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Оценка уровня развития транспортного комплекса мегаполисов

Цель исследования. *Статья посвящена вопросам оценки уровня развития транспортного комплекса крупных городов. Несмотря на широкое разнообразие исследований по этой проблеме, в настоящее время отсутствует универсальный подход к оценке уровня развития транспортного комплекса на уровне мегаполисов. В представленном исследовании поставлена цель – разработать инструмент, позволяющий комплексно оценить различные аспекты развития городского транспорта, значимые для всех категорий его пользователей, а также провести сравнительный анализ ведущих мегаполисов мира по уровню транспортного развития на основе предложенной методики.*
Материалы и методы. *В рамках исследования применяется подход, связанный с построением интегральных индексов, а также рейтингованием городов на основе полученных значений. Материалы и расчеты базируются на использовании данных, полученных из авторитетных открытых источников, а также информационных систем государственного и муниципального управления.*
Результаты. *С учетом результатов анализа мировой практики авторами предложен Индекс развития транспортного комплекса, предназначенный для оценки уровня транспортного развития мегаполисов, выявления слабых и сильных сторон их транспортного комплекса, определения оптимальных путей его дальнейшего совершенствования и разработки на этой основе рекомендаций в области транспортной политики. Индекс состоит из четырех субиндексов, отражающих основные направления развития транспортного сектора: качество транспортного обслуживания населения, доступность транспортных услуг для населения, безопасность дорожного движения и воздействие транспорта на окружающую среду, а также эффективность грузовой логистики. Индекс охватывает все наиболее значимые направления транспортного развития города и характеризует развитие транспортного комплекса с позиции разных категорий пользователей его услуг. Индекс рассчитан для группы сопоставимых мегаполисов в следующем составе: Гонконг, Лондон, Мехико, Москва, Нью-Йорк, Санкт-Петербург, Сингапур, Стамбул, Токио и Шанхай. В результате исследования сформирован рейтинг транспортного развития городов за 2010, 2015, 2016 и 2017 годы. Результаты исследования показали, что в рассматриваемый период наиболее развитыми транспортными системами обладали Токио и Лондон. Наилучшую динамику изменения Индекса за последние семь лет продемонстрировали Москва, Санкт-Петербург и Шанхай.*
Заключение. *Предложенная методика исследования позволяет как оценивать степень результативности отдельных регулирующих мер, известных в практике других городов, так и моделировать их влияние на транспортный комплекс города. В заключение приводятся рекомендации по дальнейшему развитию транспортных комплексов городов.*

Ключевые слова: *интегральные индексы; рейтинги городов; развитие транспортного комплекса; развитие мегаполисов; городской транспорт; личный транспорт*

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Assessment of the level of metropolitan cities transport system development

Purpose of the study. *The study focuses on issues of the level assessment of transport system development of large cities. Despite the wide variety of studies on this issue, there is currently no universal approach to assessing the level of development of the transport system at megalopolises. The present study aims to create a tool for a comprehensive assessment of various aspects of urban transport development that are important for all categories of transport users, and to provide a comparative analysis of the world's leading megacities in terms of transport development based on the proposed methodology.*
Materials and methods. *In the study, the authors apply an approach related to the construction of integral indexes and ratings of cities based on the values of these indexes. In the calculations of the index, the authors use statistical data from authoritative open sources and information systems of national and municipal government.*
Results. *Based on the results of the world practice analysis, the authors propose the Urban Transport Development Index developed in order to compare the level of transport system development in various cities. The Index provides an opportunity to identify the weaknesses and strengths of cities, to find reserves for the further improvement and development of recommendations in the field of transport policy on this basis. The Index consists of four sub-indexes: the availability of transport services for the urban population, the quality of transport services, road traffic security and the ecological impact of transport, and freight logistics performance. The Index reflects the main aspects of urban transport development and shows the views of different categories of population on the level of transport services. The paper examines the level of transport system development for 2010, 2015, 2016 and 2017 of a group of comparable cities, which includes Hong Kong, London, Mexico, Moscow, New York, St. Petersburg, Singapore, Istanbul, Tokyo and Shanghai. The results showed that Tokyo and London have occupied the leading positions during the period under review. For the seven years Moscow, St. Petersburg and Shanghai have showed the best dynamics of the Index.*
Conclusion. *The proposed method allows both to evaluate the effectiveness of individual regulatory measures known in the practice of other cities, and to simulate their impact on the transport system of the city. The paper concludes with recommendations for further development of cities' transport systems.*

