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RATIONALE OF COMPLEX INDICATOR OF QUALITY OF PUBLIC TRANSPORT

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Abstract

The significance of the criteria for assessing the quality of the urban passenger transport is investigated in the article. The results of the processing of field studies have identified factors that can be used for the assessment of the quality of the projects of urban passenger transport. The method of estimation of indicators of quality for the passengers during the trip is given and the values of weighting coefficients of individual quality indicators for the elements of the trip are determined. The method of determining the complex quality indicator during the performance of the trips in the projects of public transport is developed. It is shown that the trip components influence the quality of passenger trips in the following order: waiting time at the stop, time of the pedestrian part of the trip, travel time, dynamic coefficient of capacity utilization.

Keywords: passenger, transportation, quality, value, route, approach, waiting time, trip, stop.

1. INTRODUCTION

The public transport system is one of the most important components of urban infrastructure, without which the normal existence of the modern big city would be impossible. Passenger transport is an essential part of the city life, the main task of which is well-timed, good quality passenger transportations satisfaction. It is one of the key factors which ensure the livelihood of the population. For instance, in London, more than 10 million passengers use public transport services every day (Transport for London, 2017). The efficient and reliable operation of public transport is an important factor of social and economic stability. In the present crisis, it is necessary to increase the speed of communication and travel comfort, considering the solvency of the population. The quality of public transport services has a considerable influence on labour activity, cultural development and recreation of the population.

2. ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

The current level of passenger transportation does not meet modern requirements relating to the quality of passenger transportation. Travel time prescribed by standards for the passenger trips is not provided, due to low speed connections of main types of urban passenger transport, the need to perform transfers because of imperfect route network and time spent to approach stops (Borisovich Ed., 2003). In large European cities, more than 50% of public transport users spend more than 1 hour for every day movement to work. (Ciobanu, Bugheanu, Ciobanu, 2015).

Passenger transportation by urban transport should be done with big conveniences, safety and possibly less time spent on the trip. This requires the design of a qualitative transport service for citizens. Quality management consists of processes which ensure that the product of the project and the project itself will satisfy the needs of those members of the project for whom it was created. Quality management in modern projects is carried out at all stages and covers all its aspects (Dolia & Ivanov, 2014). Quality of service for the passengers using urban transport is an important social and economic problem for every city.

Improving the quality of passenger transportation in the urban passenger transport system is one of the most important tasks given by the needs of society in the field of transport (Kush, 2015; Cronin Jr. & Taylor, 1992; Parasurman, Zeithaml & Berry, 2002). In the opinion of researchers, the assessment of quality of passenger transportation in urban transport should be carried out in order to solve problems such as the definition and specification of requirements for the quality of transportation for the real/actual city, based on a systematic study of the growth of quality requirements and advances in quality management, development of organizational and technical measures for the improvement of vehicle production in all areas, in order to achieve the established quality standards, monitoring the implementation of designed measures and attraction of quality management system of passenger transportation in urban passenger transport. This gives transportation engineering specialists the opportunity to choose one from the package of possible tools (Decision support system). It will also provide the mechanism for assessing the actions to improve the level of the transport services that have the greatest impact on the quality of passenger transportation.

According to the opinion of researchers, one of the most significant criteria for assessing the quality of public transport services is the general amount of time which residents of the city spend to get from the starting point to the end of their trip (Velmozhin, Gudkov & Mirotin, 1998). Other researchers characterize the quality of public transport by the rate of release of vehicles on the line, filling ratio, utilization rate of working time of the vehicle, communication speed, intensity of the movement of the transport, traffic interval, regularity ratio, indicator of the effectiveness of service, indicator of cost effectiveness, generalized indicator of the quality of work (Borisovich, 2003, Kush, 2015; Velmozhin, Gudkov & Mirotin, 1998). Scientists also consider the severity of accidents (Prioni &Hensher, 2000), compliance with safety and comfort requirements (Glumov &Yakubovskiy, 2017).

By the mid-90s of the previous century, researchers used the quality coefficient as the main indicator of quality; it is defined as the ratio of time spent on a trip in theoretically comfortable conditions to the actual travel time spent on a trip in the real conditions (Gudkov & Mirotin, 1997). In addition to this, scientists (Bolshakov, 1981) recommend determining the quality of transport services in the cities considering standard time spent on the passenger trip; time that was spent on the passenger trip; standard coefficient of capacity utilization; actual coefficient of capacity utilization; indicator of regularity of movement. Other researchers in the work (Tarhanova, 2009) developed the concept of a complex or integrated quality indicator, which considers a range of factors of passenger service.

