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Evaluation of complexity of urban bus routes

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Abstract. Bus transport is the main (often the only) passenger transport connecting all cities of Uzbekistan and their rural settlements and has an important social significance. In modern conditions, the main factor that motivates passengers to choose certain routes and modes of transport in public transport is safe and high speed. Operational conditions on city bus routes vary in complexity, requiring a special approach to planning traffic, measures to ensure fast and safe movement on the route, standardization of the quality of services, and the introduction of fair systems of state financial support. The current methods and technologies for determining the level of complexity of the direction recommended by researchers require specialists to conduct complex tests or special knowledge. There is a need for simple and universal methods of assessing the complexity of the route so that the competent authorities regulating the activities of urban public transport and transport operators can quickly make decisions. This article systematizes the factors influencing the complexity of regular routes served by bus companies operating in the structure of urban public transport and proposes a method of assessing the index of route complexity.

1 Introduction

To encourage the use of public transport by the population of large cities, the quality of services provided should be attractive enough to compete with private cars. This is determined by the following set of interrelated indicators of the quality of services in the system of urban public transport (UPT):

- ease of use;
- speed of transport or time spent on movement;
- reliability of transport;
- safety of transport services;
- affordability of the definition of transport services.

Among all the quality indicators, the time spent using transport services, especially for the population of megacities, is of paramount importance. Thus, it can be concluded that the main criterion for the effective organization of the activities of modern UPT today is the time spent by passengers on transport.

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The main demand of passengers to minimize travel time can be met through the coordination of transport processes along the routes and the effective use of stops due to the interdependence of vehicles and passenger traffic. Therefore, scientific research aimed at improving the organization of bus transportation following the criteria of consistency of stop time indicators on routes and stops, taking into account the characteristics of passenger traffic, is relevant.

In today's world, the time taken by passengers to get from their destination to their destination for work, study, or other purposes is 45 minutes; in cities with a population of more than 1 million - 45 minutes, from 500 thousand to 1 million people - 40 minutes, from 250 thousand to 500 thousand - 35 minutes, 250 thousand It is advisable to have 30 minutes [1].

As the speed of the rolling stock and the speed of communication increase, the time spent on passenger traffic decreases, and the service culture improves. One of the main factors affecting the speed of buses on the route is the complexity of the route.

Many scientists and experts have conducted research to solve the problem of determining the level of complexity of bus routes. At the same time, it should be noted that their approach to determining the level of directional complexity is based on their goals and is devoted to studying the group of factors that cause complexity or the impact of these factors on the final indicators describing the object under study.

Based on the analysis of common methods of assessing the complexity of the route, the use of rolling stock in determining the complexity of urban bus routes is related to average technical speed, average daily walking distance, working hours, passenger flow, etc .; route parameters - parking lots, intersections, traffic lights, road condition, pedestrian crossing, turns, etc .; Traffic conditions on the route - indicators such as the intensity of traffic, the organization of public transport, the level of road lighting, etc. [2,3].

A. Nazarov [4] proposes a model for assessing the complexity of the route using the factors that affect the driver's performance along the route.

Methods for estimating the complexity of the route and classifying them based on fuel and other operating costs are also proposed [3,5].

A.V.Sotskov [6] developed an integrated indicator calculation method of route complexity based on traffic flow density, speed, road capacity, and traffic safety parameters.

Influence on the reduction of passenger travel time and operator costs [7–9], reduction of travel time and speed through the establishment of the high-speed (express) network of routes [10,11], the use of intelligent transport systems on the route, the complexity of the route [12–19] in the study of optimization of urban public transport routes, taking into account the factors [20,21], the density of road networks and traffic flows, passenger flows and other factors results were obtained that indirectly serve to reveal the essence.

Based on the results of the above research, we conclude that the complexity of bus routes is determined by a combination of features classified by their duration, length, and technical complexity depending on the nature, number, and variety of barriers affecting the movement of moving content.

2 Materials and Methods

The complexity of the route can be defined as the ratio of the time spent on different stops during the performance of a single flight on the route to the time spent on the total movement.

Factors that hinder the movement of content moving in the direction can be divided into three groups:

1) technological stops (time spent at stops to get passengers on and off the bus);

2) obligatory stops (time spent on stops at regulated and unregulated intersections, regulated and unregulated pedestrian crossings, left turns, right turns, roundabouts);

3) accidental stops (stops to prevent traffic accidents, traffic jams, etc.).

