DOI: 10.31319/2519-8106.2(47)2022.268389
UDC 621.129.12
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INCREASING THE EFFICIENCY OF USING PUBLIC BUSES ON THE TRANSPORTATION ROUTES OF THE CITY OF KAMIANSKE

The work solves an important task of increasing the efficiency of the use of public buses, which is related to ensuring an increase in the passenger capacity utilization ratio, i.e. filling the buses. The authors proposed a technique aimed at optimizing the passenger capacity of a vehicle unit, namely the rational capacity of buses for operation on routes by periods of the day. Optimal filling of rolling stock should correspond to fluctuations in passenger traffic and change in the number, capacity and distribution of buses on the transport network. Adjusting the distribution of buses along routes in time and in accordance with the demand for passenger transportation is aimed at meeting the condition that the demand for transportation and their provision are equal to each other.
***Keywords**: bus, vehicle, passenger flow, transportation route, result, calculation.*

У роботі розв'язується важлива задача по підвищенню ефективності використання автобусів загального користування, яка пов'язана з забезпеченням підвищення коефіцієнта використання пасажиромісткості, тобто наповнення автобусів. Авторами запропонована методика, яка спрямована на оптимізацію пасажиромісткості одиниці транспортного засобу, а саме раціональної місткості автобусів для роботи на маршрутах по періодам доби. Оптимальне наповнення рухомого складу повинно відповідати коливанням пасажиропотоків та змінюватися кількість, місткість і розподілення автобусів по транспортній мережі. Корегування розподілення автобусів по маршрутах у часі і відповідно з попитомна пасажирські перевезення спрямовано на дотримання умови, щоб попит на перевезення і їх забезпечення дорівнювали один одному.
***Ключові слова**: автобус, транспортний засіб, пасажиропотік, маршрут розвезення, результат, розрахунок.*

Formulation of the problem

The profit from urban transportation of passengers in the city of Kamianske does not cover the costs that arise during their performance. One of the reasons for this state of affairs is the low average utilization ratio of the passenger capacity of vehicles.

One of the reasons for low occupancy of buses is their suboptimal capacity. Overcapacity reduces the average passenger capacity utilization ratio or causes the need to use vehicles with long intervals, and undercapacity increases costs due to the use of less efficient passenger vehicles. The movement of vehicles with long intervals or a sufficiently large passenger capacity utilization ratio reduces the quality of passenger service. Therefore, the passenger capacity of a vehicle unit, which is used on urban transportation routes, is subject to optimization.

Analysis of recent research and publications

The organization of bus traffic in the city of Kamianske is carried out according to the route principle.

The essence of the route principle of passenger flow consists in the organization of the movement of vehicles along certain, previously established directions — routes that are divided by stopping points into separate sections. The driving mode on the route represents starts, runs, braking and stops at stops to reproduce the passenger exchange. The characteristics of the traffic organization of this type are determined by the length of the route between the stops, the maximum speed of the bus on the route, running time and speed, speed of connection [1,2].

It is not possible to change the capacity of buses in a wide range due to the limited model range of buses used for urban passenger transportation, the coefficient of variability of passengers is a value that is not regulated and has a random nature, which means that operating with these indicators to increase the efficiency of use will not bring significant result. To increase the productivity of buses, it is necessary to reduce the flight time and increase the filling of rolling stock [3].

In order to reduce the flight time, it is necessary to increase the connection speed, that is, to increase the technical speed and to reduce the idle time at intermediate stopping points. An increase in technical speed is impossible due to road safety conditions, and a decrease in idle time at intermediate stops will cause a deterioration in the quality of passenger service.

As the analysis of the technology of transporting passengers by buses in the city of Kamianske showed, the average daily filling of buses is not uniform throughout the hours of the day and is not very large, which means that in order to increase productivity, it is necessary to increase the capacity utilization ratio by rationally organizing the movement of buses on routes, that is, depending on the passenger flow, determine the required number of rolling stock units by hour of the day, as well as its optimal capacity.

The need for rolling stock is established based on the need to assign to each route such a number of buses of a certain passenger capacity that ensures the minimum costs of the carrier under the conditions of mastering the passenger flow in compliance with regulatory requirements for the quality of transport service [2,3]. At the same time, the types and number of buses are chosen for the future in order to form a rational structure of the rolling stock fleet. The distribution of buses along the routes is carried out under the same conditions, additionally taking into account the availability of rolling stock at the disposal of the carrier. The distribution of buses is a necessary stage in the transition from passenger flow to the number of buses on the route [4,5]. In the general case, they are guided by the preservation of the 1—2 minute interval of buses for passengers and the costs of operating buses. These costs increase in proportion to the passenger capacity of the bus, but as it increases, fewer buses are needed, so the costs for different types of buses are different.