Keywords: *integral indexes, city ratings, transport system development, urban development, public transport, private transport*

Introduction

Transportation is one of the key sectors of the modern urban economy. The role of transport system is emphasized by its significant contribution to the formation of macroeconomic indicators of the relevant region, country and world as a whole (its share in world GDP is about 5 % [1]), as well as its essential influence on other sectors of the economy and the social sphere. The high socio-economic importance of transport determines the need for an adequate regulation of this sector and hence the need to create an evaluation and monitoring system in order to assess the effectiveness of the regulation.

To date, the world practice has gained a rich experience in development of the indexes characterizing the level of countries and cities transport development from different positions. Among the most well-known approaches to assessing the transport development are the Transportation Services Index of the New York State University, George Washington University and the United States Bureau of Transportation Statistics, the Logistics Performance Index of the World Bank and the Index of Inland Freight Transport Volume developed by the Eurostat. The analysis of the world practice shows that, despite the wide variety of studies on this issue, there is no universal approach to assessing the level of urban transport development. Some of the existing indexes evaluate transport development by a few individual, most representative indicators. Other indexes evaluate the separate aspects of the urban transport development more profoundly, without ensuring the completeness of their coverage. Thus, there is a lack of index that comprehensively reflects the major aspects of urban transport development.

This article presents the results of the development of the Urban Transport Development Index, calculated for the ten leading megapolices of the world for 2010, 2015, 2016 and 2017. The study revealed the strengths and weaknesses of the transport systems of the cities. The final section of the article provides recommendations for the further development of the cities based on the best world practices.

1. Urban transport development: the world practice of statistical analysis

Nowadays there is a wide variety of methods to identify the rate of transport development in different countries and regions. The most popular approach is related to the construction of integral indexes and rankings based on them. This sort of indexes is developed by official statistical bodies, international and national research centers and independent analytical companies. A number of important organizations generate global rankings based on the evaluation of the level of transport development, which convincingly demonstrate the competitiveness of the country or region in the world economy.

The well-known indexes directly or indirectly characterizing the level of transport development may be divided into two groups: *specialized indexes*, which reflect the transport sector's level of development in individual, specific aspects, such as the quality of transport services, the volume of freightage, traffic density, etc., and *general indexes*, which provide an evaluation of the transport sector as one of the elements of the economy as a whole.

The *Transportation Services Index* is one of the first *specialized transport indexes* developed in 2002 by the joint effort of researchers from the New York State University in the city of Albany, George Washington University and the United States Bureau of Transportation Statistics [2]. This index demonstrates the volume and dynamics of transport services provided to the population. It consists of two subindexes: the freight index and the passenger one. The first sub-index measures the freightage performed by freight trucks, rail, internal waterways and pipelines and by air, excluding sea-going vessels and courier and postal services. The second subindex reflects passenger turnover performed by urban public transport, intercity rail and air services, and does not include intercity bus services, excursions, taxis, as well as the use of bicycles and other non-motor means of transportation.

