International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 11, Issue 12 [December. 2022] PP: 128-134

The Study of Public Transport Occupancy Rate Patterns in Belarusiancities

Siarhei Azemsha [1] and Kapski Denis [2]
[1]*Belarusian State Transport University, Belarus*
s-azemsha@yandex.ru
[2]*Belarusian National Technical University, Belarus*

Abstract.

The occupancy rate of public transport is a very important indicator: its low values lead to low transportation profitability, and high occupancy values reduce the quality of services provided to passengers. To assess the public transport occupancy rate, it is proposed to use the following criteria: average occupancy per flight, coefficient of trip capacity, passenger density coefficient. Some previous studies show that the values of the above criteria have different meanings in different cities. So, for example, average occupancy per flight varies from 15.6132 pass to 26.327 pass. Coefficient of trip capacities varies from 15.32% to 19.7%. Passenger density coefficient varies from 26.71% to 33.9%. It was also found that there is a significant unevenness in public transport occupancy rate on the hours of the day and, on some routes, on the directions of movementand on cities.Such recessions in the public transport occupancy rate have a negative impact on the economic performance of public transport.
The purpose of this work is to summarize the results of previous studies by individual cities and toevaluate confirm or refute by scientific methods the effect of the number of inhabitants of a cityto the public transport occupancy rate. The sample consists of four cities with a population of 67,500 to 536938 inhabitants. In two of these cities, surveys were conducted twice: once in 2018, and the second in 2019.The total number of flights surveyed is 3294.Surveys were conducted on weekdays and weekends, as well as during all periods of the day.

Keywords: public transport occupancy rate, modular vehicles, passenger, public transport, regression analysis, average occupancy per flight, coefficient of trip capacity, passenger density coefficient.

Date of Submission: 09-12-2022 Date of Acceptance: 23-12-2022

---

1 Introduction

Public transport greatly affects to the life of modern cities. Therefore, plans for its development and improvement should be included in sustainable urban development plans. The successful functioning of public transport is usually determined by its financing. The amount of income received from transportation depends on the number of passengers carried. Therefore, the level of public transport occupancy rate is a very important indicator. Low public transport occupancy rate result in low payback. On the other hand, too high values sharply reduce the quality of services provided to passengers, which can lead to their outflow. Therefore, the study of public transport occupancy rate and it management is an urgent task of our time. The purpose of this work is to summarize the results of assessing the public transport occupancy rate in the cities of the Republic of Belarus and to establish the main patterns in this field.

2 LiteratureReview

In [1], the occupancy rate of public transport in Slovakia is investigated. The authors indicate that changes in passenger demand create problems for carriers who decide to assign vehicles of a certain capacity to work on the route. Similar decisions are made when purchasing passenger vehicles. The authors analyzed the occupancy of trolleybuses on 4 city trolleybus routes. The total number of flights analyzed was 631. The authors estimated the degree of capacity utilization by passenger density coefficient - the ratio of the maximum passenger flow per flight to the bus capacity. An example of the results of a study of occupancy is shown in Fig.1.

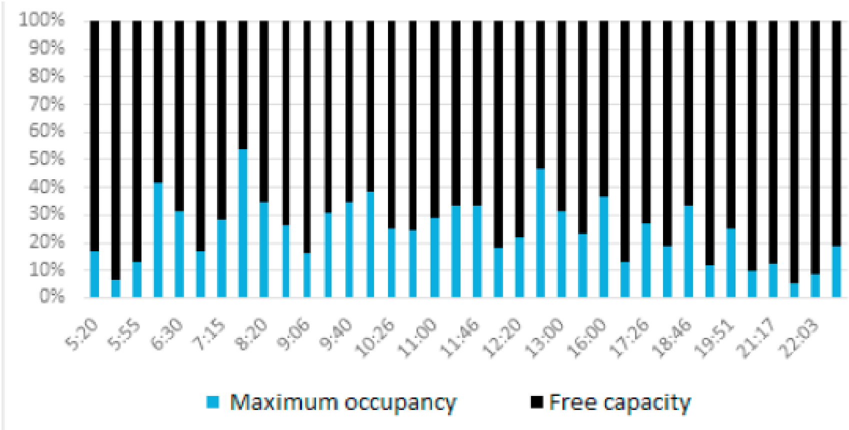

Fig.1. An example of plotting the maximum capacity of trolley buses [1].

