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ANALYSIS AND ASSESSMENT OF THE REGULARITY OF MASS URBAN PASSENGER TRANSPORT IN THE CONDITIONS OF THE CITY OF RUSE

Summary. One of the quality indicators of the transport service in passenger transport is the regularity of the movement of vehicles. Apart from the planned traffic intervals, it depends on a number of factors related to the traffic conditions of the public transport in the locality (intensity and composition of the traffic flow, passenger traffic structure, traffic lights regime, atmospheric conditions, etc.). The paper assesses the regularity of mass urban passenger transport traffic in the conditions of the city of Ruse, Bulgaria, by probing the estimation of the arrival intervals of the means of transport at the stops along a given route.

1. INTRODUCTION

At the end of 2017, the total number of the population of Bulgaria is 7 005 559, while the inhabitants in the cities are 5 181 755, i.e., over 74% of the country's population lives in cities, and this percentage is steadily increasing. Cities are growing in size and territory. Migration to the cities is dictated by better working conditions, as well as by material motives related to better pay for labor, and by the fact that cities offer more opportunities for education, spiritual and cultural development, etc.

Urban growth has led to serious difficulties in road traffic and speeds, including public transport, as well as parking difficulties.

The problems that the Bulgarian cities are experiencing today are similar to those encountered by western cities at the beginning of mass motorization:

- The population is buying cars at an accelerated rate;
- Reducing the speed of public transport traffic forces even more people to buy cars;
- Uncontrolled parking;
- Disparaging attitudes toward pedestrians.

All this leads to a deterioration in the quality of life in cities. The speed of traffic significantly decreases, causing frequent congestion and road accidents, hampering the movement of both individual transport and vehicles, and serving urban mass passenger transport (MUPT) lines. Some of the most important conditions for high-quality passenger service are safety; regularity of traffic; and reliability of the transport process significantly deteriorates.

According to a detailed study of the traffic in Ruse [18], the distribution by way of transportation in the city is shown in table 1.

The share of trips by car—32.4% (car—driver (28%) +passenger car (2.1%) + taxes (2.3%)) is about 50% higher than the share of public transport (20.1%). This is a clear symptom that the city's transport system is functioning poorly.

The idea that the problem of congestion can be solved by further expansion of the street road network has always had its supporters, but it requires serious investment and, in the long run, will make the city less comfortable to live.

Table 1

Way of moving in the city of Rousse

Way of moving	**Percentage ratio for the mode of movement**
On foot	43,5
Personal car—driver	28
Passenger car—passenger	2,1
Mass passenger transport	20,1
Bicycle	2,4
Taxi	2,3
Business transport	1,1
Motorcycle	0,5

One of the measures to reduce passenger car journeys is to increase the attractiveness of public transport and to take measures to promote its use.

In this sense, research into maintaining and improving the quality of passenger transport services is important in supporting the processes of enhancing the use of public transport. Assessing the regularity of MPT traffic is an important condition for improving the operational management of transport. This paper assesses the regularity of MPT traffic in the conditions of the city of Ruse, Bulgaria, by probing the estimation of the arrival intervals of the means of transport at the stops along a given route.

2. QUALITY OF THE TRANSPORT SERVICE FOR MASS URBAN PASSENGER TRANSPORT

Improving the quality of passenger transport can be understood as a set of activities to reduce passengers' travel time and increase the convenience of traveling.

One of the main criteria for the quality of the transport service is the total travel time of the passenger from the starting point to the destination. These criteria directly or indirectly incorporate features such as message speed, vehicle boarding/disembarkation, moving with a vehicle, and walking to the initial embarkation and destination.

Ensuring the quality of passenger transport today is one of the highest priorities in the service rendered to the population. Different authors [2 - 5] consider the quality of urban passenger transport by stating a number of criteria: passenger travel time; regularity of traffic along the routes; rolling stock filling factor; road accidents. The articles [19, 20] set out the principles of the so-called "green logistics". Trolleybus transport fully complies with these principles.