A considerable amount of specialized indexes is used to evaluate the freight logistics performance. Here we should mention the *Index of Inland Freight Transport Volume Relative to GDP*, calculated on the annual basis by the Eurostat, the European Union Statistical Department, both for the European Union as a whole, and separately for each of its member states [3]. The Index is calculated as a share of freightage in the structure of the GDP (in 2005 prices) and includes internal transportation by the three means — automobile, railway and water. To calculate the exact figure, the authors use the territorial principle, assuming that all freightage performed on the territory of the country under consideration is taken into account, regardless of what country it actually belongs to. In case of motor transport the property of the freight is defined according to the place of registration of the transport means. The result of certain errors is the fact that some of the European Union members do not perform a statistical stock-taking of freightage involving transportation means of less than 3.5 tons of freight-carrying capacity. Another problem is concerned with stock-taking of international freightage, especially transported by air and water.

The level of freight transport development is also being evaluated by authoritative international bodies. Once in two years, the World Bank calculates the *Logistics Performance Index* for

167 countries of the world, which consists of six main indicators: efficiency of customs operations, quality of trade and transport infrastructure, simplicity in organizing deliveries with competitive prices, the level of logistics services, possibility to trace one's cargo and the timely delivery of cargo to the recipient [4]. Logistics experts' opinions collected from all over the world constitute the information basis for this index.

Another example of evaluation of the level of transport development is the provision of *Transport Services Index*, developed in France [5]. This indicator reflects the changes in the costs of services of three types of transportation — freight, passenger and supplementary services in the transport sphere. The specific feature of calculations here is the fact that it embraces practically all transport services, with the exception of space sector and the tourist agencies' activities.

The Shipping Index is being actively used in Australia and is calculated by a major logistics firm The Depth Logistics [6]. This indicator takes into account the number of units of certain types of equipment (bulldozers, excavators, graders, cranes, etc.) loaded on board of the ship, and their costs. Such an approach allows to analyze indirectly the state and trends in the development of machine-building, mining, and construction sectors of the national economy.

A separate group of transport indexes and rankings concerns the evaluation of road congestion level. Another widely known indicator is the TomTom company's index, which develops navigation systems for cars. Using GPS navigators' data *TomTom Traffic Index* measures congestion on the road networks of 390 cities in 48 countries [7]. It gives drivers detailed information about the impact of road congestion on their city's travel times. The largest cities' congestion ranking is generated on the basis of these data.

Indexes of motor transport development are calculated by the INRIX company, one of the world's leading suppliers of information services for car drivers [8]. The INRIX company annually develops the ranking of world cities with the most intensive road traffic. The calculation of the *INRIX Congestion Index* is based on the principle of comparison of the overall time needed to cover a certain part of the route in rush hours with a free flow situation.

State bodies also participate in the motorways' traffic density evaluation. In particular, the State Statistical Service of the Netherlands produces a monthly *Traffic Density Index*, based on the analysis of the traffic flow at the country's main roads on workdays and weekends [9].

The Castrol Company, one of the major producers of car oils and lubricants, has also demonstrated an original approach to the analysis of motorways' traffic. Their *Stop-start Index* is based on the calculation of the number of stops made by a vehicle with the following starts: the number of stop-starts, calculated on average per 1 km of the road within city limits is multiplied by an average car run during one year [10]. The result enables to evaluate the level of congestion. The rating, created by the company, embraces on the whole 78 largest cities of the world.

A typical example of *general indexes* demonstrating the level of urban transport development in the context of the entire economic system is *the Global Competitiveness Index*, developed by the World Economic Forum experts [11]. It aims to produce an estimation of the ability of the country and its institutions to ensure stable rate of mid-term economic growth. The index is based on 12 integral indicators, one of which demonstrates the development of infrastructure (including the transport one). The transport indicator evaluates the quality of motorways, railways, sea ports, air transport infrastructure and passenger turnover of airlines.

A similar indicator *the Global City Competitiveness Index* is developed by the British Research Centre, The Economist Intelligence Unit, for the largest cities of the world [12]. This research was initiated in 2012 by the Citigroup financial company in the framework of the project "Points of Growth". The main goal of this research was to find a way for modern cities to attract investments and spread their economic, political and cultural impact. According to this approach the cities are evaluated by 31 criteria of socio-economic and political nature that are grouped into 8 integral indicators. The indicator of physical capital takes into account the quality of public transport, motorways, sea-ports, regional and international means of transportation.

