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7 QUALITY MANAGEMENT OF PASSENGER TRANSPORT BY ROAD TRANSPORT IN TIME DEFICIT CONDITIONS

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ABSTRACT

This section examines the theoretical and methodological aspects of assessing the quality of passenger transportation by road under time constraints. The standards for customer time expenditure on passenger transportation by road under time constraints in urban conditions are substantiated by quality levels (high; medium; low) and groups of cities (Group I — cities with a population of over 1 million people; Group II — cities with a population of 500 thousand to 1 million people; Group III — cities with a population of 250 thousand to 500 thousand people; Group IV — cities with a population of less than 250 thousand people). Attention is paid to the methodological aspects of assessing the quality of domestic regional passenger transportation by road under time constraints. The methodological and applied aspects of managing the quality of passenger transportation by road under time constraints are highlighted. Alternatives for improving the quality of passenger transportation by road transport in conditions of time shortage are identified: optimization of the density of the road network and bus intervals on routes; optimization of the length of the stages and the speed of connections on bus routes. Examples of solving the problem of choosing the optimal directions for increasing the density of the road network and reducing the intervals of bus movements on routes are considered. Variations of solving the problem of optimizing the length of the stages and the speed of connections on bus routes are considered, provided that a high-speed mode and an express mode of bus movement are introduced alongside the usual modes of movement of passenger road transport rolling stock. The key stages of the methodology for surveying the route bus network and implementing methods for managing the quality of passenger transportation by road transport in conditions of time shortage are characterized. Attention is paid to planning (including standardization) of indicators and sub-indicators of the quality rate of passenger transportation by road transport, in particular the rate of bus fleet utilization and bus operating speed.

KEYWORDS

Quality, passenger transportation, road transport, time deficit, bus route.

7.1 THEORETICAL AND METHODOLOGICAL ASPECTS OF ASSESSING THE QUALITY OF PASSENGER TRANSPORTATION BY ROAD TRANSPORT IN CONDITIONS OF TIME DEFICIT

Today, road transport is the undisputed leader of land transport in passenger transportation in the world (**Table 7.1**).

Table 7.1 Passenger transportation by road transport in some countries of the world

Countries	Passenger transportation by road, million passenger-km	% of passenger transportation by land transport*
Australia	275309	96.89
Azerbaijan	16892	99.39
Croatia	25529	97.93
Czech Republic	93335	93.19
Finland	69600	96.00
France	777509	90.00
Georgia	5212	95.02
Germany	836625	93.57
Hungary	80447	93.67
Iceland	7557	100.00
Italy	657691	95.96
Japan	750471	72.14
New Zealand	53658	98.65
Norway	59211	97.08
Poland	252807	94.08
Spain	348402	95.22
Sweden	98813	92.49
Switzerland	99197	87.39
Turkey	336188	96.93
United Kingdom	584032	94.98
USA	6171807	99.75

Source: compiled by the authors

*Note: *calculated by the authors based on data [1]*

And in Ukraine, road transport traditionally provides transportation of more than 90 % of passengers [2], so the issue of improving the quality of passenger road transportation remains relevant.

Of course, the quality of passenger transportation by road is a complex, comprehensive concept that includes many diverse aspects, such as:

– highly qualified professional drivers and fair tariffs for transporting customers by bus routes [3–8];

– perfect design characteristics of buses [9, 10];

– regularity, rhythm, uninterruptedness and convenience of transporting customers by bus routes [11–15];

– accessibility and safety of services for transporting customers by bus routes, in particular in accordance with the Sustainable Development Goals [16–26];

– information support for customers, automation of business processes of partner interaction [27–33], etc.

In this study, the authors are based on the thesis that the most valuable and scarce human resource in the modern world is time, therefore the key criterion for the quality of passenger transportation by road transport should be the time spent by customers on movement and its minimization.

Let's believe that the time spent by customers on movement consists of:

– time to move to/from the bus stop (t_1);

– time of initial waiting for the bus (t_2);

– time of the next waiting for the bus (in case of refusal of transportation after the initial waiting for the bus) (t_3);

– direct time of transportation by road transport (buses) (t_4);

– time for transfers (t_5).