The following indicators for assessing travel quality are offered in ref. [1]:

- Reliability—passengers traveling from the stop of departure to the stop of arrival (travel time);
- Convenience—the physical environment in which the transport service is made in terms of travel convenience, overview, etc.;
- Safety—release from danger or risk of traveling in public transport;
- Politeness—behavior of the transport service provider, correctness, courtesy, and sociability of the service staff;
- Accessibility—frequency of urban passenger transport;
- Understanding—investigating the transport service provider, passenger interests, knowledge, and analysis of their requirements in the form of transport work;
- Sociability—ability to communicate in urban passenger transport.

The author [1] proposes to measure and evaluate the quality indicator and also to minimize gaps between planned and actual quality indicators.

All of these factors determine the approach to the shipment process from the "service provider"/carrier's point of view. But it is necessary to take into account the opinion of the "user of the service", i.e., of the passenger. The intensification of the transport process of UPT servicing depends on the application of a set of factors influencing travel time, travel comfort, service reliability and traffic safety, and travel costs in cash. All this can be presented in the block diagram shown in Fig. 1 [10].

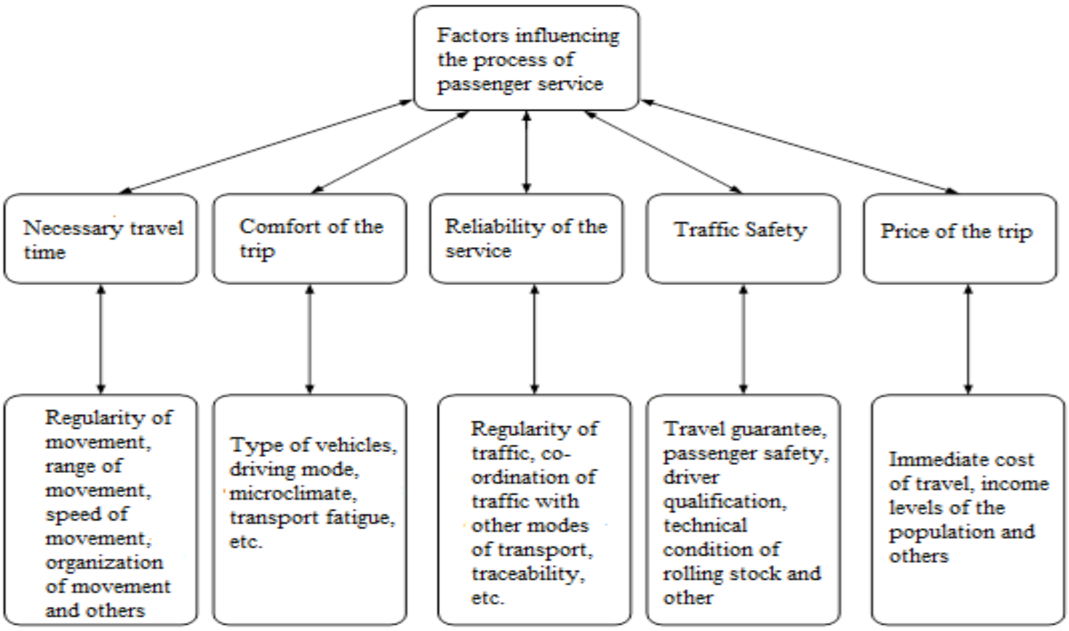

Fig. 1. Consumer value during carriage

According to ref. [7], the rate of vehicles may be considered regular if the coefficient of variation is within $\pm 0{,}2\sigma / t_u^{cp}$, where t_u^{cp} is the average range of traffic between the means of transport. A course with deviations exceeding these values is considered to be irregular—the TS schedule is disturbed, which is of great importance to both the carrier and the passenger [9].

An analysis of the quality indicators for passenger transport services allows the following conclusions to be drawn:

- The criteria proposed by the authors for the effective functioning of MPT are different in their content nature;
- Many of the indicators do not determine the actual level of transport service because they typically characterize the work of the individual units of the MPT and do not reflect the passengers' process;
- Many of the indicators require hard-to-determine information and a significant amount of computational work, which complicates the process of transport quality planning.