In the opinion of researchers assessing the quality of passenger transport services with the complex indicator, it is advisable to use a weighted arithmetic average of single indicators (Beirão & Cabral, 2006). Planning the quality of the process of transportation at public transport routes is based on determining the validity of separate quality indicators. Total quality management, in the broadest sense, could be best understood if the feelings of the buyer (who is a consumer of the services) will be considered. Here, one of the main factors can be the performance of service. Regarding consumers, quality is the degree of conformity of service to the requirements, specifications and expectations of consumers (Bichkivskiy, Stolyarchuk & Gamula, 2004). When identifying the level of expected quality, it is advisable that the set of measurement and quality assessment criteria is based on the client's expectations (Konečný& Kostolná, 2014).

Existing methods of assessment of the quality of projects in urban passenger transport do not fully take into account the subjective assessment of service conditions by passengers (Friman & Fellesson, 2009; Friman, 2004)

3. RESEARCH PROBLEM AND PURPOSE STATEMENT

The research aims to develop the method for determining the complex indicator of quality for routine trips in urban passenger transport projects based on subjective assessment of quality of service by passengers.

The following tasks were solved to achieve the settled goals:

- conducting the full-scale survey to assess the importance of quality criteria of public transport for the passengers;
- development of method for determination complex quality indicator of public transport;
- analysing the impact of trip parameters on the meaning of complex quality indicator.

4. DATA AND RESULTS OF RESEARCH

The quality of service is determined by the operation indicators of public transport. These indicators are continuously used by passengers when choosing the type of public transport and type of connection. In urban passenger transport, there are two types of trips: 1) for labour, 2) for cultural and social purposes. While performing different kind of trips, passengers can assess the quality of services individually.

All indicators of the quality of public passenger transport passengers can be assessed by different levels of impotency. The significant level of indicators of quality of public transport for passengers can be determined by conducting surveys. There are many methods of surveys which are used to improve the efficiency of urban passenger transport. To survey the importance of public transport parameters as indicators of quality, the questionnaire method was used. It is based on the filling of special questionnaires for passengers – users of public transport.

The survey was conducted at stops of public transport: buses, trolleybuses and trams and 311 passengers were interviewed. At the same time, the travel time of passengers varied from 20 to 85 minutes. It was a survey of passengers, in which they were asked to specify the criteria for labour, cultural and social trips, which, in their opinion, affect the quality of service of public transport. The passengers' answers were recorded in the questionnaire. The number of criteria that was specified by each passenger was not limited.

Following up the survey, all the answers were analyzed and processed. The criteria noted by passengers were divided in groups for labour, and separately for cultural and social travels. During the passengers' survey, it was determined that the quality of public transport service is determined by the following criteria: travel time, waiting time for the vehicle, time of approach to the stop, the number of connections, traffic safety, service culture, etc.

After determining the factors that, according to the passenger's opinion, characterize the quality of service, a questionnaire was developed, with the help of which expert assessment of the significance criteria was held. Passengers were in the role of experts and they were asked to assess factors on a scale, from the most meaningful one (to assign a rank 1to the most significant factor) to the least significant one for labour, cultural and social trips.

During the next stage, data of the conducted survey was processed separately for labour, cultural and social types of trips. To assess the consistency of expert opinion, Kendall's coefficient of concordance was used (Marozzi, 2014):

$$W = \frac{12S}{m^2(n^3 - n)}, \qquad (1)$$

where m – number of experts;
n – number of factors;
S – sum of squared deviations, which is defined as follows:

$$S = \sum_{j=1}^{n}(X_j - X_{cp})^2, \qquad (2)$$

where X_j – the sum of ranks for j-th factor;
X_{av} – the average amount of ranks, which is defined as follows:

$$X_{av} = \frac{\sum_{j=1}^{n} X_j}{n}. \qquad (3)$$

The resulting coefficient of concordance indicates the consistency of expert opinion. For the labor trip W = 0,62, and for cultural and social trips W = 0,55.

To test the statistical weight of coefficient of concordance, Pearson empirical criterion value was calculated using the formula:

$$\chi^2 = \frac{12S}{mn(n+1)}. \qquad (4)$$

The calculation results are shown in Table 1.