In Japan, *the Index of Industrial Production* is being published monthly [13]. This index is an important indicator of the economic situation in the country and a powerful instrument in monitoring production, unloading and formation of output stock for the needs of national industry. The index evaluates such urban transport development indicator as a freight turnover of the industrial sector.

The Index of Services, calculated in Britain, evaluates the contribution of the services sector to the Gross Added Value on a monthly basis [14]. The methods of its calculation envisages taking into account four sectors of the national economy, that is, trade and hotel and restaurant business; transport, storage and communication; business services and finance; and state services, as well as other forms of activities, connected with the production of services. Among the indicators used in the index calculation there are the volumes of freight transported to the United Kingdome by different means of transportation.

The London Stock Exchange, called The Baltic Exchange Ltd.,

counts its own daily *Baltic Dry Index* [15]. This indicator reflects the average cost of the raw materials transported by bulk carriers and is calculated on the basis of contracts, signed during the day. This index is very sensitive to the dynamics of the volume of shipping operations, therefore, it can be considered as an indicator of global economic activity.

The analysis of the world practice of assessing the level of transport shows that, despite the wide variety of studies on this problem, there is a lack of universal approach to assessing the level of urban transport development. Well-known general indices evaluate transport development by individual, most representative indicators as one of the aspects of the economic development as a whole. Specialized indexes evaluate the separate directions of the urban transport development more profoundly, without ensuring the completeness of their coverage. In this regard, it seems relevant to create an index that comprehensively reflects the various aspects of urban transport development, important for all categories of transport users.

2. The Concept of the Urban Transport Development Index

The Urban Transport Development Index has been developed in order to compare the levels of transport complex development in various cities, as well as to define its weak and strong points, to find reserves for the further improvement and provide some recommendations in the field of transport policy on this basis.

The Index reflects the main aspects of urban transport development and shows the views of different categories of population on the level of transport services. The aspects were systematized during the analysis of plans, programs and strategies for the transport development of the leading cities in the world. The structure of the index and the list of indicators included in its composition also is based on the results of the analysis of empirical studies aimed at identifying the factors of choice of public and cycling transport or a private car [16; 17; 18; 19; 20; 21; 22]. Such an approach is aimed to provide a comprehensive and maximally objective evaluation of the level of cities' transport systems' development.

The Index consists of four subindexes reflecting the main trends in urban transport development, which are: availability of transport services for the urban population, quality of transport services, road traffic security and the ecological impact of motor transport, and freight logistics performance. The interests of different layers of the population were taken into account by the use of subindexes measuring the transport services' quality and availability. These data are calculated, on the one hand, in relation to car-owners, and on the other hand, in relation to people using public transport, pedestrians, or cyclists. The data on transport services in the business field is presented by a subindex of the freight transport efficiency.

The indicators of a city Index and subindexes range from 0 to 10 points, where 10 points signify the highest level of transport development (the city leads in the respective group according to all analyzed indicators), while "0 points" is the lowest indicator (the city falls behind all the other cities under review).

The assignment of points the cities is maid according to the following formulas:

1) when the indicator has a positive effect:

$$2)\ y_j = \frac{x_j - \min(x_i)}{\max(x_i) - \min(x_i)} \times 10,$$

3) when the indicator affects negatively:

$$y_j = \frac{\max(x_i) - x_j}{\max(x_i) - \min(x_i)} \times 10.$$

Where,

y_j = the number of assigned points for the city j,

x_j = the value of the indicator for the city j,

$\min(x_i)$ = the minimum value of the indicator x among all the cities under consideration,

$\max(x_i)$ = the minimum value of the indicator x among all the cities under consideration.

