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Technical and operational assessment of the introduction of express bus traffic on urban routes in Jizzakh

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Abstract

The work is devoted to solving an urgent scientific problem of substantiating the rational parameters of the express mode of movement on urban bus routes. The conditions for the expediency of introducing an express mode of bus movement on urban routes, based on the parameters of passenger traffic, have been established. The developed method of forming a list of stopping points that should be serviced by buses operating in express mode of movement takes into account the unevenness of passenger traffic and, accordingly, the intervals of bus movement during the day. The developed method for determining the rational parameters of the express mode of movement on urban bus routes, based on the economic, social and environmental performance indicators of the transportation process, takes into account the dynamic distribution of passenger correspondence between the regular and express routes, depending on the number of buses and the list of stops on the express route. A technical and operational assessment of the introduction of express bus traffic on the city route No. 1 in Jizzakh was carried out.

Keywords: Express mode, passenger traffic, route, redistribution of correspondence, stage length, bus filling, speed of communication, transportation costs.

Introduction

In modern conditions, most cities in Uzbekistan are experiencing significant problems associated with an increase in transportation costs due to an increase in the dynamism of life and the number of people living or working in cities. Despite some budgetary support, the above factors lead to a constant increase in the cost of fuel and lubricants, repair and maintenance of vehicles. As a result, the efficiency of urban bus passenger transport remains insufficient and leads to unprofitability or low profitability of most motor transport enterprises. In these difficult economic conditions, the main task of road transport enterprises is to identify such options for organizing transportation on routes that would lead to minimum costs, maximum productivity of vehicles, but at the same time take into account the possibility of transporting passengers with specified quality indicators.

One of the effective ways to solve the above tasks is to organize express traffic on urban bus routes. This measure makes it possible to reduce the time spent by passengers on movement, increase the use of buses and the level of public transport services. Since express buses have fewer stops along the way, they carry out less braking and acceleration, which contributes to a significant reduction in fuel and lubricants costs, routine repairs and maintenance, as well as reduces the amount of harmful emissions into the city atmosphere[1].

It should be noted that the introduction of an express mode of bus traffic on urban routes makes it possible to achieve significant economic and social effects without increasing the number of buses on the route. On the contrary, it becomes possible to remove some buses from the route without compromising the quality of passenger transport services[2].

Despite these advantages, the express mode of movement has not been widely used in the cities of Uzbekistan, primarily due to the lack of a unified methodology by which its rational parameters can be determined[3]. It should also be noted that the reorganization of traffic modes using express services is defined as an urgent measure in the Concept of development of ground passenger transport of the Republic of Uzbekistan for 2023-2030[4].

Analysis of publications: According to the Law of Uzbekistan "On Road Transport", the transportation of passengers on a public bus route can be carried out in three modes of movement: regular, express and minibus mode[5]. The normative definition of the express mode of movement according to cannot always take into account all the variants of uneven passenger flows on urban bus routes[6].

Therefore, many researchers[7-9] use the concept of technological mode of movement, dividing the express mode according to into: express, semi-express, high-speed and abbreviated (Figure-1).

Simultaneous use of several bus modes on the same route forms a combined driving mode. The most effective combined mode is the mode of movement using conventional (off-track) and express communication, which allows you to increase the speed of communication, reduce the time spent by passengers on movement, and increase the degree of use of vehicles. The latter effect leads to a reduction in the cost of transportation and an increase in the profitability of the ATP.

The analysis of their scientific works allowed us to establish that the existing developments either do not fully take into account the interests of all participants in the transportation process, or have a narrow scope of application. It is these factors that significantly limit the widespread introduction of the express mode, despite its significant potential to improve the efficiency of urban passenger transportation. Based on the performed analysis, the need has been established to develop a method for determining the rational parameters of the express mode of movement on urban bus routes, which will increase the energy efficiency of urban buses, the degree of use of vehicles, increase the speed of communication and reduce the time spent by passengers on movement.

The study developed a method for determining the rational parameters of the express mode of movement on urban bus routes, based on the economic, social and environmental performance indicators of the transportation process, which takes into account the dynamic distribution of passenger correspondence between the regular and express routes, depending on the number of buses and the list of stops on the express route. The structure of a comprehensive indicator for evaluating the effectiveness of the express mode of movement was also proposed, taking into account the amount of transport work, the level of bus occupancy and the time spent by passengers on movement.