From the analysis, the authors calculated that the average passenger density coefficient on the routes considered is 33.43% for single vehicles and 31.83 for articulated ones [1]. Based on this analysis, the authors conclude that it is advisable to redistribute trolleybuses of different capacities along routes and flights. According to the authors, the model that will be updated over a certain period due to possible changes in demand and infrastructure may become future promising ways to solve the problem identified in the article. Thus, the carrier can appropriately respond to changes in demand to reduce the cost of transportation.

In [2], the authors found that the Paretto law applies to the occupancy rate on many routes – only 20% of the bus capacity is used for 80% of the route's route. The article [3] presents a method for assessing the public transport occupancy rate based on data recorded by the wait in motion system. Analysis of the measurement data allowed to propose the following function that describes the level of public transport occupancy [3, p. 5]:

$$Y = 152{,}05X + 9624{,}4 \quad (1)$$

whereX – number of passengers, Y – wait of vehicle.

The coefficient of determination for this expression is 0.79. The authors do not give the values of the remaining statistical criteria. It should be noted that the method proposed by the authors allows you to quickly and accurately determine the number of passengers carried between bus stops. At the same time, such installations are quite expensive. Also it is practically impossible to assess the change in occupancy over the length of the route, all the more in one day to conduct continuous surveys of passenger flow.

In [4], is provided information about the dynamics of changes of the buses occupancy rate the the EU countries. The authors emphasize that the occupancy rate varies widely between Member States. For example, in the UK, a average about 9 people, while in France is about 25. The authors explain the differences between Member States by the different organization of public transport (tariffs, frequency, availability, etc.), as well form of ownership of bus companies. Similar studies for the USA are given in [5]. In [6], it is noted that factors affecting the amount of passenger traffic are: hour of the day, day of the week, and season of the year. The authors found that the distribution of passenger traffic along the route is subject to the Pearson distribution law. In [7], an analysis of the change in the population in the constituent entities of the Russian Federation in 2012 relative to 2006 was made, as well as a change in the number of passengers transported by rail over the same period. The results showed the absence of patterns in the change in traffic with a change in population. In [8], an analysis of the influence of various indicators on the demand for passenger transportation by rail was made. The author concludes that the main such factors will be the level of the region's economy, local transport potential, conditions of population mobility and their income level. In [9], the authors show the existence of a relationship between the specific share of passengers using public road transport and the ratio of the fare to the budget of the cost of living. It has been established that with the growth of this ratio, the specific share of passengers using public road transport decreases. In the article [10], the authors show the patterns of distribution of passenger traffic between the stopping points of the route. I.e. knowing the passenger flow, we can estimate the number of passengers between each pair of stopping points on the route. In the article [11, p. 30], the authors show a model of the time series (trend) of annual passenger traffic from the time factor, and the Fourier series was used to analyze and predict intra-year fluctuations by the seasonal wave model (seasonal fluctuations). Based on the forecasted passenger traffic data thus obtained, the authors propose various measures to ensure profitability: increasing the tariff, reducing the capacity of the bus working on the route, and increasing the interval. In the article [12], the authors investigated the passenger flow of urban electric vehicles by combining information from the databases of the electronic fare payment system and navigation data from trolleybuses. As a result, the authors received information about changes in passenger traffic between routes by the days of the week and by