Formulation of the purpose ofresearch

The purpose of the work is to optimize the passenger capacity of public buses for operation on the routes of the city of Kamianske.

Main material presenting

As a criterion of optimality, it is proposed to accept the minimum of the objective function Z_h in the form of the sum of costs S_p, which arise during transportation, and passenger losses from waiting for vehicles at stops for a certain time period P_p, for example, for 1 hour [6]

$$Z_p = S_p + P_p \Rightarrow \min q, \qquad (1)$$

where q — is the value of the capacity of the vehicle, pas.

Hourly costs can be calculated using the formula

$$S_p = S_t \cdot n_t, \qquad (2)$$

where S_t—the amount of costs for one turn of the bus on the passenger transportation route;n_t—the number of bus turnovers on the transportation route in 1 hour.

The value S_t can be calculated by the formula

$$S = l_t \cdot S_{km} + t_t S_c, \qquad (3)$$

where l_t—the length of the turn on the route, km.;S_{km}—expenses for 1 km. mileage of the bus on the route; t_t—duration of the turnover period on the route, hours;S_c—expenses for 1 hour of bus operation on the route.

The length of the turn is determined from the characteristics of the route [6,7].

The duration of the turnover period is determined based on the characteristics of the route and the buses operating on it, according to the formula

$$t_t = \frac{l_t}{\upsilon_t} + t_c, \qquad (4)$$

where υ_t—average technical speed of the bus per turn on the route, km/h;t_c—total idle time at intermediate and final stops on the route per turnover.

The values of S_{km} and S_c can be calculated using the formulas

$$S_{km} = a_{km1} + a_{km2} \cdot q, \qquad (5)$$

$$S_c = a_{g1} + a_{g2} \cdot q, \qquad (6)$$

where a_{km1}, a_{km2}, a_{g1}, a_{g2}—dependency parameters.

The value of n_t is determined by the formula

$$n_t = n_{tr} = \frac{A_r}{t_t}, \qquad (7)$$

where n_{tr}—traffic schedule of vehicles on the route;A_r—the number of buses operating on the route.

On the other hand, the required bus frequency can be determined along the busiest section of the route using the formula

$$n_{tr} = \frac{Q_c}{q}, \qquad (8)$$

where Q_c—the maximum hourly passenger flow along the route sections in the busiest direction, pas/h; q—passenger capacity of the bus.

Losses of passengers from waiting for buses when they operate according to the interval of movement is determined by the formula

$$n = \frac{Q_{oc} \cdot C \cdot J}{2} = \frac{Q_{oc} \cdot C}{2n_c}, \qquad (9)$$

where Q_{oc}—the total hourly volume of passenger transportation on the route, pass;C —the cost of losing a passenger for 1 hour of waiting for a bus;J—interval of buses on the route($J = \frac{1}{n_c}$).

In turn, the value of Q_{oc} can be calculated using the formula

$$Q_{oc} = 2Q_{ac} \cdot n_{cc} = \frac{2Q_{lc}}{k_u} \cdot n_{cc}, \qquad (10)$$

where Q_{ac}—average hourly total loading of buses on the route;n_{cc}—the average coefficient of variability of passengers for one bus trip on the route;$k_u = \frac{Q_{lc}}{Q_{ac}}$—coefficient of unevenness of the passenger flow along the route sections per bus turnover.

After the transformations of the equations, we get that Z_c is determined by the expression

$$Z_c = \frac{Q_{lc} \cdot q\left(l_t(a_{km1} + a_{km2}q) + (l_t/v_t + t)(a_{g1} + a_{g2}q)\right)}{q C_l \cdot k_u / n_{cc}} = \min q. \qquad (11)$$

The derivative of $Z_c$with respect to q, which is zero and will determine the optimal value of q_{opt}

$$q_{opt} = \sqrt{\frac{Q_{lc} \cdot k_u \cdot (l_t a_{km1} + a_{g1}(l_t/v_t + t_c))}{C_l \cdot \eta_{cc}}}. \qquad (12)$$

However, the value of Q_{lc} can change during the day, while the capacity of the bus operating on the route remains the same. Therefore, the decision should be made based on the minimum value of the objective function

$$Z = \sum_{i=1}^{n} Z_{c_i} = \min q, \qquad (13)$$

where Z_{ci}—value of the objective function for the i-th hour of the day;n—the number of hours per day during which passengers are transported on the route.