The quality of passenger transportation by road transport in conditions of time shortage is proposed to be assessed by the quality rate as the ratio of the estimated value of the time spent on movement in reference conditions (t_m^e) and the estimated value of the time spent on movement in actual conditions (t_m^a):

$$K_q = \frac{t_m^e}{t_m^a}. \quad (7.1)$$

The elements of time spent by road transport companies' customers on travel are calculated as follows:

1) travel time to/from the bus stop:

$$t_1 = 0.0075\left(\frac{2000}{\delta} + \frac{1000L_{tot}}{N_{stop}}\right), \quad (7.2)$$

where δ – density of the road network, km/km^2; L_{tot} – total length of the bus route, km; N_{stop} – number of stops on the bus route;

2) initial waiting time for the bus:

$$t_2 = \frac{i}{2}\left[3 - 2K_{rp} + 2K_{rp}\left(1 - K_{rr}\right)\left(\frac{\Delta i}{i}\right)^2\right], \quad (7.3)$$

where i – weighted average interval of bus movement along the route, min.; Δi – deviation from the time of arrival and departure of buses at the control points of the route, min.; K_{rp} – run performance rate:

$$K_{rp} = \frac{N_r^a}{N_r^{pl}}, \quad (7.4)$$

where N_r^a – actual number of runs performed on the bus route; N_r^{pl} – planned number of runs provided for by the bus route schedule; K_{rr} – run regularity rate:

$$K_{rr} = \frac{N_r^r}{N_r^a}, \quad (7.5)$$

where N_r^r – the number of regular runs performed on the bus route

3) the time of the next waiting for the bus (in case of refusal of transportation after the initial waiting for the bus):

$$t_3 = \frac{T}{2} d \left(2 - K_{rp} - \frac{1}{Y_d} \right), \quad (7.6)$$

where T – duration of the peak period, min.; d – transfer rate; Y_d – dynamic rate of bus capacity utilization;

4) direct time of transportation by road transport (buses):

$$t_4 = \frac{60 l_t^{av} d}{V_r}, \quad (7.7)$$

where l_t^{av} – average distance of a client's trip on a bus route, km; V_r – speed of buses on the route, km/h;

5) time for transfers:

$$t_5 = (d - 1)(0.015 l_t + t_2), \quad (7.8)$$

where l_t – average distance of the client's transfer, m.

In this case, the time spent by clients of road transport enterprises on movement is determined during peak hours and by average daily values:

– by peak hour indicators:

$$t_4^p = 11.75 + 3\left(1.2 + 0.17\sqrt{F}\right), \quad (7.9)$$

where F – built-up area of the city, km^2;

– by average daily indicators:

$$t_4^{av} = 12.25 + 3\left(1.2 + 0.17\sqrt{F}\right). \quad (7.10)$$

Based on the above-mentioned patterns, the norms of customer time expenditure for passenger transportation by road transport in conditions of time deficit in urban conditions were determined by quality levels (high; medium; low) and groups of cities (Groups I–IV) (**Table 7.2**).

Table 7.2 Norms of customer time expenditure for passenger transportation by road transport in conditions of time deficit in urban conditions

Groups of cities by the "population" criterion	Quality level	Time spent, min.
Group I cities with a population of over 1 million people	– high – medium – low	32 40 49
Group II cities with a population of 500 thousand people to 1 million people	– high – medium – low	28 35 43
Group III cities with a population of 250 thousand people to 500 thousand	– high – medium – low	24 30 37
Croup 4 cities with a population of less than 250 thousand people	– high – medium – low	20 25 32

Source: developed by the authors

While in the regional context, the quality of passenger transportation by road transport in conditions of time deficit includes the time spent on moving to the bus stop (t_1), waiting for the bus (t_2) and direct transportation of customers (t_4).

In this case, the time of moving customers to the bus stop is determined as a weighted average value per resident of the region as follows:

$$t_1 = \frac{7.5}{P_{tot}}\left(3P_o + \frac{1}{\delta}P_{no}\right), \tag{7.11}$$

where P_{tot} – the total population of the region, people; P_o – the population of the region that uses regular bus services, people; P_{no} – the population of the region that does not use regular bus services, people.