The purpose and objectives of the study: The aim of the work is to obtain a quantitative technical and operational assessment of the impact of the introduction of express bus traffic on the selected urban route of Jizzakh. To achieve the purpose of the study, it is necessary to conduct a survey of passenger traffic on the route; calculate the technical and operational indicators of the passenger transportation process; justify the expediency of introducing an express mode of movement; determine the lists of stopping points that should be part of the express route, determine the rational parameters of the express route; to carry out a technical and operational assessment of the impact of the introduction of express bus traffic.

Materials and Methods

The urban route No. 1 ("Kahramon"-"Osiye-bozor") was chosen as the object of research. There are 25 Isuzu HC45 buses operating on the route with a capacity of q_n=39 passengers in normal mode. The main characteristics of Route No. 1 are shown in Table-1.

Table-1: Main characteristics of route No. 1.

The name of the indicator	Values
Route length L_m , km	24,1
Duration of the trip t_p, minutes	68
Speed of movement V_c, km/h	21.2
Operating speed V_e km/h	18.4
Number of stopsn_{ost}	24
Bus travel interval I (morning rush hour), minutes	5
The provided capacity on the Q_{pred} route (morning rush hour), pass	552

Passenger traffic surveys on Route No. 1 were conducted using a tabular method (using the Transit Wand software product) during the morning rush hour for the direct (busiest) direction of Orom Bozor→Cook bozor.

Let's consider a compatible analysis of the passenger flow diagram along the route $H_{j,j+1}$and passenger exchange at stopping points Q_j, which states that the provided capacity on the route provided by Q_{pred} is sufficient to master passenger flows on the busiest section of the route $Q_{pred} > H_{max}$, and passenger exchange at stopping points is characterized by significant unevenness.

On the other hand, the exhaust route of such a number of buses, which ensures the development of maximum passenger traffic only on the busiest stage of the route, leads to their underutilization on other stages of the route, which leads to a decrease in the utilization factor of bus capacity, and consequently increases the cost of transportation.

The structure of the distribution of transport work on the route is shown in Figure-1, the analysis of which shows that in the vast majority of route crossings, the proportion of unproductive transport work W_N (1) ranges from 10 to 70%. In general, the potential transport work of P_{poten} on the route is 11,361.6 pass.km (2), and the actual actual P_{fakt} (according to the survey results) is 8,651.6 pass.km. Thus, W_N is equal to 2,538.2 pass.km., which is 23% of P_{poten}, which significantly reduces the efficiency of buses.

$$W_N = P_{poten} - P_{fakt} \quad (1)$$

$$P_{poten} = q_n \cdot L_M \cdot \Psi \quad (2)$$

However, a decrease in the number of buses on the route will lead to over-normalized filling of vehicles and even to the refusal of passengers to board, which will lead to a decrease in the quality of transport services. Thus, there is a need to introduce a combined traffic mode with express service on route No. 1, which will free up some of the vehicles (by increasing their carrying capacity) and reduce the total cost of passengers on the trip (by increasing the speed of buses).

Also, according to the results of the survey, it was found that: the maximum passenger traffic on the route is H_{max} =543 passengers; the average passenger traffic is H_{sred} =425.4 passengers; the average length of the passenger trip is l_{sred} =10.6 ser km; the coefficient of passenger variability is η_{izm} =1.92. Calculated from (3-4), the values of the normalized coefficients of variability k_{izm} and unevenness of passenger flows on the sections of the k_{uch} route (which determine the conditions for organizing the corresponding modes of movement on bus routes) are 0.52 and 0.77, respectively, which confirms the expediency of introducing a combined mode with express service on route No. 1 (Figure-2).

$$k_{izm} = \frac{1}{\eta_{izm}} = \frac{1}{1{,}92} = 0.52 \quad (3)$$

$$k_{uch} = \frac{1}{\eta_{uch}} = \frac{H_{sred}}{H_{max}} = \frac{421.5}{543} = 0.78 \quad (4)$$