Taking into account the daily change of Q_{lc}, the optimal value of the passenger capacity of a passenger transport unit is determined by the formula

$$q_{opt} = \sqrt{\frac{2Q_{lc.a} \cdot k_u \cdot (l_t a_{km1} + a_{g1}(l_t/t + c))}{C_l \cdot \eta_{cc}}}, \qquad (14)$$

where $Q_{lh.a}$—average hourly passenger flow on the busiest section of the route during periods when the operation of vehicles on the route is organized without informing passengers about the schedule.

Thus, on the basis of the conducted research, a dependence was obtained that allows to optimize the passenger capacity of buses for work on city routes [6].

The calculation of the rational capacity of the bus is given on the example of route No. 4 Railway Station — Budivelniki Blvd. during the hours of the day from 6:00 a.m. to 9:00 a.m.

$$q_{opt} = \sqrt{\frac{2 \cdot 340 \cdot 2{,}227 \cdot (7{,}3 \cdot 1153 + 18295 \cdot 0{,}97)}{1000 \cdot 2{,}08}} = 137\text{pass.}$$

The rational capacity of buses for work on the routes that were studied by periods of the day is given in tabl. 1.

Table 1. Rational capacity of buses for work on routes by periods of the day

route number	rational capacity by periods of the day, pas										
	6-9	9-11	11-12	12-13	13-15	15-16	16-18	18-19	19-20	20-22	23-24
4	137	489	228	219	356	261	493	225	177	344	161
6	358	620	173	193	618	308	615	198	158	361	189
14	304	374	154	168	412	298	368	243	169	311	194
23	190	425	203	224	408	422	431	199	117	182	182
23[a]	210	403	378	301	399	416	406	212	193	208	170

Having the value of the rational calculated capacity of the rolling stock, the standard capacity of the existing bus fleet is selected.

The values of the standard capacity of buses, which are determined based on the rational, are given in tabl. 2.

Table 2. Standard capacity of buses for work on routes by periods of the day

routenumber	rational capacity by periods of the day, pas																	
	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20	20-21	21-22	22-23	23-24
4	121	180	153	121	85	85	40	85	121	121	153	180	180	121	121	85	40	40
6	40	65	65	40	40	40	40	65	65	80	80	121	121	65	40	40	40	40
14	121	153	153	121	80	80	40	80	80	121	153	153	121	80	80	60	60	40
23	80	121	153	153	80	80	65	65	80	121	121	153	121	80	80	40	40	40
23[a]	65	65	121	121	153	121	85	85	65	153	121	80	80	65	65	80	65	40

Conclusions

In this way, it was established to ensure optimal filling of rolling stock that corresponds to fluctuations in passenger traffic, and the number and distribution of rolling stock along the transport network of the city of Kamianske was calculated.

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ПІДВИЩЕННЯ ЕФЕКТИВНОСТІ ВИКОРИСТАННЯ АВТОБУСІВ ЗАГАЛЬНОГО КОРИСТУВАННЯ НА МАРШРУТАХ РОЗВЕЗЕННЯ МІСТА КАМ'ЯНСЬКОГО

Шматко Д.З., Сасов О.О., Бондюк Д.М.

Реферат

Задача організації руху міського автомобільного транспорту загального користування являється забезпечення достатньо високої якості пасажироперевезень при мінімальній собівартості. При врахуванні нерегульованих випадкових коливань пасажиропотоків у часі і по довжині того чи іншого маршруту, затримки руху пасажирського транспорту при роботі в загальному потоці руху, стає зрозумілим, що складання оптимального розкладу руху автобусів є досить складна задача. Організація оптимального перевезення пасажиропотоків повинна передбачати максимальне корисне використання рухомого складу, який виходить на лінію, по кількості автобусів і по їх пасажиромісткості, тобто використання середнього коефіцієнтузаповнення транспортних засобів.

Однією з причин низького наповнення автобусів являється їх неоптимальна місткість. Оптимальний підбір пасажирського рухомого складу підвищує середній коефіцієнт пасажиромісткості, та сприяє усуненню великих інтервалів руху автобусів. Тому пасажиромісткість одиниці транспортного засобу, який застосовується на міських маршрутах перевезень, підлягає оптимізації.

У статті запропонована методика обчислення оптимальної пасажиромісткості одиниці пасажирського транспорту, яка спирається на середньогодинний пасажиропотік на найбільш завантажених маршрутах. Отримане рівняння дозволяє обрати раціональну пасажиромісткість автобусів, які виходять на маршрути м. Кам'янського по різних періодах доби.

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