the hours of the day. But this information was not correlated with the capacity of public vehicles, which does not make it possible to calculate the public transport occupancy rate. In [13], the authors examine passenger flows on seasonal routes and, on their basis, make suggestions for adjusting the routes and the work schedule of passenger vehicles.
It was shown for Belarus [14] that the public transport occupancy rate is low. The passenger density coefficient is on average 30%, which in general is combined with the foreign experience described in [1]. In [15] it was shown that there is a significant unevenness in the use of passenger vehicle capacity by the hours of the day and, on some routes, in the directions of movement. In the [16] showed, that the level public transport occupancy rate is affected to the economic performance of the carrier. Thus, the public transport occupancy rate is a very important quantity, which determines the quality of transportation services, and also affects the economic efficiency of such a service. A whole series of studies to assess the public transport occupancy rate was conducted in some cities of Belarus, but the results have not yet been published.
The purpose of this work is to summarize the results of previous studies by individual cities and to evaluate confirm or refute by scientific methods the effect of the number of inhabitants of a city to the public transport occupancy rate. The sample consists of four cities with a population of 67,500 to 536938 inhabitants. In two of these cities, surveys were conducted twice: once in 2018, and the second in 2019. The total number of flights surveyed is 3294. Surveys were conducted on weekdays and weekends, as well as during all periods of the day.

3 Main part

3.1 Criteria for evaluation of public transport occupancy rate

The public transport occupancy rate was evaluate by the following criteria:
- average occupancy per flight (Of), pass, - the ratio of passenger kilometers performed to the flight length;
- the coefficient of trip capacity (Ktc) - the ratio of the passenger-kilometers of transport work performed to the maximum possible transport work, determined by the multiplying of the bus capacity to the trip distance;
- passenger density coefficient (Kpd) is the ratio of the maximum passenger flow per flight to the bus capacity.

In previous studies, statistical characteristics of the above criteria were found for a number of Belarusian cities.

3.2 Distribution of criteria for evaluating public transport occupancy rate

In previous studies, it was found that the values of the criteria characterizing the degree of public transport occupancy rate in different cities in general are subject to the Generalized extreme value distribution. This law has three parameters: location ($\mu \in R$), scale ($\sigma > 0$) and shape ($\xi \in R$).The values of these parameters for each criterion for evaluation of public transport occupancy rate for each city, as well as the population of cities are shown in Table 1.

Table 1 –Values of parameters of Generalized extreme value distribution by city

City	Year	Population	Of, pass			Ktc			Kpd		
			μ	σ	ξ	μ	σ	ξ	μ	σ	ξ
Gomel	2018	535693	19,76392	10,80863	0,02958	0,12863	0,06984	0,060989	0,22983	0,11945	0,022752
Mogilev	2018	381313	15,35579	9,51105	0,032155	0,12484	0,077326	0,032155	0,22567	0,12908	-0,003123
Mogilev	2019	383313	17,09843	10,09533	0,04104	0,13997	0,084915	0,089643	0,24797	0,143057	0,058587
Mozyr	2018	111733	14,27220	9,85288	0,038142	0,12993	0,084411	0,126912	0,19508	0,119999	0,100088
Gomel	2019	536938	16,01126	10,0575	0,154986	0,10922	0,067539	0,161011	0,18697	0,109428	0,139064
Svetlogorsk	2018	67500	10,33883	7,93018	0,082596	0,09874	0,078923	0,105996	0,18323	0,133110	0,132493

A hypothesis was put forward on the existence of a connection between the parameters of the Generalized extreme value distribution and the population of the city.Figure 2 shows the range of μ for average occupancy per flight (Of)from the population of the city.

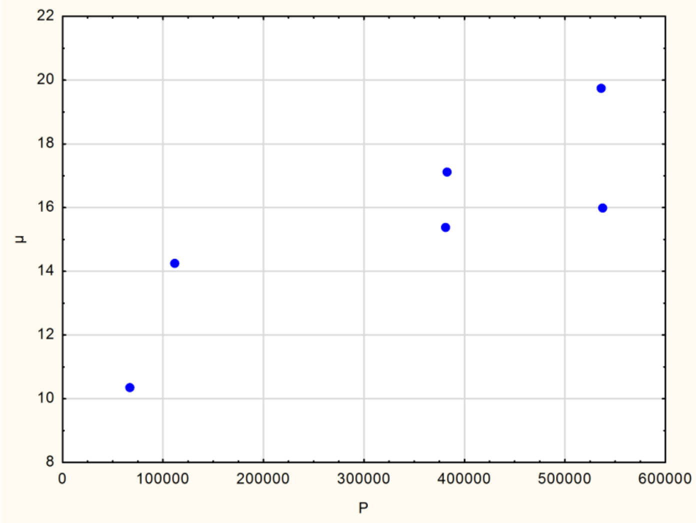

Figure 2 - Dependence μ for average occupancy per flight (Of) from the population of the city

The results of the regression analysis performed in [17] are shown in table 2.