The waiting time for bus customers will be calculated as follows:

$$t_2 = 7K_{rp}\left(1-K_{rr}\right)+i\left(1-K_{rp}\right)+5. \tag{7.12}$$

The time for customer transportation will be determined as follows:

$$t4 = \frac{60 l_t^{av}}{V_r}. \quad (7.13)$$

Thus, the total time spent by customers on trips using the regular bus network within the region will be:

$$t_t = \frac{7.5}{P_{tot}}\left(3P_o + \frac{1}{\delta}P_{no}\right) + 7K_{rp}\left(1 - K_{rr}\right) + i\left(1 - K_{rp}\right) + 5 + \frac{60 l_t^{av}}{V_r}. \quad (7.14)$$

The developed methodology for assessing the quality of passenger transportation by road transport in conditions of time deficit allows solving the following tasks:

– to assess the quality of passenger transportation by road transport in conditions of time deficit in urban conditions and within the region;

– to determine by calculation the actual time costs of customers for transportation using the regular bus network;

– to analyze the time costs of customers for transportation by road transport by elements and, thanks to this, to comprehensively form a list of measures to improve the quality of passenger service, in particular by minimizing the time costs of customers for transportation to/from the bus stop, initial waiting for the bus, subsequent waiting for the bus (in case of refusal of transportation after the initial waiting for the bus), transportation by road transport, making transfers;

– to determine the optimal structure of the bus fleet for a specific route, group of routes or a separate region.

7.2 METHODOLOGICAL AND APPLIED ASPECTS OF MANAGING THE QUALITY OF PASSENGER TRANSPORTATION BY ROAD TRANSPORT IN CONDITIONS OF TIME SHORTAGE

The goal of managing the quality of passenger transportation by road transport in conditions of time shortage is to minimize the time spent by customers on travel.

In this context, two complexes of methods for improving the quality of passenger transportation by road transport should be distinguished, aimed at:

– optimizing the density of the road network and bus intervals on routes;

– optimizing the length of stages and the speed of connections on bus routes.

Let's consider these methods in more detail.

The replenishment of the bus fleet, as well as the redistribution of the existing rolling stock of passenger road transport, is aimed at developing the route network, reducing travel intervals or their simultaneous change.

An increase in the density of the road network has a positive effect on reducing the time spent by customers on traveling to/from the bus stop.

Reducing the intervals of bus movements on routes reduces the time spent by customers on waiting at the bus stop.

The criterion for choosing the optimal use of passenger road transport rolling stock is the minimum of the total time spent by customers on moving to/from the bus stop and the time spent by customers on waiting at the bus stop:

$$t_1 + t_2 \to \min. \tag{7.15}$$

The effectiveness of management decisions in the context of the need to minimize customer time spent traveling to/from the bus stop is determined by the annual savings of this indicator:

$$E_{t_1} = \left(t_{1(1)} - t_{1(2)}\right)\frac{P}{d}, \tag{7.16}$$

where $t_{1(1)}$, $t_{1(2)}$ — time to travel to/from the bus stop before and after the implementation of management decisions, respectively, min.; P — annual volume of passenger transportation, passengers.

In this case, the transfer rate (d) is taken depending on the group of cities according to the "population" criterion (**Table 7.2**) in the following amount:

— Group I: $d = 1.4$;
— Group II: $d = 1.3$;
— Group III: $d = 1.2$;
— Group IV: $d = 1.1$.

The amount of annual savings in customer time spent on travel to/from the bus stop, achieved due to an increase in the density of the motor transport network, will be determined as follows:

$$E_{t_1} = \left(\frac{15}{\delta_1} - \frac{15}{\delta_2}\right)\frac{P}{d}, \tag{7.17}$$

where δ_1, δ_2 — the density of the motor transport network before and after the implementation of management decisions, respectively, km/km^2.

The annual savings in customer time spent waiting at the bus stop, achieved by reducing bus intervals on routes, will be determined as follows:

$$E_{t_2} = \frac{i_1 - i_2}{2K_{rp}}\frac{P}{d}, \tag{7.18}$$

where i_1, i_2 — the weighted average intervals of bus traffic on routes before and after the implementation of management decisions, respectively, min.