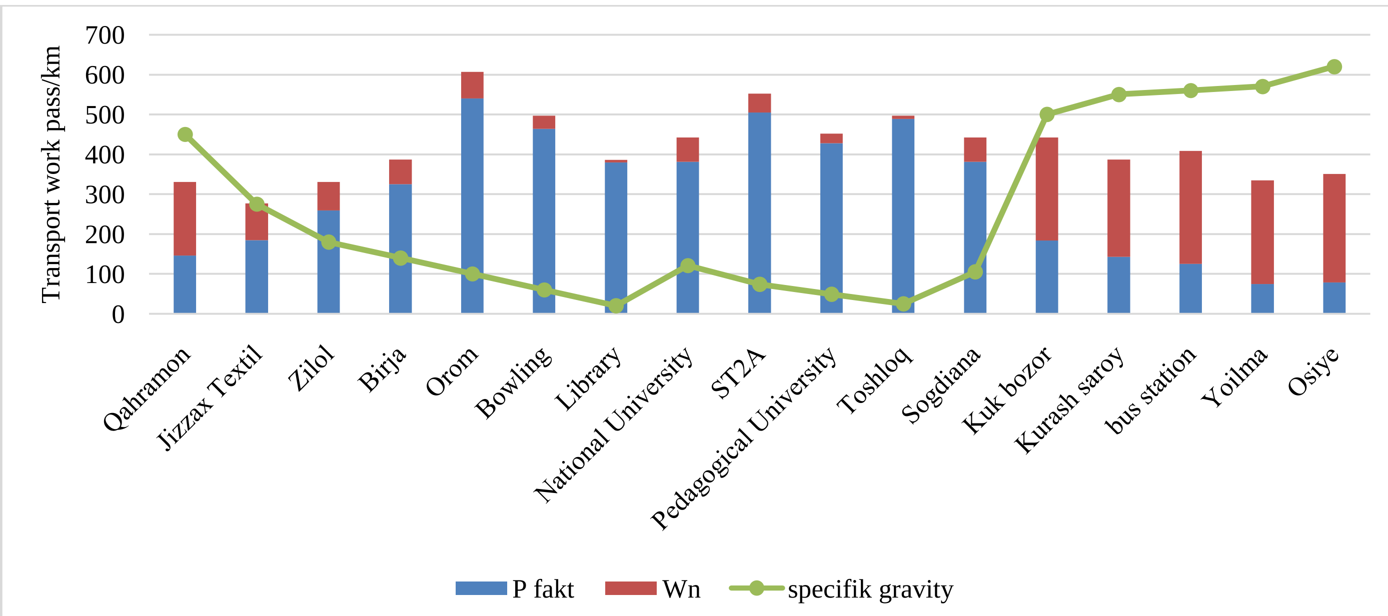

Figure-1: The structure of the distribution of transport work on route No. 1.

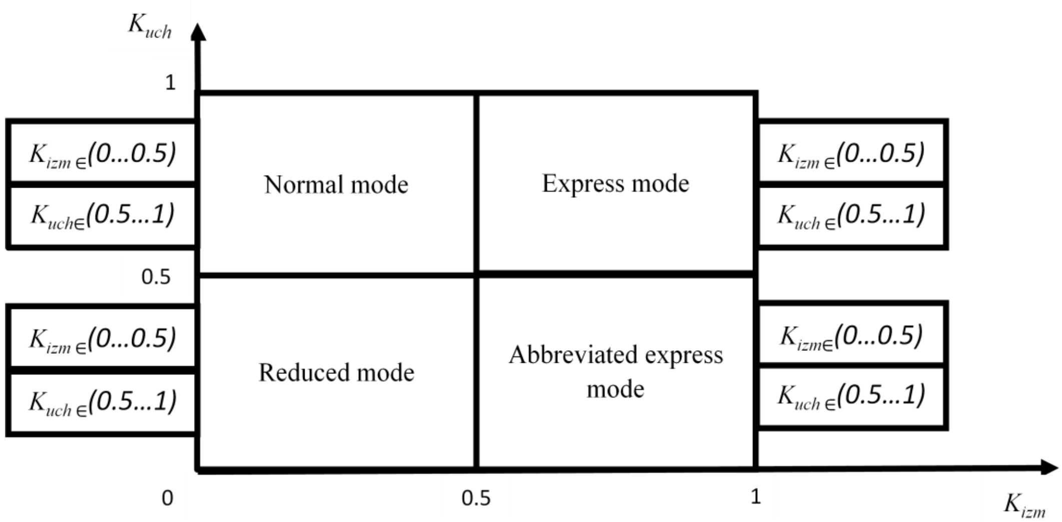

Figure-2: Conditions for the expediency of organizing traffic modes on bus routes.