Table 2 - Results of a regression analysis between μ for average occupancy per flight (Of) and the population of the city

	BETA	BETA standarderror	B	Bstandarderror	t(4)	p-value
intercept			11,11358	1,597952	6,954890	0,002246
P	0,841660	0,270004	0,00001	0,000004	3,117220	0,035622

From table 2 it can be seen that the desired dependence has the form:

$$\mu = 11,11358 + 0,00001\ P \quad (2)$$

For this expression, the correlation coefficient is 0.842, the coefficient of determination is 0.708. The resulting model is significant according to Fisher and Student's criteria.
A similar analysis was carried out for the remaining values given in Table 1. ItsresultsareshowninTable 2.

Table 2 - Results of the search for dependencies between the parameters of the law of distribution of quantities describing the degree of use of public transport capacity and the population of the city

Of, pass			Ktc			Kpd		
μ	σ	ξ	μ	σ	ξ	μ	σ	ξ
11,11358 + 0,00001 P	$\sqrt{5,506\cdot10^{10}+6,025\cdot10^{5}\cdot P}$	-	-	-	-	$e^{7.741\cdot10^{-7}\cdot P-1.73628}$	-	$\frac{22.423}{P^{0.463214}}$

In Table 2, a dash is added in a number of cells. This means that it was not possible to obtain a significant statistical regression equation for the variables. However, it should be noted that the values of the correlation coefficient in this case exceeded 0.7.
Analysis of the regression equations given in Table 2 showed that the parameters of the distribution law of generalized extreme values behave as follows:
- location (μ) and scale (σ) grow with the growth of the population of the city;
- shape (ξ) decreases with population growth.

3.3 Dependence of the criteria for assessing the use of the capacity of passenger vehicles on the number of inhabitants

Previous studies have evaluated the average occupancy values of passenger vehicles and their dispersion measures. TheirgeneralizingresultsareshowninFigure 3.

