliminary studies are presented in Table. 2.

Table 2. Results of preliminary studies of the degree of filling parking lots

The preliminary sample size, units	Arithmetic mean X	Variability range W	C_f	Dispersion σ^2	Standard deviation σ	Representation error M	Marginal sampling error $\varDelta$	The required sample size n, units
100	0.6	0.8	0.199	0.0253	0.1592	0.016	0.032	112.6

Thus, the sample size was 113 parking lots. To select specific objects, a preliminary ranking of parking lots by size was made (Figure 2).

As can be seen from the figure, the vast majority of parking has a capacity of 21 to 50 cars. It was from this array that 113 parking lots were selected using random numbers for daily observations for 1 month.

Information on transport infrastructure enterprises (car services, gas stations, etc.) was collected by analyzing available statistical information [22, 23].

Based on the analysis of available statistical materials, data were obtained on the total number and area of transport infrastructure enterprises in Tashkent (table 3).
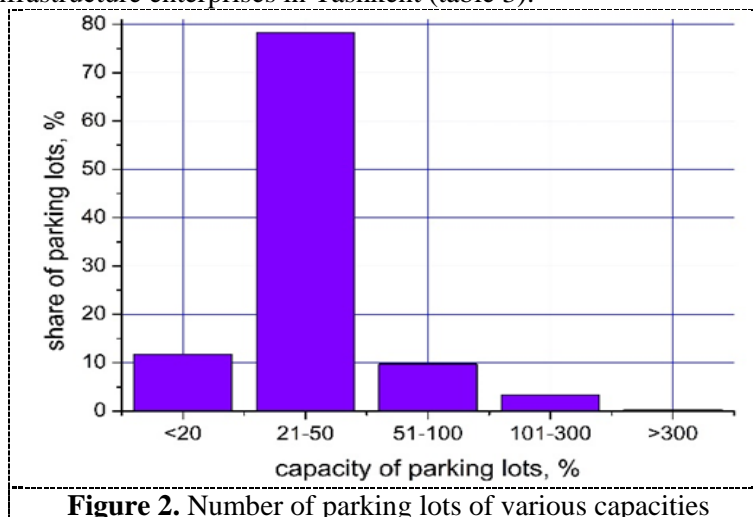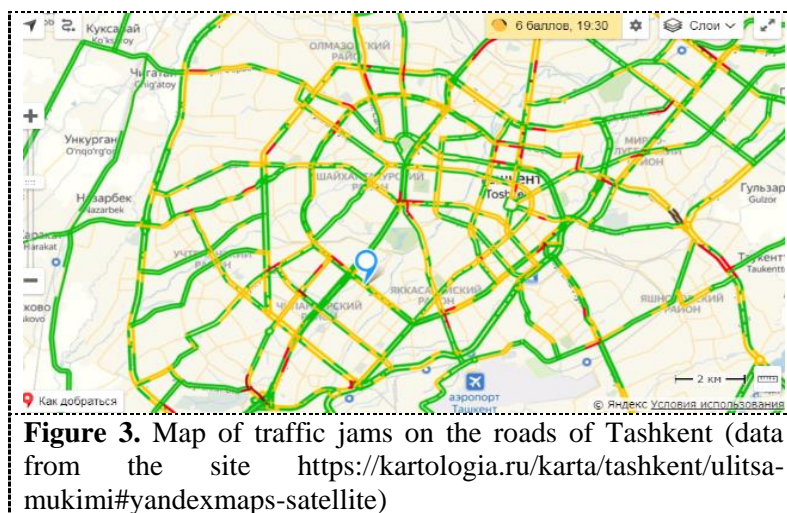

Figure 2. Number of parking lots of various capacities

Table 3. The territory occupied by transport infrastructure enterprises

Type of enterprise	Quantity, units	The average area of a 1 enterprise, m^2	Total area, m^2
Driving school	65	175	11375
Parts stores	224	75	16800
Petrol stations	120	1007	120840
Motor show	56	1500	84000
Car service	197	200	39400
Car wash	206	154	31724
Subtotal			304139