Table. 1 The analysis of interviews with experts in the labour, cultural and social trips

Factor number	Factor name	Type of trip			
		Labour		Cultural and social	
		X_j	X_{av}	X_j	X_{av}
1	Travel time	525	2177,5	846	2171,8
2	Occupancy rate of the vehicle	1788		888	
3	Culture of service	2248		2035	
4	Traffic safety	1151		1162	
5	Time of approach to the stop and time of departure from the stop	1784		2146	
6	Number of connections	1613		1868	
7	Waiting time for the vehicle	930		1565	
8	The quality of the road surface	2742		2767	
9	Exterior and interior cleanliness	2831		2153	
10	Equipment of stopping points	2964		2983	
11	Information support of the trip	2926		2996	
12	The toll collection system	3416		3508	
13	Design features of the vehicle	3390		3316	

After analyzing the expert's survey, the diagram of importance of qualitative service factors for passengers during labor, cultural and social trips was built (Figures 1 and 2).

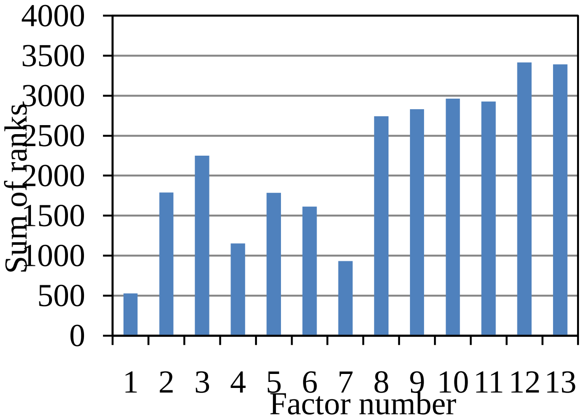

Figure 1. Diagram of importance of qualitative service factors for passengers during labour trips

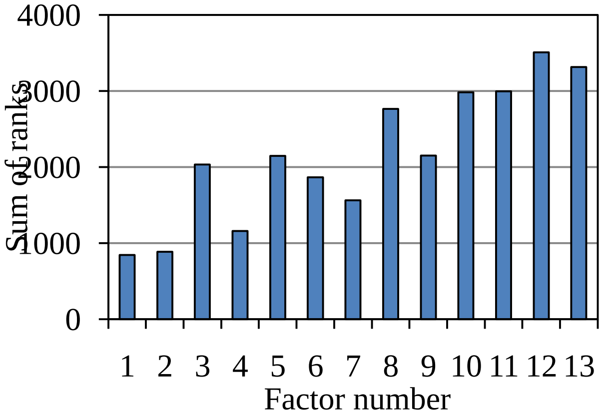

Figure 2. Diagram of importance of qualitative service factors for passengers during cultural and social trips

Based on its analysis, the significance of factors was also defined. To determine the statistical weight coefficient of concordance during the labour trips, the calculated value of criterion is χ^2 = 2310,77, while during the cultural and social χ^2 = 2054,78. In agreement with expert's opinions, the calculated value is higher than tabular one (21,0) for the significance level 0,5 and the number of degrees of freedom m =12. As a result, it was concluded that the resulting coefficient of concordance is significant and the expert's opinion is not accidental.

The analysis of existing approaches for the assessment of the quality of passenger transport services has shown that the definition of indicators that describe this parameter should be based on subjective assessment of passengers (Mazzulla & Eboli, 2006). To find this assessment, diagrams of relevance factors which derived from a survey of passengers were used as the evidence. Five key indicators were selected among thirteen main indicators that can be used in planning the qualitative projects of urban passenger transport. Calculations are based on the sum of their ranks.

It has been suggested that the maximum value of the quality coefficient should be equal to one. As a result, the sum of all weight factors of single indicators is equal to one and looks as follows:

$$\sum_{i=1}^{n} x_i = 1, \qquad (5)$$

where x_i –the weight ratio of the single *i*-indicator;

n – the amount of single quality indicators.

To carry out dependence (5), meaning of ranks of evaluation factors varied in proportion to their contribution to the sum of the ranks of all factors of quality. Because the most important factors have the lowest rank, the mutual value of the rank was used in the calculations, which was determined by the relationship:

$$x_i = \frac{\frac{1}{R_i}}{\sum_{j=1}^{n} \frac{1}{R_j}}, \tag{6}$$

where R_i –the rank value of the *i*- quality indicator.