The time spent on stops on one route can be calculated as follows:

$$t_m = \sum_{i=1}^{n} m_i p_i t_i \qquad (1)$$

In where: t_m is total time spent on stops, hours;
m_i - i is the number of stops of the type;
p_i - i is the probability of a type stop;
t_i - i is average time spent on type stops, hours.
In this case, the I_m index of route complexity can be calculated as follows:

$$I_m = \frac{t_m}{t_u} \qquad (2)$$

In where: t_u is the total time spent on a flight on the route, hours.

3 Results

The probability of stops causing complexity of the route and the time spent on them are obtained based on experience at peak times. This is because the maximum passenger flow is observed during peak hours, and the factors that impede movement are the most active. The direction complexity index takes values from 0 to 1, and the closer it is to 1, the higher the level of complexity.

Table 1. The number of road elements affecting the complexity of the routes served by bus company No. 2 in Tashkent.

№	Routines	14	17	24	60	63	72	89	96
1	Route length (м)	14.4	21.2	24.8	14.2	19.8	17.1	17.4	21.8
2	Time to move in busy hours	1	1	1	1	1	1	1	1
3	Number of stations	26	35	41	26	33	26	32	29
4	Number of traffic lights	28	26	36	28	31	22	25	26
5	Number of pedestrian traffic lights	10	11	18	13	25	22	13	15
6	Number of pedestrian crossings	22	24	27	21	15	16	18	22
7	Number of intersections	10	13	11	14	14	17	15	13
8	Number of roundabouts	1	1	0	2	0	1	0	1

We cannot say that the number of road elements and other complexities available on the routes affects the speed of movement in terms of the amount available. True, in the qualitative organization of technological processes, as mentioned above, the stopping times at the stations that make them up are the same amount of constant. However, traffic intensity is a dynamic process, and road elements and other existing obstacles may or may

not be encountered other than technological process elements. Therefore, it is advisable to use analyses based on multi-step unknown statistical calculations in the project processes and experimental data for real conditions.

Table 2. Data recorded in the GPS system of routes served by bus company No. 2 in Tashkent (by time distribution).[†]

№	Route number	Route length, km	Route time, min.	Number of daily routines	Total downtime, min		Average speed, km / h	Maximum speed, km / h	Lowest speed, km / h	Distance traveled at maximum speed, km	Distance traveled at minimum speed, km
					at stations	other					
1	14	14.4	52	14	15	10	42	60	22	7	5.7
2	17	21.23	65	12	17	9	42	60	21	6	4
3	24	24.85	60	10	15	10	35	50	22	6.5	6.8
4	60	14.15	50	12	20	9	36	50	20	4.5	6.1
5	63	19.85	45	14	19	10	38	60	21	4	9
6	72	17.05	50	12	15	8	45	60	15	7	4.3
7	89	17.40	60	10	17	8	47	50	20	6.5	4.8
8	96	21.76	45	12	15	10	39	50	23	6.8	5.9

Based on the available indicators, the share of total downtime during one-time routes is as follows:

Table 3. Indices of complexity of routes served by bus company No. 2 in Tashkent.[‡]

№	Route number	Route length, km	Route time, min	Number of daily routines	Total downtime		The total time to stop	The complexity index of routine
					at stations	other		
1	14	14,4	52	14	15	10	25	0.48
2	17	21,23	65	12	17	9	26	0.40
3	24	24,85	60	10	15	10	25	0.42
4	60	14,15	50	12	20	9	29	0.58
5	63	19,85	45	14	19	10	29	0.64
6	72	17,05	50	12	15	8	23	0.46
7	89	17,4	60	10	17	8	25	0.42
8	96	21,76	45	12	15	10	25	0.56

The calculation results show that among the bus palace No. 2, the complexity of route № 63 is the highest at 64%, and route 17 is the lowest – 42 %. However, the road elements and other factors that make up the existing complexity along the routes expressed a different result. At the same time, it is advisable to consider the complexity of the routes when determining the working hours of drivers operating on the routes.

Today, the main problems in the process of passenger service on public transport in major cities, including Tashkent, are the increase in economic efficiency, traffic safety, and

[†] Source: It was calculated by under the report of No 2 bus organization.
[‡] Source: It was calculated by under the report of No 2 bus organization.

environmental protection, which tends to increase the quality and attractiveness of transport services. Overcoming such complex problems further complicates the problem's solution, as the increase in the quality and economic efficiency of one depends on the natural decrease of these indicators. This shows the need for a more precise approach to the use of material resources through the application of specific and appropriate calculation methods, increasing the efficiency of all types of energy resources used in relation to the work performed. Finding a positive solution to existing problems requires the development of calculation and analysis methods that are easy, simple, and reliable to use in the practice of transport operators. They allow operators to take measures to minimize the energy consumption that occurs in the dynamic changes of various processes in transportation.