Let's consider the solution to the problem of choosing the optimal directions for increasing the density of the motor transport network and reducing the intervals of bus traffic on routes using a specific example.

In the city of Group I, the average interval of bus traffic on routes is 7 min, the density of the motor transport network is 2 km/km^2. The planned volume of transportation for the next year is 200 million passengers and an increase in the number of buses by 10 %. It is necessary to determine which of the indicators – the density of the motor transport network or the interval of bus traffic on routes – should be developed first.

To solve this problem, it is necessary to determine points on the following lines:

$$\Delta t_1 = f(\delta = 2) = 0.350 \text{ min}, \tag{7.19}$$

$$\Delta t_2 = f(i = 7) = 0.245 \text{ min}. \tag{7.20}$$

Comparing the obtained values according to the criterion of minimizing customer time costs, it is possible to that under the given conditions it is more rational to increase the density of the motor transport network.

The planned increase in the number of buses by 10 % will logically allow to increase the density of the motor transport network by 10 % with unchanged bus travel intervals along the routes:

$$\delta_2 = \delta_1 \cdot 1.1 = 2.0 \cdot 1.1 = 2.2 \text{ km/km}^2. \tag{7.21}$$

Thus, the annual savings in customer time costs for moving to/from the bus stop will be:

$$E_{t_1} = \left(\frac{15}{2.0} - \frac{15}{2.2} \right) \frac{2 \cdot 10^8}{1.4} = 97.4 \text{ million min} \approx 1.6 \text{ million h}. \tag{7.22}$$

Let's conduct an experiment and slightly transform the initial data of the problem: assuming that the city group, the planned volume of passenger transportation and the increase in the number of buses are maintained, let's imagine that the interval of bus traffic along the routes is 10.1 min, the density of the motor transport network is 2.92 km/km^2. In this case, let's take the run performance rate as 0.97.

Under the given conditions, it is more rational to reduce the intervals of bus traffic along the routes.

The planned increase in the number of buses by 10 % will logically allow reducing the intervals of bus traffic along the routes by 10 % without increasing the density of the motor transport network:

$$i_2 = 10.1 \cdot \frac{1}{1.1} = 9.2 \text{ min}. \tag{7.23}$$

Then the annual savings in customer time spent waiting at the bus stop will be:

$$E_{t_2} = \frac{10.1 - 9.2}{2 \cdot 0.97} \cdot \frac{2 \cdot 10^8}{1.4} = 66.3 \text{ million min} \approx 1.1 \text{ million h}. \tag{7.24}$$

Increasing the speed of passenger transportation by road transport can be achieved through the modernization of rolling stock, improvement of the route bus network, improvement of road conditions, automation of the road traffic management system, etc.

Of course, the above measures require an integrated approach, significant material costs and, as a rule, cannot be implemented only by the resources of road transport enterprises that provide passenger transportation services.

In turn, road transport enterprises can contribute to increasing the speed of customer transportation by introducing a high-speed mode and an express mode of bus traffic alongside the usual modes of traffic of passenger road transport rolling stock.

In the high-speed mode of traffic, buses stop only at individual stops along the route.

In the express mode of traffic, buses move between the initial and final destinations without other stops along the route.

Increasing the speed of customer transportation by road when implementing high-speed and express bus traffic is achieved by increasing the length of the stages:

$$V_2 = V_1 + V_s \lg \frac{l_2}{l_1}, \tag{7.25}$$

where V_1, V_2 – speed of buses on the route before and after the introduction of the high-speed mode and express mode, respectively, km/h; V_s – standard change in speed of buses on the route (V_s = 10 km/h); l_1, l_2 – length of the stages before and after the introduction of the high-speed mode and express mode of buses on the route, respectively, m.

The effectiveness of the introduction of the high-speed mode and express mode of buses alongside the usual modes of movement of passenger road transport rolling stock is determined by the annual savings in customer time spent on trips:

$$E_{t_4} = \left(\frac{1}{V_1} - \frac{1}{V_2}\right) l_t^{av} \cdot P_2, \tag{7.26}$$

where P_2 – the annual volume of passenger transportation by buses in high-speed mode and express mode on the route, passengers.