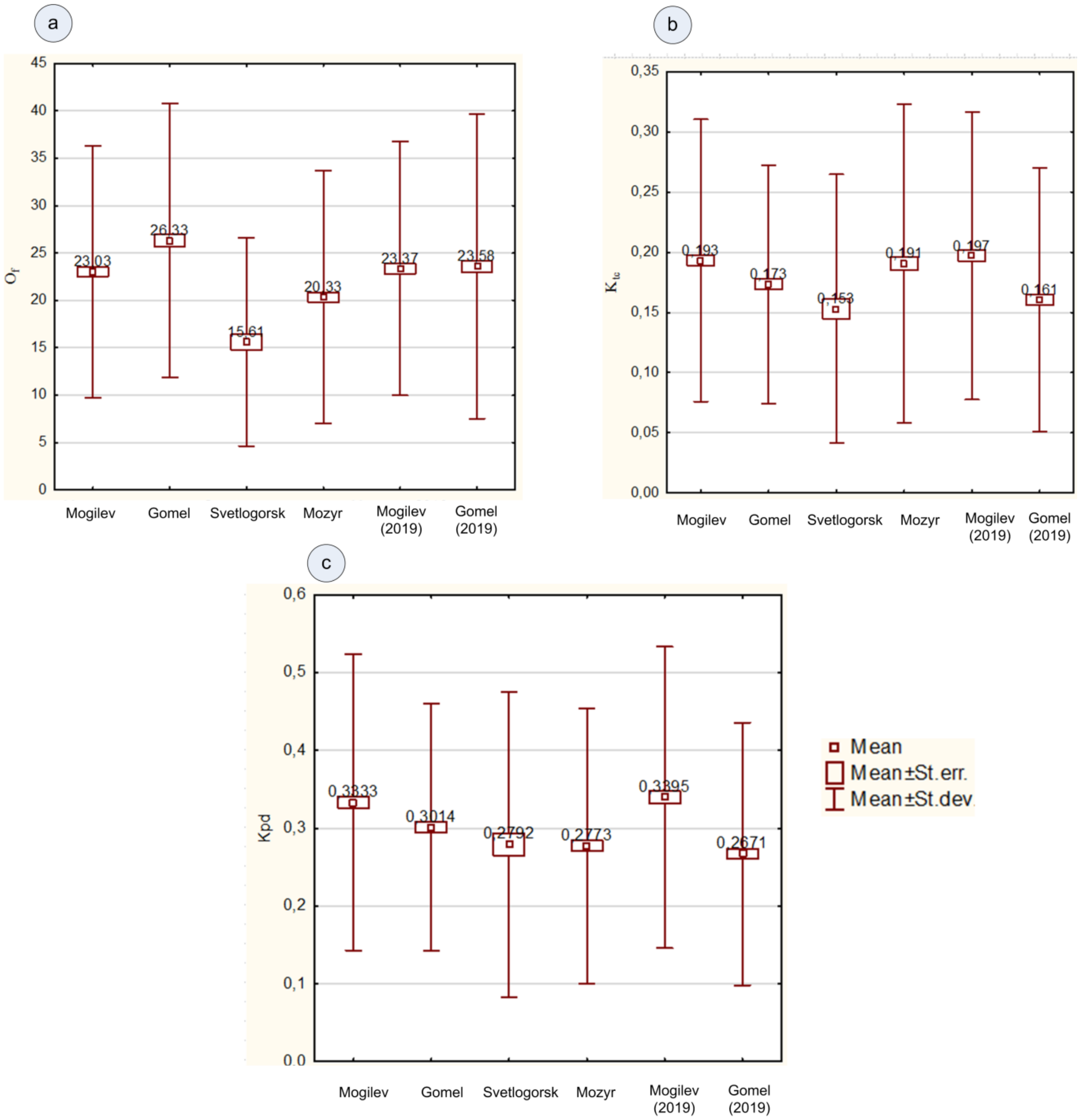

Figure 3 - Diagram of the range of criteria for using the capacity of passenger vehicles by city: a - average occupancy per flight (Of), pass; b - coefficient of trip capacity (Ktc); c - passenger density coefficient (Kpd) [14–16]

Figure 3 shows that the average values of capacity utilization indicators for different cities are different. An analysis of the significance of such differences, performed using the Kruskal-Wallis Rank analysis of variance and the median test implemented in [17], showed that these differences are significant.
A hypothesis was put forward about the presence of a statistical relationship between the criteria for assessing the level of occupancy of public transport in the city and the number of inhabitants of this city. As a graphical illustration of such a dependence, Figure 4 shows the scatterplots of average occupancy per flight (Of) and their standard deviations (Ofsd) depending on the number of city residents.