One of the important indicators of transport stability is the speed of traffic flows. Even though this indicator is classified as economic (Mumbai), the speed of transport and the presence of traffic jams have a direct impact on environmental pollution. Since simultaneous and regular monitoring of traffic in the field is not possible, Yandex open access service was used to determine this indicator (https://yandex.uz/maps/10335/tashkent/?l=trf%2Ctrfe&ll=69.279565%2C41.311151&z=12).   Map data is updated in real-time, based on GPS data of moving vehicles. They provide information on the state of the road situation and the average speed of traffic flows. Information on traffic jams is presented on average over the territory of the city in points on a scale from 1 to 10. An example of a map of the occurrence of traffic jams is shown in Figure 3.
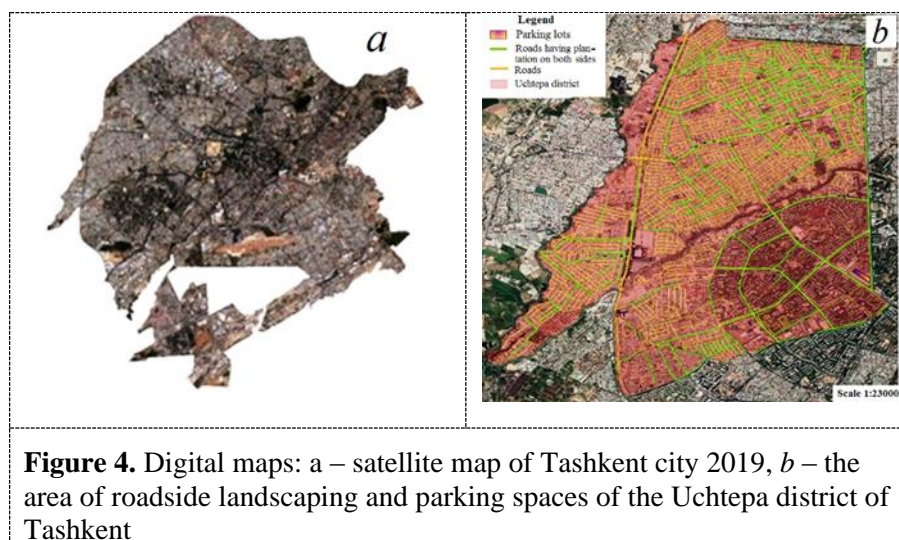
To collect data on the speed of traffic flows, we regularly (every hour daily from 7^{00} to 23^{00}) read information from the indicated on-line cards for 5 months (September - January).

Figure 3. Map of traffic jams on the roads of Tashkent (data from the site https://kartologia.ru/karta/tashkent/ulitsa-mukimi#yandexmaps-satellite)

3. Results and Discussion

Based on the results of work in the Quantum GIS program, a digital map of Tashkent was obtained (Figure 4a).

Map processing for determining the total area of open public parking lots and the length of roads with bilateral landscaping was carried out for each administrative district of Tashkent separately. The results for Uchtepa district are presented as an example (Figure 4b).

Figure 4. Digital maps: a – satellite map of Tashkent city 2019, *b* – the area of roadside landscaping and parking spaces of the Uchtepa district of Tashkent

On the layer of the Uchtepa district, the road was digitized along all the streets and the total length of all streets was calculated at 350 017 meters (all streets were taken into account, except for driveways between houses). After this calculation, a road with two-sided greening was digitized and also calculated, the length of these streets is 96.334 meters. Then, open parking lots were found and digitized throughout the area and their total area was calculated, which amounted to 0.175641 km^2. At the end of this work, a map layout was created, its legend was added, and a scale of 1:23000 was chosen. Similar work was carried out in all areas of Tashkent. The results are presented in Table. 4.

Table 4. The length of roads and the area of open parking lots in the districts of Tashkent

The name of the district	Area, ha	The parking area, ha	The length of the streets, m	Length of streets with two-way landscaping, m (share of the total length, %)	
Almazar district	3378	20.1355	420 305	117 397	(27.5 %)
Bektemir district	2138	12.7165	271 358	68 995	(26 %)
Mirabad district	1672	10.5139	207 530	54 787	(26.4 %)
Mirzo-Ulugbek district	3617	20.5281	448 951	122 561	(27.3 %)
Sergeli district	4893	30.7755	609 351	161 478	(26.5 %)
Uchtepa district	2820	17.5641	350 017	96 334	(27.5 %)
Chilanzar district	3043	19.5105	380804	98 247	(25.8%)
Shaykhantakhur district	2717	15.9223	354243	93 166	(26.3 %)
Yunusabad district	4106	26.1738	524 864	133 315	(25.4 %)
Yakkasaray district	1400	8.4201	158768	39 692	(25 %)
Yashnabad district	3715	24.2385	431 857	120 920	(28 %)
Tashkent city	33500	206.4983	4 15848	1 106 892	(26.6 %)