Based on the method proposed in [1] for determining the stopping points that should be served by buses with an express mode of movement, which, unlike existing ones, takes into account changes in bus intervals during the day (5-7), three variants of the express route were formed, which consists of $Z_1 = 8$, $Z_2 = 13$and $Z_3 = 16$ stops (Figure-5).

$Z_1(\frac{F_j}{Q_j} < I)$- 8 bus stops:
1→2→3→12→14→24→26→27;

$Z_2(\frac{F_j}{Q_j} < 1{,}5I)$- 13 bus stops:
1→2→3→8→12→14→18→22→24→23→25→26→27;
$Z_3(\frac{F_j}{Q_j} < 2I)$ - 16 bus stops:
1→2→3→4→8→12→14→17→18→21→22→24→23→25→26→27.

$$Z_1 \in \left(\frac{F_j}{Q_j} < I\right) \quad (5)$$

$$Z_2 \in \left(\frac{F_j}{Q_j} < 1.5I\right) \quad (6)$$

$$Z_3 \in \left(\frac{F_j}{Q_j} < 2I\right) \quad (7)$$

where F_j is the number of passengers passing by the j-th stop, pass.:

$$F_j = H_{j-1,j} - B_j \quad (8)$$

Method was proposed for determining the rational parameters of the express mode of movement on urban bus routes, taking into account the dynamic distribution of passenger correspondence between the regular and express routes, depending on the number of buses and the list of stops on the express route. The essence of determining the rational parameters of such a mode is the mathematical modeling of the transportation process on the route, as a result of which the components of models (9) and (10) are calculated for certain combinations of stopping points on the express route and the number of buses operating in normal (A^{ob}) and express modes (A^{e}). In the future, based on the formed criterion, such parameters of the route operation are selected, which are characterized by maximum efficiency and quality of transportation.

$$W_N \to min;\ W_N \geq 0;\ A_{posle} < A_{do} = \sum A_i;\ \gamma_i \in [\gamma_{min} \cdots \gamma_{max}] \quad (9)$$

$$\sum T \to min;\ A_{do} = A_{posle} = \sum A_i;\ A_{min}^{ob} = t_{oб}^{ob} / I_{max}^{dop} \quad (10)$$

Where: A_{do}, A_{posle} - the total number of buses on the route operating before and after the introduction of the express mode, respectively;