Within the framework of the research, the data of transport development indicators have been formed, which include over 200 absolute and relative indicators. The data available in statistical original sources were analyzed on the basis of a system of quality criteria; the main requirements were the availability of appropriate data for the required time period, and the feasibility of calculation methods. A wide range of analytical methods was used, such as modeling, the use of alternative indicators, and data verification on the basis of various original sources, etc.

The calculation of the Index was made for a group of comparable cities, which includes Hong Kong, London, Mexico, Moscow, New York, St. Petersburg, Singapore, Istanbul, Tokyo and Shanghai.

Proceeding from the results of the initial statistical database analysis, a set of 69 indicators was included in the Index, which give information for the period from 2010 to 2017. Other data, not included in the Index directly, were used as the alternative indicators of the trends under review. They were used to define the degree of comparability of the available data and, in case of their absence, for substitution. The initial sources of data for the calculation of an Index are the information systems of the national statistical bodies, municipal government bodies (including transport complex department) and materials of the leading independent analytical centers.

3. The comparison of the leading cities of the world in terms of transport development

In the course of the research the ranking has been created according to the level of transport system

Table 1.

The values of the Urban Transport Development Index

City	2010 year		2015 year		2016 year		2017 year	
	Points	Rank	Points	Rank	Points	Rank	Points	Rank
Tokyo	7.1	1	7.0	1	7.1	1	7.1	1
London	6.7	2	6.9	2	7.0	2	6.8	2-3
Moscow	4.5	8	6.5	4	6.7	3	6.8	2-3
New York	6.0	3	6.5	3	6.6	4	6.5	4
Singapore	6.0	4	6.1	5	6.2	5	6.3	5
St. Petersburg	4.0	9	5.1	7	5.4	6	5.3	6
Hong Kong	5.2	5	5.1	6	5.3	7	5.3	7
Shanghai	4.7	6	5.0	8	5.1	8	5.2	8
Istanbul	4.6	7	4.5	9	4.7	9	4.7	9
Mexico	3.1	10	3.0	10	3.0	10	3.2	10

Source: authors' calculations.

development for 2010, 2015, 2016 and 2017 (see Table 1).

London and Tokyo have occupied the leading positions in the ranking during the period. In 2010 and 2015 the third place in the ranking belonged to New York, in 2016 Moscow outstripped New York and in 2017 it shared 2nd position with London. In 2010–2017 there was a rapid growth of the Index for some megapolices in comparison with other cities under consideration, which ensured an increase in position of Moscow (from 8th place in 2010 to 2nd-3rd place in 2017) and St. Petersburg (from 9th to 6th). Nevertheless, over the past seven years, the positive dynamics of the Index has been noted for all the analyzed cities. A significant increase in the Index was achieved in Moscow (by 2.35 points), St. Petersburg (by 1.37 points), Shanghai (by 0.53 points), New York (by 0.44 points) and Singapore (0.39 points).

3.1. The quality of transport services

Transport services' quality subindex summarizes the factors which define the average time of the trip by various transport means, the degree of comfort provided by different means of urban transport, availability of innovative services for the users of transport services, quality of transport infrastructure, availability of convenient payment systems, etc. The leaders in terms of the transport services' quality in 2017 are New York, Tokyo and Singapore (see Fig. 1). A significant increase in the subindex for New York in recent years resulted in the primacy of the city in the field of quality of transport services. From 2010 to 2017 Moscow significantly raised its position from 7th to 4th place in the ranking of the quality of transport services.

3.2. The availability of transport services for the population

The index of transport services' availability for different groups of urban population, namely, individual car owners and users of public transport, reflects such aspects as the availability of various urban transport means (including the new ones, such as car-sharing, cycles rental, etc.); the fleets of different transport means, volume of passenger shipping; availability of different types of city transport routes, etc. The top three leaders in terms of accessibility of transport for all population groups in 2017 are London, Tokyo and New York, with a slight lag behind New York, Moscow is in fourth place (see Fig. 2). For the past five years Moscow has climbed 1 position in the ranking. This increase in the index characterizing the availability of transport services is due to the relatively high level of provision of the population with the main types of transport, the development of the route system, the creation of new routes and types of transport — the Moscow central ring, car-sharing system, bicycle rental, etc.