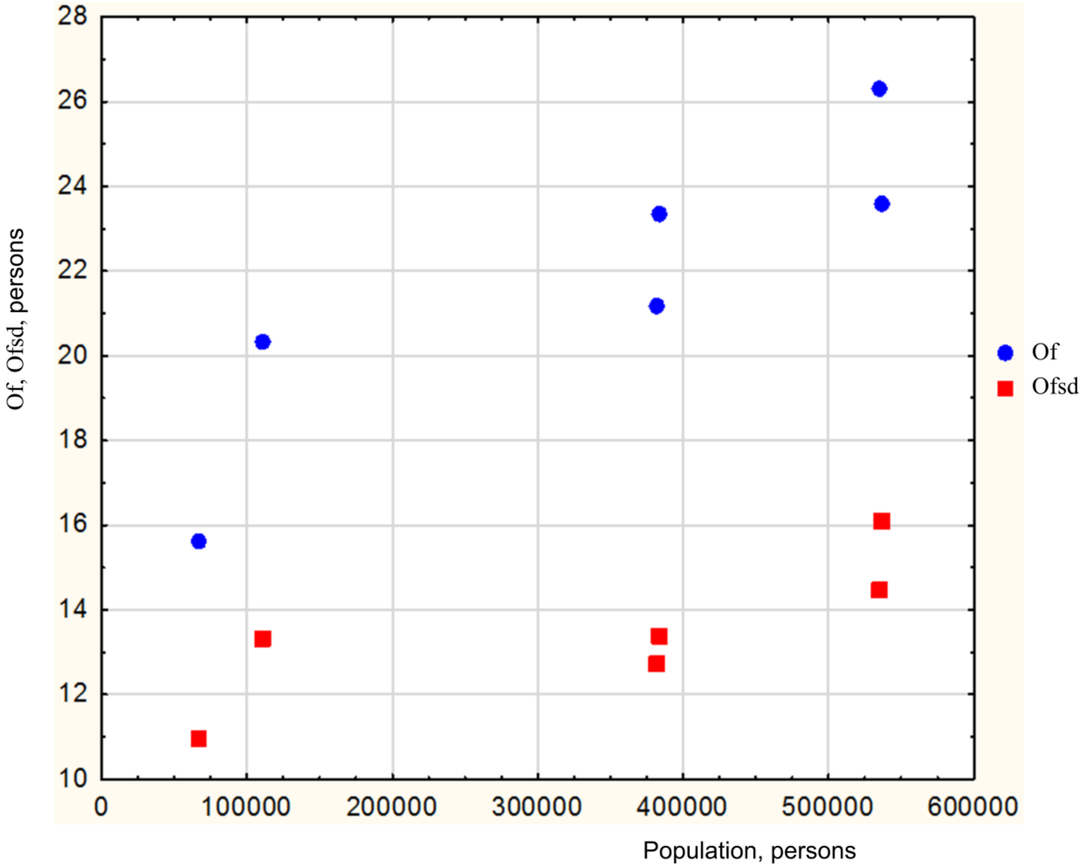

Figure 4 - Scatterplots of average occupancy per flight (Of) and their standard deviations (Ofsd) depending on the number of city residents

Further nonlinear regression analysis implemented in [17] made it possible to obtain the following dependences:

$$O_f = 16,3744 + 1,593 \cdot 10^5 \cdot P \quad (3)$$

$$O_{fsd} = e^{0,424 \cdot 10^5 \cdot P + 11,04797} \quad (4)$$

where P is the population of the city, pers.

For expression (3), the correlation coefficient is 0.89, and the determination coefficient is 0.79. For expression (4), such statistical characteristics are equal to 0.98 and 0.96, respectively. Both obtained regression expressions are significant according to Fisher's and Student's criteria.Expressions 3 and 4 show that with an increase in the number of city residents the average occupancy per flight (Of) and their standard deviations (Ofsd)will also grow.
In a similar way, a regression analysis was carried out for the coefficient of trip capacity (Ktc)and the passenger density coefficient (Kpd). Based on the results of such an analysis, no significant regression models were found. At the same time, it should be noted that the correlation coefficients of these regression models are quite high (more than 0.8).

4 Conclusion

In this paper, a generalization of previously conducted studies aimed at assessing the degree of use of the capacity of passenger vehicles is made.Wherein the public transport occupancy rate was evaluate by the following criteria:
- average occupancy per flight (Of), pass, - the ratio of passenger kilometers performed to the flight length;
- the coefficient of trip capacity (Ktc) - the ratio of the passenger-kilometers of transport work performed to the maximum possible transport work, determined by the multiplying of the bus capacity to the trip distance;
- passenger density coefficient (Kpd) is the ratio of the maximum passenger flow per flight to the bus capacity.
It was found that the values of this criteriain general are subject to the Generalized extreme value distribution.

Regression analysis established the relationship between the parameters of this distribution law and the population of the city (Table 2).
It was also shown that the criteria for assessing the occupancy of public transport and their standard deviation have a positive correlation with the population of the city. At the same time, with an increase in the number of inhabitants, the values of such criteria also increase.
At the same time, the occupancy rate of public transport is low, which leads to increased transportation costs. Therefore, further research should be directed to the development of measures to increase the criteria for assessing the occupancy rate of public transport.