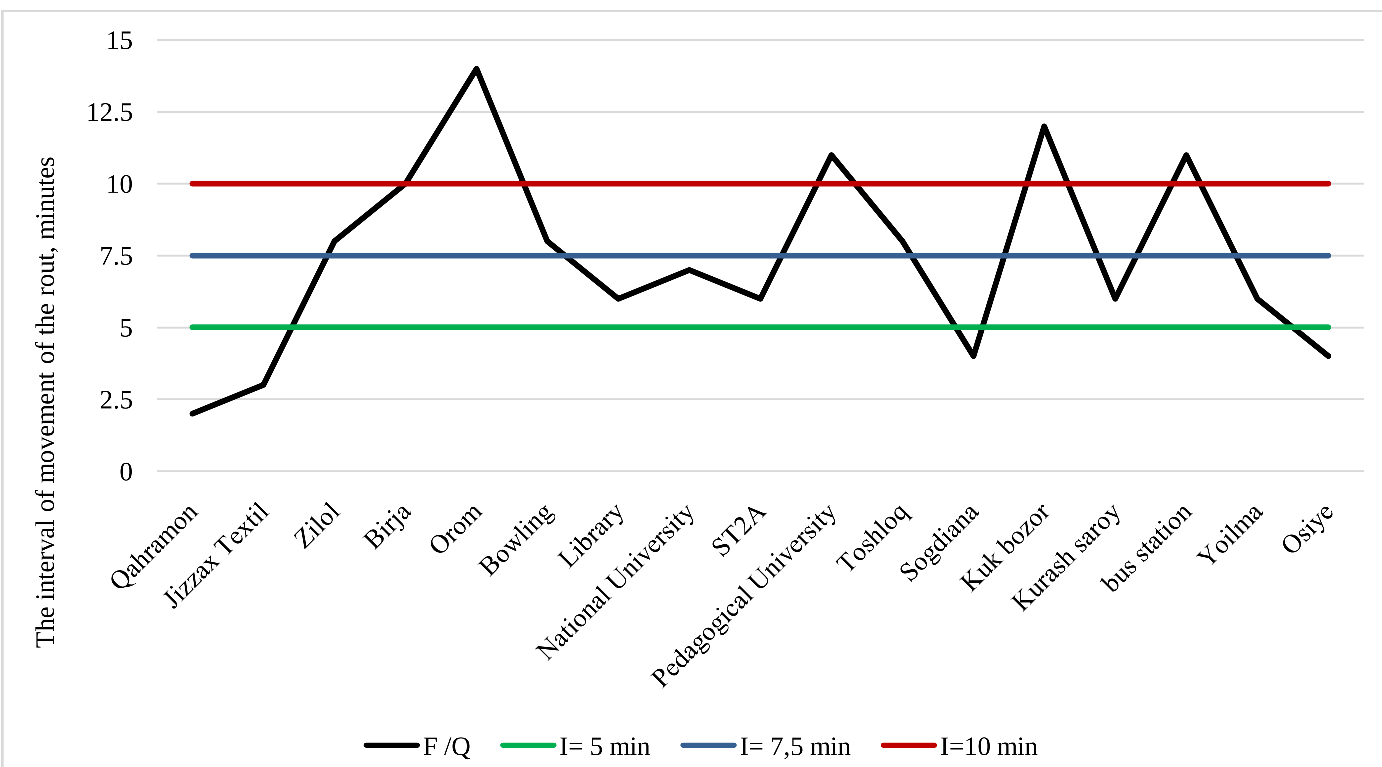

Figure-3: Definition of express route options.

A_i - the number of buses operating in the *i*-th traffic mode; $\sum T$- total time spent by passengers on the route, hour.; A^{ob}_{min} - the minimum allowable number of buses operating normally, provided that the maximum allowable travel interval is not exceeded; A^{ob}_{oborot} - the duration of the turnover of buses operating in normal mode, min.; I^{dop}_{max} - the maximum allowed interval for buses, min.; γ_i- the coefficient of utilization of the capacity of buses operating in the *i*-th mode of movement, $[\gamma_{min} \cdots \gamma_{max}]$ its minimum and maximum values in accordance with the conditions of economic feasibility and basic requirements for the quality of passenger transportation.

In accordance with the restriction regarding not increasing the maximum allowable travel interval by conventional buses, modeling must be carried out for several data groups, in each of which:

$$\begin{cases} A^{ob} = const \in \left[A^{ob}_{min}; A-1\right] \\ A^{E} \in var[1; A - A^{ob}]. \end{cases} \quad (11)$$

Changing the combination of stops on the express route Z_i and the number of buses that operate in normal A^{ob} and express A^E modes, you can get a plural number of values of W_N, which was chosen as the main criterion for transportation efficiency:

$$\begin{vmatrix} W_N^{Z_i}(A^{ob} = A^{ob}_{min}, A^E = 1), \ldots W_N^{Z_i}(A^{ob} = A^{ob}_{min}, A^E = A - A^{ob}) \\ W_N^{Z_i}(A^{ob} = A^{ob}_{min} + 1, A^E = 1), \ldots W_N^{Z_i}(A^{ob} = A^{ob}_{min} + 1, A^E = A - A^{ob}) \\ W_N^{Z_i}(A^{ob} = A^{ob}_{min} + 2, A^E = 1), \ldots W_N^{Z_i}(A^{ob} = A^{ob}_{min} + 2, A^E = A - A^{ob}) \\ W_N^{Z_i}(A^{ob} = A^{ob}_{min} + 3, A^E = 1), \ldots W_N^{Z_i}(A^{ob} = A^{ob}_{min} + 3, A^E = A - A^{ob}) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ W_N^{Z_i}(A^{ob} = A - 1, A^E = 1), \ldots W_N^{Z_i}(A^{ob} = A - 1, A^E = A - A^{ob}) \end{vmatrix} \quad (12)$$

Considering that 25 buses are operated on route No. 1, and $A^{ob}_{min} = 6$,, according to the accepted modeling conditions, 190 variants of the combined mode organization for each Z_1 were calculated, and their total number (taking into account Z_1 , Z_2 and Z_3) was 570 variants.