3.3. Road safety and ecological impact

Road safety and ecological impact subindex reflects such factors of transport complex devel-

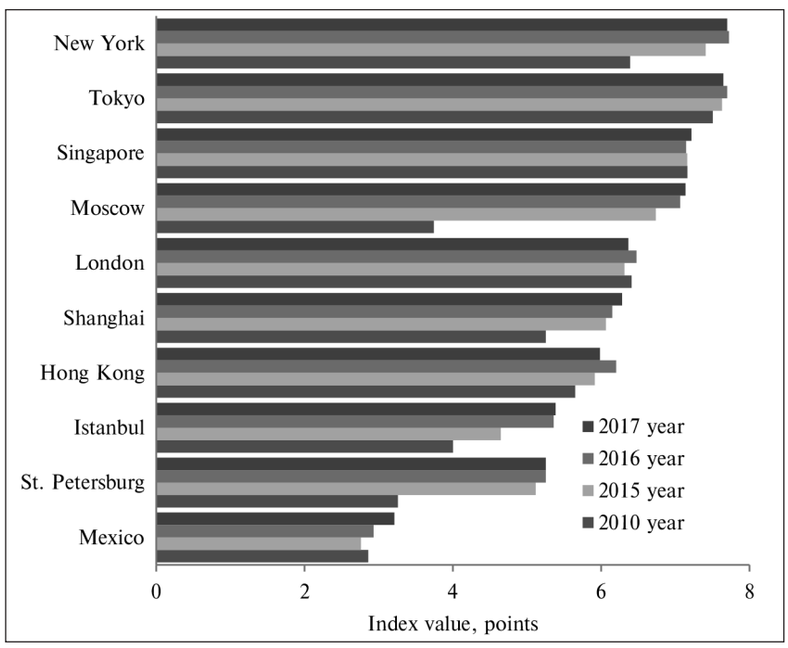

Fig. 1. The index of the transport services' quality

Source: authors' calculations

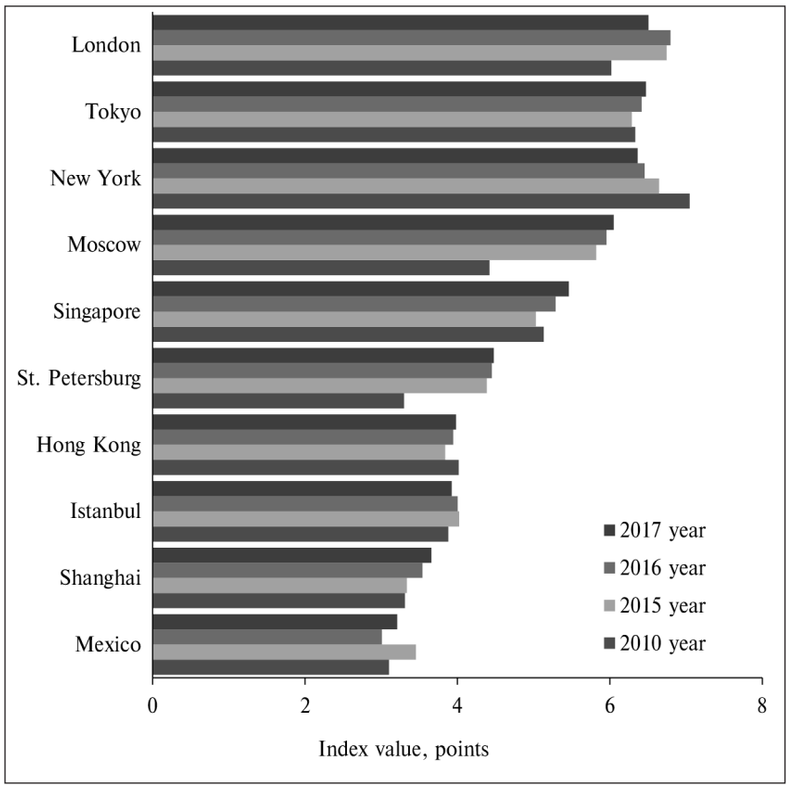

Fig. 2. The index of transport services' availability for the population

Source: authors' calculations.