Let's consider an example of calculating the annual savings in customer travel time in the event of the introduction of high-speed mode and express mode of bus traffic at a road transport enterprise alongside the usual modes of traffic of passenger road transport rolling stock.

A bus route with a length of 24 km in the forward and reverse directions is characterized by the following technical and economic indicators: average speed of buses on the route – 18 km/h; average distance of a client's trip – 4.5 km; average length of stages – 600 m; annual volume of passenger transportation – 2 million passengers. It is planned to introduce transportation in high-speed mode (with a total number of stops – 6) and express mode on the route. It is expected that 500 thousand passengers will use the high-speed and express services during the year.

Let's determine the average length of the stages in the high-speed mode of bus traffic on the route:

$$l_2 = \frac{l}{N_{stop}} = \frac{24}{6} = 4 \text{ km.} \tag{7.27}$$

Next, let's determine the speed of the bus route:

$$V_2 = 18 + 10\lg\frac{4}{0.6} = 26.23 \text{ km/h.} \tag{7.28}$$

Thus, the implementation of a high-speed mode on a bus route will contribute to an increase in the speed of passenger transportation by road:

$$\Delta V = \frac{V_2 - V_1}{V_1} \cdot 100 = \frac{26.23 - 18}{18} \cdot 100 = 45.7 \text{ \%.} \tag{7.29}$$

Accordingly, the efficiency of the introduction of a high-speed mode on a bus route will be:

$$E_{t_4} = \left(\frac{1}{18} - \frac{1}{26.23}\right) 4.5 \cdot 5 \cdot 10^5 = 39.2 \text{ thousand h.} \tag{7.30}$$

In the case of the implementation of an express mode on the route, the following speed is expected:

$$V_2 = 18 + 10\lg\frac{12}{0.6} = 31 \text{ km/h.} \tag{7.31}$$

The implementation of express traffic on a bus route will contribute to an increase in the speed of passenger transportation by road:

$$\Delta V = \frac{31 - 18}{18} \cdot 100 = 72.2 \text{ \%.} \tag{7.32}$$

The efficiency of the introduction of express traffic on a bus route will be:

$$E_{t_4} = \left(\frac{1}{18} - \frac{1}{31}\right) 4.5 \cdot 5 \cdot 10^5 = 52.4 \text{ thousand h.} \tag{7.33}$$

The required number of runs in high-speed mode and express mode is determined by the actual passenger flow on the bus route. In this case, it is important that the use of bus capacity is the same as in the normal mode of bus traffic on the route, or that the decrease in the level of bus occupancy correlates with the increase in the speed of the connection.

The developed methodology for examining the route bus network and implementing methods for managing the quality of passenger transportation by road transport in conditions of time shortage can be conditionally divided into the following stages:

Stage I. Collection of the following data for each bus route:

– length of the bus route;
– time of the return run on the bus route;
– daily duration of the bus route;
– number of return runs per day by bus brand;
– number of return runs during peak hours by bus brand;
– maximum passenger flow on the busiest section of the bus route during peak hours;
– daily passenger flow of the bus route;
– average distance of a client's run on a bus route;
– number of bus stops on the route.

In addition to the specified data for the city as a whole and for each district of the city, the following information is required:

– area of the built-up part of the city;
– density of the motor transport network;
– total length of bus routes;
– total number of stops on bus routes;
– run performance rate;
– run regularity rate;
– average distance of a passenger's trip;
– daily volume of passenger transportation.

Stage II. Drawing up motor transport schemes for the city as a whole and for each district of the city separately without interruption of bus routes. Residential areas, industrial zones, bus stops are indicated on the schemes, on the basis of which the possibility of organizing the movement of buses of different sizes along the streets of a certain district of the city is determined.