Assessment of the quality of functioning of public transport can be carried out for trips with one route or for movements all over the network. To assess the quality of movements during routine trips, the following parameters of quality should be used as single indicators: time of the pedestrian part of the trip, which includes time spent to approach and leave the stop; waiting time for the vehicle; time spent on the trip; occupancy rate of the vehicle, which can be assessed by dynamic coefficient of the use of the vehicle capacity. The result of the assessment of significance of the factors aforementioned showed that the time of the pedestrian part of the trip was rated with a score of 1784, waiting time for the vehicle – 930, time spent on the trip – 525, occupancy rate of the vehicle – 1788, the number of transfers – 1613. As a result of calculations, the following weight coefficients of single quality indicators during the routine trip were obtained. The values are as follows: for pedestrian component of traffic movements x_{pd}= 0,137, for the waiting time x_w= 0,262, for the travel time x_{tr}= 0,465, and for the dynamic coefficient of capacity utilization x_{ccu}= 0,136.

To assess the quality of passenger service for every single quality indicator, it is proposed to use the ratio of the minimum values to the actual ones.

The minimum value of travel time can be the part of the trip with a maximum speed of communication, which is achieved in the city. It is suggested to use one minute as a minimum waiting time. As a minimum time spent approaching the stop and time of departure from the stop it is also advised to use one-minute time. As a minimum occupancy rate of the vehicle it is advised to use traffic conditions while sitting. This value depends on the seating capacity of the vehicle, which is determined by the type of vehicle that is used on the route. The actual parameters of the trip can be determined by field surveys.

Consequently, the complex indicator of quality of public transport during the trip can be represented in the following form:

$$C_q^{tr} = \left(\frac{t_{pd_{min}}}{t_{pd_a}}\right)^{0,137} \cdot \left(\frac{t_{w_{min}}}{t_{w_a}}\right)^{0,262} \cdot \left(\frac{t_{n_{min}}}{t_{n_a}}\right)^{0,465} \cdot \left(\frac{\gamma_{d_{min}}}{\gamma_{d_a}}\right)^{0,136}, \qquad (7)$$

where C_q^{tr} – the complex indicator of quality of public transport during the trip;
$t_{n_{min}}$ – the minimum possible travel time, min.;
0,137; 0,262; 0,465; 0,136 –the weight coefficients of single quality indicators during the trip;
t_{n_a} – the actual travel time, min.;
$\gamma_{d_{min}}$ – the dynamic coefficient of capacity utilization (all seats are occupied);
γ_{d_a} – the actual dynamic coefficient of capacity utilization;
$t_{pd_{min}}$ – the minimum time of pedestrian part of the trip, min.;
t_{pd_a} – the actual time of the pedestrian part of the trip, min.;
$t_{w_{min}}$ –the minimum waiting time for the vehicle, min.;
t_{w_a} – the actual waiting time for the vehicle, min.

To assess the physical adequacy of the proposed indicators, a simulation of change of quality indicator in various conditions of travel was conducted. Best quality conditions corresponded to minimum values of parameters: travel time at the speed connection of 40 km/h on the route that is 22 km long, which corresponds to 32 minutes; coefficient of capacity utilization (seating capacity 20, total capacity 45) corresponding to the value of 0,44; time spent to approach the stop – one minute, waiting time for the vehicle– one minute, the number of connections–one. Medium-quality conditions corresponded to medium values of the trip parameters. Substandard conditions corresponded to the worst values. Only one parameter of the trip was modified in the conducted simulation, the other parameters which correspond to the minimum, medium and maximum values respectively were not changed.

The calculation results during the performance of route and network trips are shown in Figures 1-4.