References

[1]. Peter Medviďa, MariánGogolaa and Stanislav Kubaľáka: Occupancy of Public Transport Vehicles in Slovakia.Transportation Research Procedia44 153–159(2020). https://www.researchgate.net/publication/340070494_Occupancy_of_Public_Transport_Vehicles_in_Slovakia
[2]. Ponte, C., Melo, H.P.M., Caminha, C. et al. Traveling heterogeneity in public transportation. EPJ Data Sci. 7, 42 (2018).
[3]. Loga W., Brzozowski K., Ryguła A. (2016) A Method for Estimating the Occupancy Rates of Public Transport Vehicles Using Data from Weigh-In-Motion Systems. In: Mikulski J. (eds) Challenge of Transport Telematics. TST 2016. Communications in Computer and Information Science, vol 640. Springer, Cham
[4]. N.Adra,J.L.Michaux,MichelAndre. Analysis of the load factor and the empty running rate for road transport. Artemis - assessment and reliability of transport emission models and inventory systems. Rapport de recherche. 2004, 31p.
[5]. Average Vehicle Occupancy Factors for Computing Travel Time. https://www.fhwa.dot.gov/tpm/guidance/avo_factors.pdf.
[6]. Khvostov A.A., Shipilova E.A., Rebrikov D.I. Planning and processing of passenger flow research results within the route. Scientific Bulletin of the Voronezh State University of Architecture and Civil Engineering. Series: Information Technologies in Building, Social and Economic Systems No 2 97-102 (2013) in Russian.
[7]. Surzhin K.V., Muktepavel S.V. Assessment of the influence of the factor of population on the volume of passenger traffic. Passenger complex No 4 59-64 (2015) in Russian.
[8]. Efimov S.M. Methodology for the analysis of factors determining the demand for passenger transportation. Transport World. Volume 13 No. 2114-120 (2015) in Russian.
[9]. Grigorova T.M., DavidichYu.O., Dolya V.K. Estimating the elasticity of the attendance of the ambassadors of Primorsk passenger transport. Technology audit and production reserves No. 3/2 (23) 13-16 (2015)in Ukrainian.
[10]. Bure V., Plaksina N., Mazalov V. Estimation passenger traffic characteristics in transport systems. Automation and Remote Control, September 2015.
[11]. Belokurov V.P., Motuzka D.A., ArtemovA.Yu. Improving the efficiency of the operation of vehicles during seasonal passenger traffic in the cities of resort areas. Technology of wheeled and tracked vehicles. No 3 (19) 25-33 (2015) in Russian.
[12]. Druzhinina N.G., Trofimova O.G., Trofimov S.P. Evaluation of the distribution of inter-district passenger traffic in urban electric transport. Software products and systems. No. 2 (110). 145-150 (2015) in Russian.
[13]. A.N. Novikov, A.L. Sevostyanov, A.A. Katunin, M.V. Kulev, A.V. Kulev, M.M. Savin. Inspection of passenger flows on seasonal routes of the city of Orel. World of Transport and Technological Machines. No. 4 (43). 77-84 (2013) in Russian.
[14]. Azemsha S. The Study of the Trolley Buses Occupancy. Global Journal of Management and Business Research: F Real Estate, Event and Tourism Management. Volume 19 Issue 1 Version 1.0. 6–15 (2019).
[15]. Azemsha S.A. Assessment of the uneven use of public passenger transport capacity. Logistic audit of transport and supply chains: materials of the II international scientific and practical conference (April 26, 2019), 16–23 (2019) in Russian.
[16]. Azemsha S.A. DEVELOPMENT OF PROPOSALS TO IMPROVE THE EFFICIENCY OF PUBLIC URBAN PASSENGER TRANSPORT. The Russian Automobile and Highway Industry Journal. 2019;16(5):544-557. (In Russ.) https://doi.org/10.26518/2071-7296-2019-5-544-557
[17]. Statistica 13.3. Computer program. Serial number JRR709H998119TE-A.
[18]. Kobzar A.I. Applied mathematical statistics. For engineers and scientific workers. 816 p. ISBN 5-9221-0707-0. In Russian.