In the future, from the plural $W_N = f(Z_i, A^{ob}_i, A^E_i)$ under the conditions $A^{ob}_i = const$ and $Z_i = const$, one option is selected for further investigation, which provides for $W_N \to min$; $W_N \geq 0$;.. For a comprehensive assessment of the obtained *i*-th variants of the combined mode with express combination, it is proposed to use a criterion that additionally takes into account the quality of transportation: :$\gamma^E_i < 1.5; \gamma^{ob}_i < 1.5; \sum T \to min$; and an additional economic effect, which will be observed in the case of a minimal difference in the operating conditions of both modes and an increase in the utilization coefficients of bus capacity to $\gamma^{ob} \to 1$ and $\gamma^E \to 1$:

$$K_i^{kompl} = \begin{cases} 0; \ if \ K_i(\gamma) = 0 \\ K_i(W_N) + K_i(\gamma) + K_i(\sum T), if \ K_i(\gamma) > 0 \end{cases} \to min \quad (13)$$

Where: $K_i(W_N)$ -an indicator that takes into account the decrease W_N; $K_i(\gamma)$-an indicator that takes into account the filling of buses; $K_i(\sum T)$-an indicator that takes into account the reduction in the total time spent by passengers on movement.

The calculated dependences of the components of criterion (13) are given in [1-2, 7]. The developed algorithm of the method for determining the rational parameters of the express mode of movement is shown in Figure-6.

Based on the results of the performed mathematical modeling, it was found that the maximum efficiency of the passenger transportation process on route No. 1 can be achieved with such two variants of the combined mode with express coupling: $(Z_1 = 8, A^{ob} = 12, A^E = 6)$ и $(Z_1 = 13, A^{ob} = 8, A^E = 10)$. This will free up 7 buses and reduce W_N by 89%, reduce the total cost of passengers for movement by 6%, increase the speed of communication and the utilization factor of the capacity of buses by 15 and 24%, respectively. A comprehensive assessment of the parameters of the express mode of bus traffic on route No. 1 from the point of view of technological efficiency of transportation (TET) is shown in Table-2. Considering that the combined modes that were studied are formed by a combination of regular and express services, the overall technical and economic indicators along the route were calculated as weighted averages depending on the number of regular and express flights:

$$TET = \frac{TET^{ob} \cdot \Psi^{ob} + TET^E \cdot \Psi^E}{\Psi^{ob} + \Psi^E} \quad (14)$$

The analysis of the information shown in Table-2 shows that both proposed options can significantly improve the efficiency of the transportation process on route No. 1.

Thus, the main advantages of the introduction of a combined mode with express service on route No. 1 include: the possibility of releasing 7 bus units (28%), an increase in the speed of communication by 15%, the utilization factor of bus capacity by 24% and their hourly productivity by 35%; a reduction in the duration of the flight by 10%, the total mileage by 17%, which will allow (taking into account the lower fuel costs of buses operating in express mode) to reduce the total operating fuel costs by 25%.

However, the release of some buses on route No. 1 will also lead to certain negative phenomena, namely, an increase in the travel interval by 20% and a decrease in the provided capacity by 17%, which will affect the quality of passenger transportation. We will provide an assessment of such consequences. Before the introduction of combined modes, the travel interval on the route was 5 minutes, and after that 6 minutes, which can be considered acceptable and typical for most urban bus routes.

Regarding the study of the probability of passengers being denied boarding due to excessive filling of vehicles in operation[7-8], diagrams of passenger flows along route stretches for conventional and express buses in both combined modes were constructed. An analysis of the calculations performed indicates that on some stretches of the route there is an excess of the nominal capacity of buses (mainly those that operate normally) by 10-25%. Such excess filling of vehicles does not exceed the accepted standard of 8 passengers per 1 m^2 of free cabin area and, accordingly, will not lead to passenger refusals to board at the stopping points of the route and is considered acceptable from the point of view of transportation quality during the morning rush hour[9].