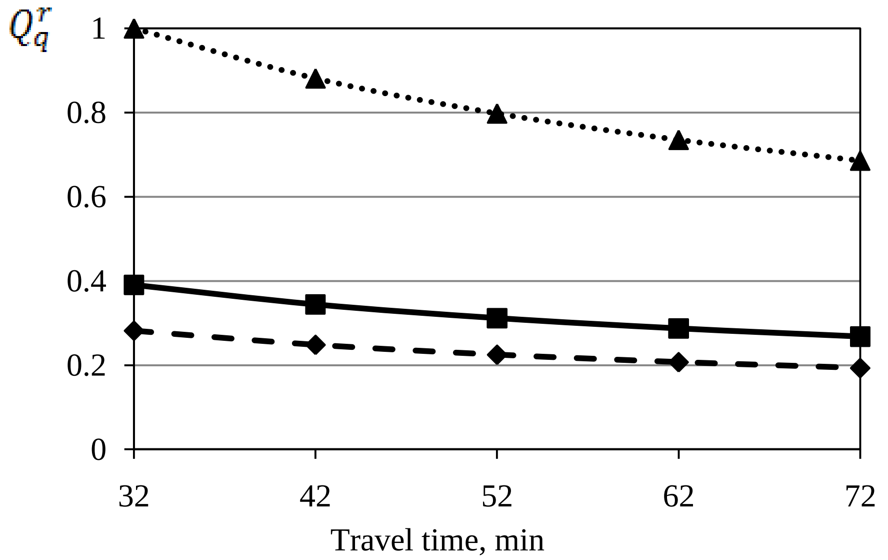

Figure 3. Change of the complex quality indicator of public transport during the trip depending on the travel time:
⋯▲⋯ – in best conditions, —■— – in medium-quality conditions, – ◆ – – in substandard conditions.

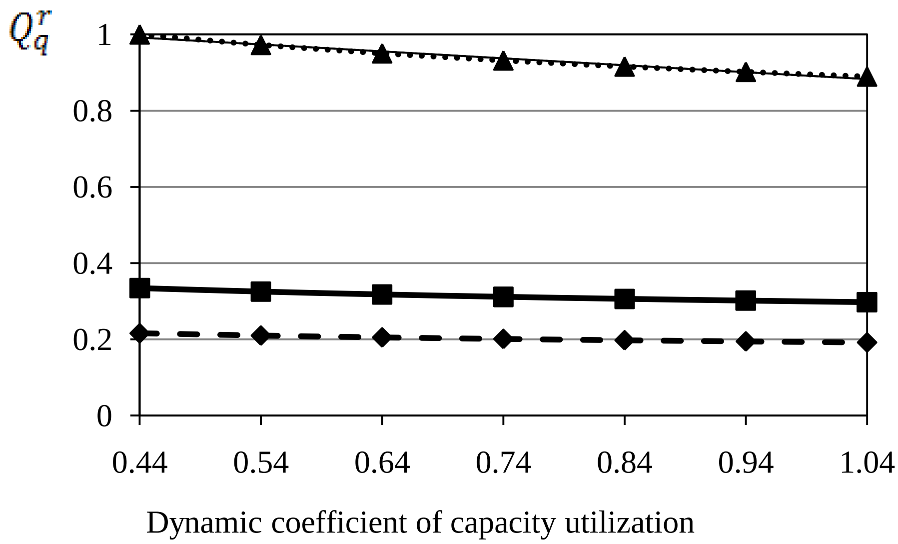

Figure 4. Change of the complex quality indicator of public transport during the trip depending on dynamic coefficient of capacity utilization:
⋯▲⋯ – in best conditions, —■— – in medium-quality conditions, – ◆ – – in substandard conditions.

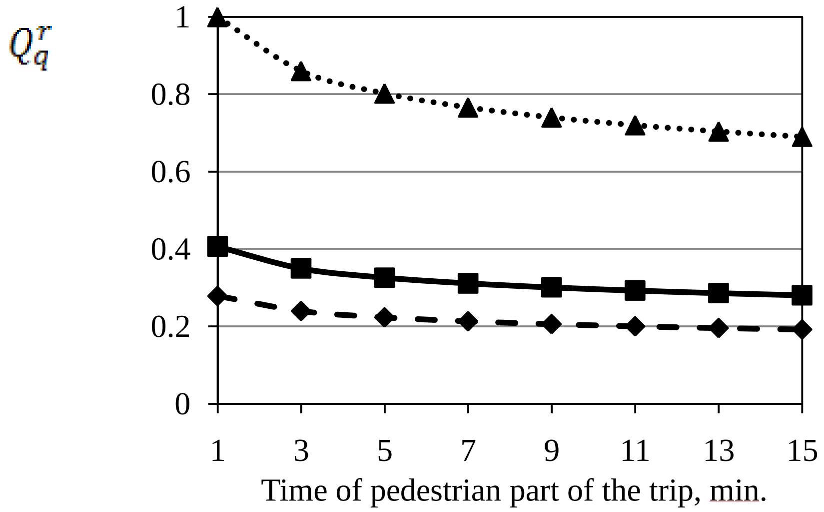

Figure 5. Change of the complex quality indicator of public transport during the trip depending on the time of the pedestrian part of the trip:
···▲·· – in best conditions, —■— – in medium-quality conditions, ‒◆‒ – in substandard conditions