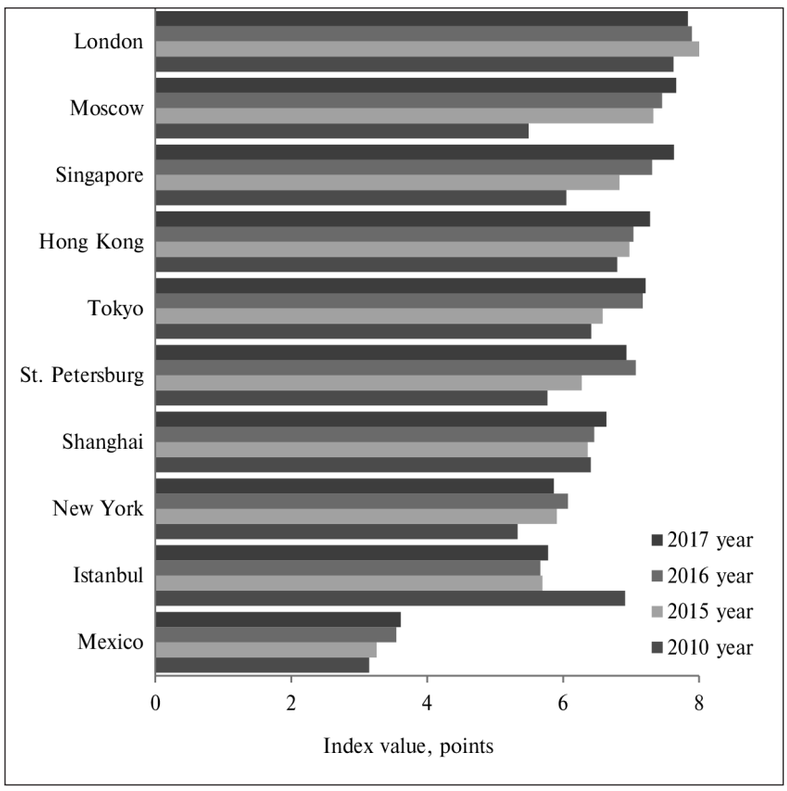

Fig. 3. The index of road safety and environmental impact

Source: authors' calculations.

opment as the rate of road accidents and their severity; the level of emissions into the atmosphere; the availability and strictness of ecological norms for different transport means; the availability and level of the use of ecologically friendly transport means.

During 2010–2017 the 1st place in terms of safety and environmental friendliness of the transport system belonged to London (see Fig. 3). Significant changes were noted in Moscow — the city has climbed 6 positions up in the rating, taking the 2nd place since 2015. The factors of such changes are a high level of provision with environmentally friendly modes of transport, a positive trend in indicators related to road traffic accidents. Over the past seven years, the rates of accidents and deaths in road accidents in Moscow have declined by more than a third.

3.4. Freight logistics performance

The city transport system performance from the point of view of the users of freight transport services is evaluated in the framework of the freight logistics performance index according to the indicators reflecting the level of freight transport development, availability of the infrastructure necessary for it, the level of toughness of restrictions regulating the transport flow within the city, etc. In 2010–2017 London, Tokyo and Moscow occupy the top positions in the freight logistics performance ranking, while having a significant lead over the other cities being analyzed (see Fig. 4).