Stage III. Study of the density of the motor transport network and intervals of movement on bus routes, determination of optimal values of these indicators. Based on the values of the density of the road network and the intervals of movement on bus routes, a management decision is made on the need to change them. In the event of a need to reduce the intervals of movement on bus routes by reducing the density of the road network, bus routes are combined on parallel intervals. However, in modern conditions of the development of the road network, the optimal value of its density significantly lags behind the optimal value of the intervals of bus movement, which leads to the need to increase the density of the road network by proportionally reducing the intervals of bus movement, which becomes possible due to the replenishment of the fleet of passenger road transport.

Stage IV. Study of the length of bus route runs and the selection of their optimal value. Based on data on the absolute value of the length of bus route runs, the speed of connection and the average distance of the customer's trip, the optimal length of the run for a particular bus route is determined. Then, initially on the bus route diagram and subsequently on the ground, the required number of bus stops and their placement are determined. The number and location of bus stops should ensure that customers can easily and safely approach them and transfer to another bus route. After the number and location of bus stops are finally determined, the speed of service on the route is adjusted.

Stage V. Comparison of the carrying capacity of the buses of the road transport enterprise and the actual passenger flow during peak hours, taking into account their unevenness in time, direction and sections of the route. At the same time, the possibility of replacing buses with more capacious ones is considered on those sections of the route where the excess of the passenger flow over the carrying capacity of the buses of the road transport enterprise is detected. This replacement can be carried out both by increasing the number of buses on the routes and by more rational distribution of buses between the routes. Such a measure allows to equalize the values of the occupancy of buses during peak hours throughout the route network and, accordingly, to improve the quality of customer transportation.

Stage VI. Research and improvement of bus traffic regimes on routes during peak hours. Such a study is carried out in order to identify the possibilities of organizing high-speed runs, express runs or shortened runs, which will allow to increase the speed of communication on the bus route, balance the occupancy of buses during peak hours and, thereby, increase the carrying capacity of buses of the road transport enterprise.

Stage VII. Drawing up a scheme of bus routes and developing proposals for changing the bus schedule on the routes. Schemes are drawn up separately for each bus route, district of the city and the city as a whole. This stage ends with the formation of a draft bus schedule for routes.

Stage VIII. Practical implementation of the developed bus schedules for routes.

Stage IX. The developed methodology for managing the quality of passenger transportation by road transport in conditions of time shortage is completed by calculating the total economic effect of the implemented measures according to the formula:

$$E = \frac{\left(t_{(n1)} - t_{(n2)}\right) \cdot \varepsilon' \cdot P}{60}, \tag{7.34}$$

where $t_{(n1)}$, $t_{(n2)}$ – time spent by customers on travel before and after the implementation of management decisions, respectively, min.; ε' – cost expression of passenger-hour, monetary unit.

7.3 METHODOLOGICAL ASPECTS OF PLANNING THE QUALITY OF PASSENGER TRANSPORTATION BY ROAD IN CONDITIONS OF TIME SHORTAGE

An integral element of managing the quality of passenger transportation by road is the planning of indicators and sub-indicators, which form the planned value of the quality rate of passenger transportation by road (**Table 7.3**).

Table 7.3 Indicators and sub-indicators of the quality rate of passenger transportation by road

	Indicators	Sub-indicators
Quality rate of passenger transportation by road transport	1. Bus fleet utilization rate	1.1. Average age of the bus fleet
		1.2. Mileage of the bus fleet since the beginning of operation
		1.3. Technical equipment of road transport enterprises
		1.4. Availability of resources for the transportation process
	2. Bus operating speed	2.1. Road condition
		2.2. Traffic intensity on the roads
		2.3. Terrain
		2.4. City group
	3. Changes in bus fleet structure	3.1. Commissioning of new, more technically advanced buses
		3.2. Decommissioning of technically obsolete buses
	4. Optimization of operational indicators	4.1. Length of stages and speed of service
		4.2. Density of the road network and traffic intervals

Source: compiled by the authors

Planning of quality indicators of passenger transportation by road transport consists in determining their absolute value for the planned period, taking into account the forecasted operating conditions, composition and mode of movement of the bus fleet, and the availability of unused reserves.

Thus, the system of planning the quality of passenger transportation by road transport should be based not on a dynamic series, but on reasonable standards.