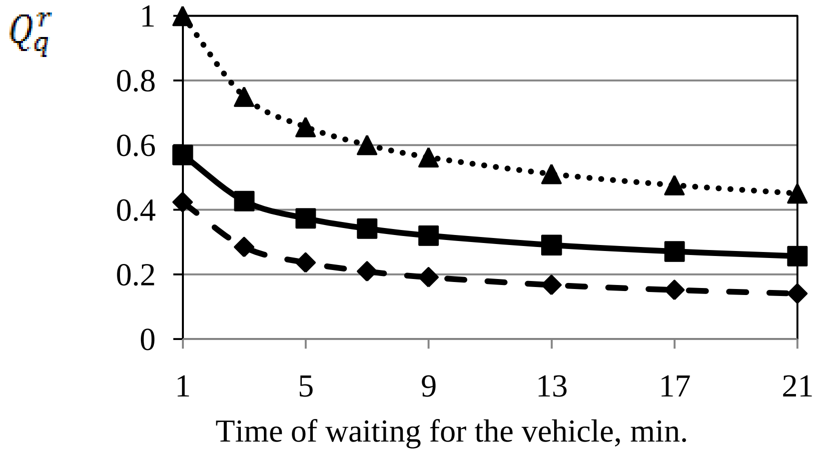

Figure 6. Change of the complex quality indicator of public transport during the trip depending on the waiting time for the vehicle:
···▲··– in best conditions, —■— – in medium-quality conditions, ‒◆‒ – in substandard conditions.

5. DISCUSSION

The analysis of the data shows that, under the best conditions, an increase of the travel time from 32 min. to 72 min. leads to the change of the quality indicator from 1 to 0,71. A similar change of the quality indicator is noticed in the medium-quality and at substandard values of the trip parameters. If the travel time is changed, then the quality indicator will also change by 30 percent on average. This notable change of the quality indicator can be explained with the high significance of travel time for passengers.

In the best travel conditions, an increase of the dynamic coefficient of capacity utilization from 0,44 to 1,04 leads to the decline of the quality indicator from 1 to 0,89. Under medium-quality conditions the quality indicator ranges from 0,33 to 0,29. In substandard conditions, quality indicator varies from 0,21 to 0,19. Changing the dynamic coefficient of capacity utilization will lead to the change of the quality indicator by 10 percent on average. A slight decrease of the quality indicator is explained by the low degree of importance of the dynamic coefficient of capacity utilization for passengers.

In the best travel conditions, changing the time of the pedestrian part of the trip leads to the change of the quality indicator from 1 to 0,72. In medium-quality conditions, the quality indicator ranges from 0,41 to 0,3, and in substandard conditions, the quality indicator varies from 0,28 to 0,2. The quality indicator decreases to 30 percent on average. Thus, there is a meaningful change of the quality indicator.

The change of waiting time for the vehicle under the best conditions of the trip leads to the change of the quality indicator from 1 to 0,5. Under medium-quality conditions, quality indicator ranges from 0,56 to 0,28. The substandard quality conditions determine the change of the quality indicator from 0,4 to 0,2. In general, changing the waiting time for the vehicle leads to a change in the quality indicator to 50 percent. This is the most significant effect on the change of the complex indicator of quality.

6. EVALUATION OF THE QUALITY OF PUBLIC TRANSPORT

Based on the dependence which determines complex indicator of quality of public passenger transport during the trip, a method of evaluation of the quality of public passenger transport was developed (Fig. 7). To determine the quality score, it is necessary to evaluate the existing conditions for the passengers during the trips and get the actual values of travel time, dynamic coefficient of capacity utilization (taking into account seating capacity), time of the pedestrian part of the trip, waiting time for the vehicle and the number of connections.