Conclusion and recommendations

The proposed Index is a tool that provides comprehensive assessment of the level of transport development in cities, taking into account the interests of all the main categories of transport users in four areas: the quality of transport services, the availability of transport services for the pop-

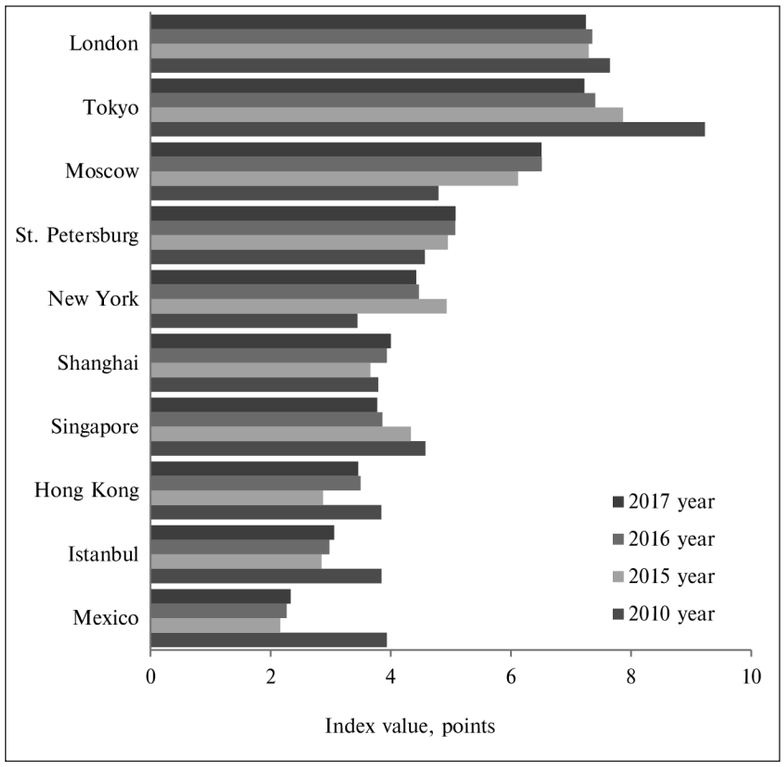

Fig. 4. The index of freight logistics performance

Source: authors' calculations

ulation, road safety and the environmental impact of transport, as well as the freight logistics performance.

The Index calculation results for 2010–2017 indicate that the leaders in urban transport development are such cities as Tokyo, London, Moscow and New York. It should be noted that for this period in most of the cities under consideration, the Index value continued to grow, which indicates a positive dynamic in the transport sector as a whole. For the seven years the largest increase in the Index was achieved in Moscow, St. Petersburg and Shanghai — their aggregate index values increased by 2.35, 1.37 and 0.53 points respectively.

During the period 2010–2017, Moscow has risen from 8th to 3rd place in the rankings. The position of the city has been significantly improved in terms of the quality and availability of transport services, primarily for public transport users. Moscow rose by 4 positions in the ranking of the quality of transport services for all groups of the population (from 8th to 4th place), by 1 position (from 5th to 4th place) in the availability ranking. There was also a positive trend in Moscow's indicators characterizing the road safety and the environmental impact of transport (from 8th to 2nd place). According to the efficiency of freight logistics, the city retained the 3rd place in the ranking compared to the other megacities under consideration.

The general trends in the urban transport development have been the road network extension and the increase in the number of passengers in urban public transport. During 2010–2017 there was the growth of motorization in most of the cities, reflected in the increase in the number of private cars per capita. The reduction in the fleet of private cars that took place in Singapore, New York and London was due to the impact of severe restrictive measures in the use of personal vehicles. A positive trend for the studied group of cities is the improvement of transport safety indicators — the level of traffic accidents and the death rate in traffic accidents per capita were significantly reduced in most cities.

The analysis showed that transport policy measures that increase the Index value for a city can be grouped in the following areas:

– development of intelligent transportation systems;

– improving the connectivity of roads;

– improving the environmental performance of urban public and personal transport;

– road traffic optimization;

– parking space optimization;

– transportation.

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