One of the most pressing issues facing city bus companies is the need to determine the exact amount of daily fuel consumption for any time of the year, considering all the complexities of the routes. Determining that fuel consumption varies according to different route complexity allows, on the one hand, precise control of its consumption and, on the other hand, to increase fuel economy as a result of effective use of the dynamic characteristics of vehicles.

Before the pandemic, 38.28% of the cost of transportation at Bus Palace 2 was fuel, 26.1% was depreciation, 22.6% was driver's salary, and the rest was other operating costs. The amount of these costs depends not only on the distance traveled by the moving content but also on the duration of its operation in the direction.

Although it has already been proven that a decrease in vehicle speed leads to an increase in fuel consumption, consensus on the scale of such cost growth has not yet been fully formed.

The average engine speed of a Mercedes-Bents-0345 bus running on city routes is 2600-3200 rpm, based on which it is possible to standardize the fuel consumption of the engine in 1 hour from the data in Table 2, it can be seen that the buses were moving in different speed modes from 15 km / h to 60 km / h in the specified rotation range.

Table 4. Index of change in fuel consumption of buses in the conditions of route complexity.[§]

№	Route number	Route length, km	Current travel time, hours.	Non-stop travel time, hours	Fuel overflow index
2	17	21.23	1.08	0.51	2.12
3	24	24.85	1.00	0.71	1.41
4	60	14.15	0.83	0.39	2.13
5	63	19.85	0.75	0.52	1.44
6	72	17.05	0.83	0.38	2.18
7	89	17.40	1.00	0.37	2.70
8	96	21.76	0.75	0.56	1.34

On Route 89 (Table 4), the bus would cover a given distance in 0.7 hours at an average speed of 47 km/h without stops. However, the complexity of the route does not allow it, covering an average distance of 1 hour. Based on this, the average hourly fuel consumption in the direction of the calculation is (1/0.7) - 1.43Sy. This figure can be taken as an indicator of deviation from the standard fuel norm. We do the same calculations for other areas.

From the calculations given in Table 4, it can be seen that the indicator of the route complexity associated with the stops has a direct effect on fuel consumption. However, studying the relationship between them requires the study of road inconveniences, traffic congestion, variability of passenger flow, and the impact of all types of road elements on

[§] Source: It was calculated by under the report of No 2 bus organization.

technical speed and other factors that cause complications on the routes. We will talk about this in more detail in our next speeches.

4 Conclusions

Determining the complexity of the route makes it possible to assess the operational and commercial quality of public transport services. Operational qualities are characterized by the level of technical and operational performance required to ensure the required volume of passenger traffic at a given time. Commercial qualities can be assessed in the following areas:

- competitive advantages of urban public transport routes;
- classification of routes according to the level of complexity and the introduction of a fair mechanism for subsidizing operating costs on their basis;
- identification of competitive advantages of transport service operators in the urban passenger transport market;
- to study the possibilities of the volume and composition of passenger traffic, which forms the demand for transport services at the level of volume, quality, and price of traffic;
- evaluation of the impact of economic factors on the complexity of public transport routes;
- identify problems that hinder the improvement of the quality of services of urban transport operators and identify opportunities for their rapid elimination;
- selecting the appropriate type of rolling stock and developing action tables following the dynamics of the factors affecting the change of directional complexity.

A comprehensive solution to the problem requires an interdisciplinary approach to interconnected disciplines to improve the quality and efficiency of transport services while ensuring high levels of speed, reliability, and security to commercial efficiency. This approach allows for the development of innovative systems of scientific, technical, technological, and management decisions in the design and operation of vehicles and transport infrastructure, as well as the creation of management systems that can flexibly respond to changing requirements in the field of road transport. While the operational qualities of transport services are a relative indicator that can be determined by comparison over time and in the market, they also have a specificity characteristic. Because each passenger evaluates his demand based on certain criteria and uses only services that fully meet his needs and requirements. Thus, assessing the operational quality of transport services requires a two-pronged approach - from the point of view of the interests of transport operators and customers.

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