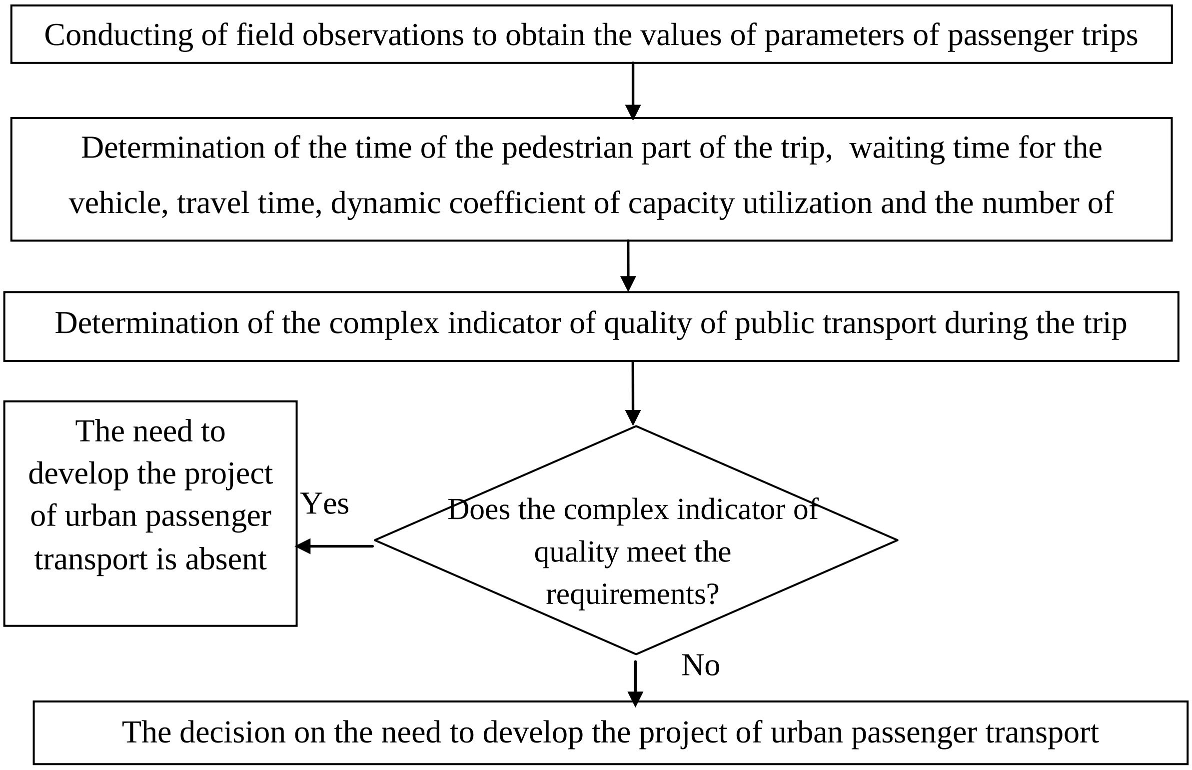

Figure 7. Method of evaluation of the quality of public transport

The values of these parameters may be obtained through field observations.

The next stage of the method consists in calculating the value of the complex indicator of quality. After the determination of the quality score, the decision on the conformity of quality to the required level is made. If the current level of quality is unsatisfactory, the decision on the need to develop the project of urban passenger transport is made.

7. CONCLUSION

The modeling of urban transport service quality indicators and interpretation of obtained data can lead to a better identification and understanding of the problems related to the organization of passenger transportation. This approach is very important for the development and evaluation of appropriate measures to determine the parameters of the transport process. Experts on the organization of the technological process of transporting passengers who analyzed the effect of transport parameters on the quality of public service require information on the patterns of changes in quality indicators, depending on the conditions of travel. Unlike the existing ones, the proposed integrated indicator of the quality of transportation of passengers during a route trip is based on data on the assessment of the importance of the parameters of transportation by passengers. This significance is mathematically formalized in the form of weight coefficients for each individual quality index: pedestrian component of movement, waiting time, travel time, vehicle's capacity load factor. The analysis of the shift in the complex index of the quality of public transportation, depending on the technological parameters of the trip, shows the degree of their impact on the quality of passengers' transportation services. Such analysis can be used as a valuable tool in the process of deciding the choice of arrangements for the organization of transportation from the perspective of improving the level of public service. The proposed model has the potential to be improved in the future by expanding the transportation parameters used for quality assessment.

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