In this case, the initial stage is planning the increase in passenger capacity taking into account the rates of movement (input and output) of the bus fleet, on the basis of which a possible reserve for increasing the number of buses on routes is determined by bringing the rate of use of the bus fleet to the normative value.

In this context, the normative value of the bus fleet utilization rate is determined by the formula:

$$K_{bfu(n)} = K_{trb(n)} \cdot \alpha, \tag{7.35}$$

where $K_{trb(n)}$ – the normalized rate of technical readiness of buses; α – the rate that takes into account the degree of use of technically serviceable buses.

In turn, the rate of technical readiness of buses is normalized depending on the sub-indicators of the rate of utilization of the bus fleet, namely:

– the average age of the bus fleet (T_{bf});

– the mileage of the bus fleet since the beginning of operation (L_{bf});

– the technical equipment of road transport enterprises (TE).

The normalized value of the rate of technical readiness of buses depending on the average age of the bus fleet is determined as follows:

$$K_{trb(n)f(T_{bf})} = 1 - 0.005 \cdot T_{bf} - 0.002 \cdot T_{bf}^{2}. \quad (7.36)$$

The normalized value of the coefficient of technical readiness of buses depending on the average age of the bus fleet and the mileage of the bus fleet since the beginning of operation will be determined as follows:

$$K_{trb(n)f(T_{bf};L_{bf})} = K_{trb(n)f(T_{bf})} \cdot K_{L}, \quad (7.37)$$

where K_L – the correction rate.

The correction rate K_L is determined using **Table 7.4** depending on the average mileage of 1 bus since the beginning of operation at the road transport enterprise.

Table 7.4 Dependence of the correction coefficient K_L on the average mileage of 1 bus since the beginning of operation at the road transport enterprise

Average mileage of 1 bus since the beginning of operation, thousand km	0–175	175–262	262–350	More than 350
K_L value	0.92	0.89	0.88	0.84

Source: compiled by the authors

The normalized value of the rate of technical readiness of buses, depending on the average age of the bus fleet, the mileage of the bus fleet since the beginning of operation and the technical equipment of road transport enterprises, is formed as follows:

$$K_{trb(n)f(T_{bf};L_{bf};TE)} = K_{trb(n)f(T_{bf};L_{bf})}\left(0.05 \cdot TE + 0.95\right). \quad (7.38)$$

The obtained value of the change in passenger capacity must be distributed by type of transportation (urban, suburban, intercity). This value can be used for:

– creating a reserve of the bus fleet;
– reducing the number of unfulfilled runs;
– developing the route network;
– increasing the density of the route network;
– reducing the intervals of movement in the existing route network.

An important component of the quality of passenger transportation by road transport is the operating speed. For cities with identical traffic conditions, a single value of the connection speed is normalized, which may differ only for individual routes depending on road conditions and traffic conditions. For this purpose, cities are divided into groups according to a number of characteristics, such as geographical location, terrain, population, etc. At the same time, the connection speed for each group is normalized by the leader, that is, by the maximum value of the operating speed in the group.

The normative value of the connection speed is adjusted by the actual stage length:

$$V_{c(s)} = V'_{c(s)} + 10\lg\frac{l_n}{l_a}, \tag{7.39}$$

where $V'_{c(s)}$ – the initially established connection speed standard, km/h; l_n – the normative stage length for a particular city, km; l_a – the actual stage length for the leader city in the group, km.

$$i_n = i_a \frac{V_{c(a)}}{V_{c(n)}}, \tag{7.40}$$

where $V_{c(a)}$, $V_{c(n)}$ – the actual and standard speed of service, respectively, km/h; i_a – the actual bus travel interval, min.

When normalizing the actual value of passenger flows and the carrying capacity of the bus fleet, changes in the speed of communication and the number of urban residents are taken into account.

An increase in operating speed is a significant reserve for increasing the efficiency of using the bus fleet.

At the same time, there are two ways to increase the operating speed without increasing the speed of movement on the routes:

– introducing high-speed runs and express bus traffic modes;

– introducing variable bus traffic modes during the day (in particular, reducing bus parking at terminal stops to a minimum during peak hours).