The table shows that the total area of open public parking is 206.5 hectares (2.065 km^2), while the area required accommodating 494.403 cars available in Tashkent is 6.2 km^2. The occupancy rate of parking lots was investigated by daily monitoring of 113 parking lots at different times of the day (morning, afternoon, evening) for 1 month. According to the results of observations, it was found that the degree of filling public parking reaches 100 % only in the daytime, not exceeding 20-30 % in the morning and evening hours. At the same time, the yards of residential buildings and roadsides of small streets are filled with cars, making traffic difficult and creating danger for pedestrians.

The data obtained allowed us to calculate the following indicators of stability.

The indicator is " Per capita road length". The calculation gives the value of this indicator of 1.627 m per 1 person, which is 2.05 times less than the national average [24] according to the table. 4, taking into account statistical information. According to [7], the low value of this indicator indicates that the availability of roads in Tashkent is insufficient, and traffic is difficult. It should be noted that in Tokyo [25] the length of roads per capita is only 0.657 m, in Moscow 0.477 m per 1 person. Therefore, according to this indicator, the transport system of Tashkent is in a relatively favorable position. The same can be said of the number of cars per unit of road length: in Tashkent, 118.9 cars per 1 km of the road, in Moscow 1269.8 aut/km. Despite this, problems with the movement of vehicles are explained by insufficient quality of traffic control.

The indicator "Public parking space per 1000 vehicle". The calculation of the results gives a value of 4170 m^2 per 1000 cars. Given the standard size of a parking space of 12.5 m^2 per 1 car, the area of public parking should be 12.500 m^2, i.e. the real value of available parking spaces is 33.36 %. Such a problem exists in many countries with rapidly developing automotive industries. However, the construction of additional parking lots is too far behind the planned growth in motorization. By 2025, according to the statements of the Automotive Industry of the Republic of Uzbekistan, it is planned to increase the level of motorization to 237 cars per 1000 inhabitants, which exceeds the current level of motorization in Tashkent (193.5 cars per 1000 inhabitants) by 1.23 times. It can be assumed that the availability of parking spaces will decrease. The level of motorization of the population itself is very high, and according to [7] it indicates the degradation of the public transport system and the lack of stability.

The construction of 20 high-rise parking lots with a capacity of 80 to 532 places planned by the city authorities until 2021 has not yet been completed. Even if such parking lots are built by 2030, this will

give a maximum of 10.000 places, that is, it will not help to solve the problem. Compared to the existing parking area, such construction will give an increase of only 1.06 times. In [26], it was planned to arrange paid parking lots along city roads starting in 2020. However, the implementation of this decision will require considerable time, since the roadside space in the city is occupied by various buildings and structures. Besides, the planned arrangement of open parking will lead to an increase in the total area of territories occupied by road transport, which does not meet the goals of sustainable development [6, 19]. It should also be noted that an increase in the number of open parking will shift the balance of the use of roadside territories, which should be equally divided into residential, commercial/industrial, and public [27]. Therefore, according to this indicator, at the existing pace of development, the stability of the transport system will not be achieved by 2030.

Observational data show that even with obvious insufficient parking lots, they often remain unfilled. The largest use of the parking space (up to 100%) has large parking lots near bazaars. Small parking lots in housing estates are usually 45-60 % full; car owners prefer to park their cars in the courtyards of residential buildings and driveways. This is due to the lack of legislative restrictions on such parking.

The indicator of the share of roads with bilateral landscaping according to the results obtained (Table 4) is 26.6%. Since the best value of this indicator is 100%, it is obvious that the state of this indicator also indicates a lack of stability.

To evaluate the indicator "average speed of traffic", information was tracked during September–January on the GIS maps of the Yandex service, which allowed us to estimate the change in traffic jams in the period from 6^{00} to 23^{00}. In fig. 5 presented graphs of average values (data averaged for all days of the week, including weekends) and maximum values (average data on days of maximum movement - from Tuesday to Friday).