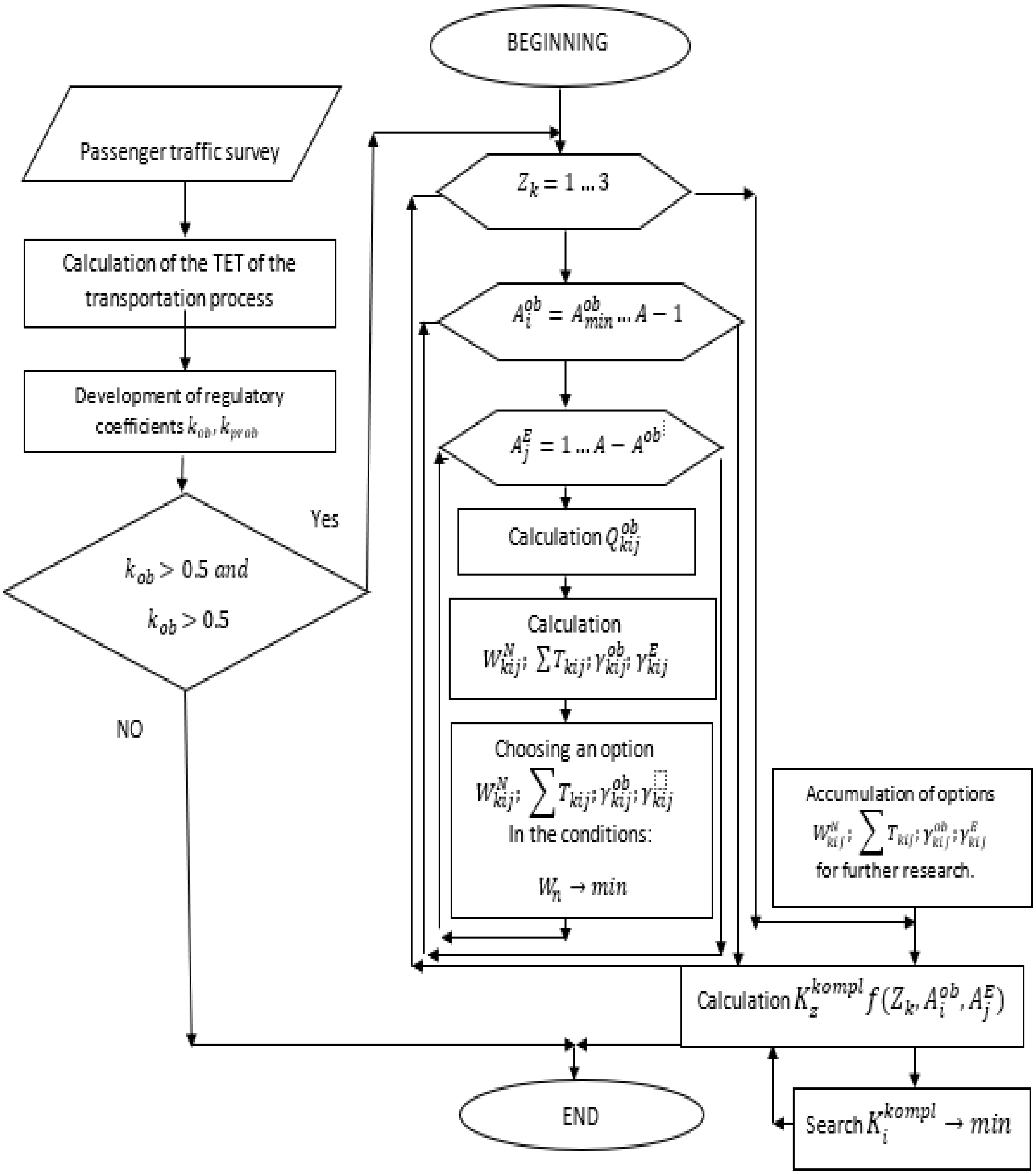

Figure-4: The algorithm of the method for determining the rational parameters of the express mode of movement.