It is advisable to introduce high-speed runs and express runs on routes with a small passenger turnover at intermediate stops or on routes with a limited number of stops with a significant passenger turnover.

The rationality of the organization and justification of the specific weight of high-speed runs and express runs are determined on the basis of an analysis of passenger flows, which is a rather laborious process. At the same time, there is a certain relationship between the specific weight of passengers on the main part of the route and the passenger turnover rate on the route.

In this context, the passenger turnover rate on the route can be represented by the expression:

$$K_{pt} = \frac{L_{tot}}{l_t^{av}}, \tag{7.41}$$

where L_{tot} – total length of bus route, km; l_t^{av} – average distance of client's trip on bus route, km.

The smaller the value of passenger variability coefficient on route, the greater is the specific weight of those passengers who follow from initial to final stop point or the majority of route.

Using the established dependence allows road transport enterprises to organize express and express runs on routes without laborious process of passenger flow research.

The rational number of high-speed and express runs on city bus routes is determined based on dependence on passenger variability coefficient at stop points (**Table 7.5**).

Table 7.5 Dependence of the number of high-speed and express runs on city bus routes on passenger variability rate

Passenger turnover rate	1.0–1.2	1.2–1.8	1.8–2.5	More than 2,5
Number (frequency) of high-speed and express runs	100 %	50 %	33 %	0 %

Source: compiled by the authors

The implementation of high-speed and express routes increases the operating speed of buses by 10–40 %, depending on the number of intermediate stops on the route before and after, as well as a number of other factors characterizing the bus fleet, road conditions, etc.

In order to maximize the carrying capacity of the bus route during peak hours, a variable bus traffic regime is established, which involves minimizing the duration of bus stops at intermediate and final stops. For this, the actual and required parking time at each stop is timed. At least 50 measurements are made on each bus route (preferably on different buses and during the shifts of different drivers).

According to the results of the study, the standards for the required duration of stops are established as arithmetic averages for groups of measurements for each stop. 10% of measurements with minimal downtime at the stop and 10 % of measurements with maximum values are excluded from the group.

These standards are used to standardize operating speeds, establish bus intervals and the number of trips during peak periods. During the off-peak period, the duration of bus stops at the final stops is increased according to the scheduled schedule in order to provide bus drivers with short-term rest to relieve fatigue (both physical and psychological).

When implementing variable bus traffic modes during the day, the dependence of the increase in the operating speed of buses during peak hours on the length of the route should be taken into account (**Table 7.6**).

Table 7.6 Dependence of the increase in the operating speed of buses during peak hours on the length of the route

Route length, km	Up to 3	3–5	5–7	7–10	10–15	More than 15
Increase in operating speed of buses during peak hours, %	15–20	10–15	7–10	4–7	2–4	2

Source: compiled by the authors

7.4 DISCUSSION OF THE RESULTS OF PLANNING THE QUALITY OF PASSENGER TRANSPORTATION BY ROAD TRANSPORT IN CONDITIONS OF TIME SHORTAGE

The cycle of work performed using the developed methods of managing the quality of passenger transportation by road transport can be completed by drawing up a bus route scheme and developing proposals for improving the bus schedule.

At the same time, drawing up bus route schemes and developing proposals for improving the bus schedule should be carried out in terms of individual routes, city districts and the city as a whole.

The development of route schemes and improving bus schedules should be based on a detailed analysis of passenger flows, transport demand and the level of road congestion at different times of the day. It is especially important to take into account peak periods to ensure the optimal frequency of runs and reduce passenger waiting time.

In addition, it is worth paying attention to the effective integration of bus routes with other types of public transport, such as trams, trolleybuses and metro (if available), in order to create a single transport network with the most convenient transfers for passengers. This will ensure quick access to key residential areas, industrial zones, business centers and socially important objects of the city.

It is also important to take into account the factors of environmental safety and economic feasibility. Reducing the duplication of routes and optimizing traffic schedules will help reduce the costs of servicing routes and reduce emissions of harmful substances into the atmosphere.

The implementation of modern information monitoring and dispatching systems will allow for prompt adjustment of schedules in real time, taking into account traffic situations and changes in passenger demand.

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