You can see that the time of the most difficult movement (traffic jams up to 7 points on a 10-point scale) falls in the evening time (from 16^{00} to 20^{00}). Traffic jams occur mainly at the intersection of major roads with the Tashkent Ring Road. The length of traffic jams is from 30 to 800 m, with a speed of movement in them from 1 to 7 km/h.
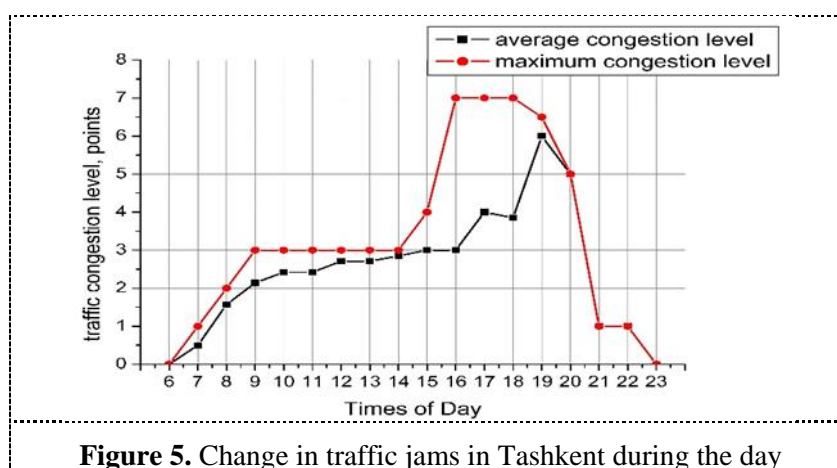

Figure 5. Change in traffic jams in Tashkent during the day

Monitoring the speed on online maps shows that the speed of the traffic flow during peak load does not exceed 15-25 km/h, buses 16.9 km/h (at an average speed of 21 km/h [28]).

The average speed of transport indicator in Tashkent is 43.3 km/h, and at peak times 21.1 km/h, for buses 16.9 km/h. This indicator can be considered quite high. For example, in Tokyo, according to [29], the average speed is 36.5 km/h. However, the development trends of transport in Tashkent lead to a decrease in the average speed and traffic jams, which in turn leads to an increase in air pollution.

4. Conclusions

The results of the studies showed that the transport stability of the transport of the city of Tashkent cannot be achieved by 2030 in terms of "land use". Transport sector development trends are mainly aimed at increasing the level of motorization. Moreover, even the existing car park is not provided with parking spaces. Besides, the capacity of urban roads is also not able to fully provide free movement. Consequently, an increase in the level of motorization will lead to even greater problems, since the pace of development of the road network and public parking lots is noticeably behind the growth of the Tashkent fleet. The areas used for transport are steadily increasing, although to ensure sustainability they should be reduced compared with the 1990 level [6]. Insufficient landscaping of roads and streets increases the level of pollutants and noise pollution in the roadside zone.

To improve the transport stability indicators discussed in this article, it is necessary:

1. Increase the degree of the greening of roads and streets, in particular, due to vertical gardening. This practice is applied in the USA, India, and other countries and allows to somewhat compensate for transport emissions and noise.
2. Promote the use of public transport and bicycles and provide appropriate infrastructure. This practice has been successfully implemented, for example, in Germany, the Netherlands, and Colombia. In particular, the use of cycling in Bogota has reduced CO_2 emissions by 86.431 t over 4 years [30]. The advantages of public transport over private in Tokyo can reduce the number of congestions [31, 32].
3. Rational use of space in existing parking lots. From [33] it is known that with proper placement of cars, you can increase the number of parking spaces by 10 -12%.
4. Instead of ground parking, ensure the construction of affordable multi-level parking lots with a total capacity of at least 400 thousand cars. At the same time, a ban on parking cars in yards and driveways of residential buildings, as well as a ban on the purchase of cars that are not provided with a parking space, should be introduced. Such prohibitions, as well as the practice of building open and closed multi-level parking lots are widely used in Japan [25, 32, 34], allowing you to regulate both traffic and the use of urban areas.
5. Increase the number of road junctions and detours at the intersections of city roads with the Tashkent Ring Road to reduce the number of congestions.

Proposals No. 1-3 can be implemented in the next 3-5 years and will improve environmental indicators of transport sustainability. The implementation of proposals Nos. 3 and 4 requires at least 10-15 years, so if they are implemented, the stability of transport in terms of "land use" and "average speed of transport" can be achieved by 2035. Considering that the rapid development of the transport system is also characteristic of other CIS countries, such as Russia and Kazakhstan, the conclusions made can obviously be applied to them.

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