Table-2: Evaluation of the parameters of the express mode of bus movement on the route from the point of view of technological efficiency of transportation

The name of the indicator	Current technology	Combined mode No. 1			Combined mode No. 2		
		$Z_1 = 8, A^{ob} = 12, A^E = 6$			$Z_1 = 13, A^{ob} = 8, A^E = 10$		
		Driving mode		Relative deviation	Driving mode		Relative deviation
	Usual	Ob	E		Ob	E	
Route length, km	20,4	20,4	20,4	0,0%	20,4	20,4	0,0%
		20,4			20,4		
Number of buses, units.	25	12	6	-28,0%	8	10	-28,8%
		18			18		
Number of stops, units.	27	27	8	-28,1%	27	13	31,1%
		19,4			18,6		
The average length of the stretch, km	0,78	0,78	2,91	109,2%	0,78	1,70	70,8%
		1,6			1,30		
Driving speed, km/h.	21,1	21,1	29,1	15,2%	21,1	26,6	15,6%
		24,3			24,4		
Operating speed, km/h.	19,4	19,4	26,0	13,6%	19,4	24,0	14,2%
		24,3			22,2		
Duration of the trip, min.	63	63	47	10,2%	63	51	11,4%
		57			56		
The duration of the revolution, min.	126	126	94	10,2%	126	102	11,4%
		113			112		
Movement interval, min.	5	10	15	20,0%	15	10	20,0%
		6			6		
Number of shipments,	12	6	4	-16,7%	15	10	16,7%
		10			6		
Provided capacity, pass.	552	276	184	-16,7%	184	276	16,7%
		460			460		
The number of passengers transported, pass.	829	585	244	0,0%	386	443	0,0%
		829			829		
Unproductive Transport work, pass.*km	2471,2	62,6	154,1	-91,2%	1,3	244,0	-90,1%
		216,7			245,3		
Bus capacity utilization coefficient	0,78	0,99	0,96	25,4%	1,00	0,95	24,4%
		0,98			0,97		
Total mileage of buses, km	244,8	122	81,6	-16,7%	81,6	122,4	-16,7%
		204,0			204,0		
Hourly bus performance, groove. / hour.	66	93	78	31,8%	92	87	34,8%
		87			89		
Fuel consumption, l / 100 km	26,2	26,2	19,8	-9,8%	26,24	21,5	-10,8%
		23,68			3,40		
Hourly fuel consumption, liters / hour.	64,24	32,12	16,18	-24,8%	21,41	26,32	-25,7%

Conclusion

One of the effective ways to improve the efficiency of vehicles and the quality of passenger service is to organize express traffic on urban bus routes. This measure makes it possible to reduce the time spent by passengers on movement, increase the use of buses and the level of public transport services without increasing the number of buses.

The aim of the work is to obtain a quantitative technical and operational assessment of the impact of the introduction of express bus traffic on the selected urban route of Jizzakh.

The urban route No. 1 ("Kahramon"-"Osiye-bozor") was chosen as the object of research. There are 25 Isuzu HC45 buses operating on the route with a capacity of q_n=39 passengers. According to the results of the passenger traffic survey, it was found that in the vast majority of route races, the proportion of unproductive transport work ranges from 10 to 70% (on average along the route 23%), which significantly reduces the efficiency of buses. The calculated values of the normalized coefficients of variability and unevenness of passenger flows on the sections of the route (which determine the conditions for organizing the appropriate modes of movement on bus routes) are 0.52 and 0.77, respectively, which confirms the expediency of introducing a combined mode with express service on route No. 1.

Three variants of the express route were formed, which consists of Z_1 = 8, Z_1=13 and Z_1=16 stops. Based on the results of the performed mathematical modeling, it was found that the maximum efficiency of the passenger transportation process on route No.1 can be achieved with the following two variants of the combined mode with express service: $(Z_1 = 8, A^{ob} = 12, A^E = 6)$ and $(Z_1 = 13, A^{ob} = 8, A^E = 10)$. This will free up 7 bus units (28%), increase the speed of communication by 15%, the utilization rate of bus capacity by 24% and their hourly productivity by 35%; reduce the duration of the flight by 10%; the total mileage of buses by 17%, which will (taking into account the lower fuel costs of buses operating in express mode) reduce the total operating fuel costs by 25%.

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