An important indicator of the quality of the transport service at the UPT is the reliability of the transport service. Here we treat:

- The regularity of the messages (evaluation of the deviations from the schedules);
- Ensuring the service level (probability of withdrawal of the potential customer from travel).

The second metric is directly related to the first-order regularity of the messages.

Regularity is a particularly important indicator for a potential traveler, as it allows him to plan his time more accurately. The study of the deviations from route schedules allows us to assess their level of acceptability to the passenger. A study of deviations from the schedules of the MPT for the city of Ruse has been carried out.

3. CHARACTERISTICS OF THE PUBLIC TRANSPORT IN RUSE

Ruse is the fifth largest city in Bulgaria with more than 140 000 inhabitants. The city is situated on an area of 127.124 km². The density of the primary street network for the city is 2.37 km/km^2, with a suitably adopted parameter 3-5 km/km². In the central urban area, the density is 3.65 km/km^2, at an appropriate 4 - 6 km/km². The condition of the majority of the road network in the municipality of Ruse is good, but some areas need asphalting, installing new traffic signs and road markings, traffic signs and nameplates, repair of road facilities, etc.

The town of Ruse is a significant economic center located along the Danube River in northeastern Bulgaria along 11 km. Ruse is an old Bulgarian town, a port on the Danube, which continues to occupy an important place in the Bulgarian economy—in the last decade, the main industrial branches in Ruse are chemical and textile, as well as tourism. At its location, Ruse is an important national transport, communication, and commercial node. It has one of the two bridges in the country over the Danube – "Danube Bridge" connecting Ruse to the Romanian city of Giurgiu, 10 km away. It is also the shortest route to the Romanian capital Bucharest, 60 km away.

The urban passenger transport (UPT) in Ruse has the following characteristics:

UPT is an important element of the city's transport system. There are around 3700 passengers on a daily basis (weekdays);

- Every year, the number of new cars bought increases. There are a little more than 400 cars per 1,000 inhabitants in Bulgaria, according to Eurostat data [17]. In 2017, 274,415 light and light commercial vehicles are registered in Bulgaria compared to 266,458 in 2016 or 7957 more (3%) [18]. According to data from the Ruse Traffic Police, for the 10-year period, the average annual passenger cars are about 10 000;
- The city passenger transport in Ruse is serviced by 3 transport companies –"Chance 99", "Geocommers", and Municipal transport—Ruse;
- Urban passenger transport is combined with trolley bus and bus transport by means of Iveco, Neoplan, Renault, Skoda, Mercedes and Isuzu, Mercedes, Neoplan, MAN, and other trolley buses [13];
- The urban transport scheme of the Municipality of Ruse includes 8 trolley bus routes – lines 2, 9, 13, 21, 24, 25, 27, and 29, which are serviced by 41 trolley buses; 18 bus routes – lines 3, 4, 5, 6, 7, 8, 10, 11, 12, 15, 16, 18, 19, 20, 23, 28, 30, and 33, serviced by 62 buses;
- There is a steady trend toward increasing travel time in the city. Traffic congestion occurs regularly, which reduces the speed of communications and increases the traffic intervals of public transport;
- Lack of priority for public transport when traffic flows;
- Inadequate adaptation of the city's transport infrastructure to the needs of citizens with limited mobility;
- Pollution of the environment by public transport. The average age of the bus park in the city is high – 14.7 years, which differs for different companies. For Chance 99 Ltd. it is 10.3 years [14], and for Geocommers Ltd. – 19.1 years [15]. The average age of the trolley bus fleet is over 20 years [16].

The main objective of the policy for development of the transport system of the city of Ruse is the organization of a sustainable public transport system, accessible to all sections of the population.

The main tasks are realization of the principle of the dominant role of the public transport and ensuring equal transport accessibility for the population of Ruse.

In Fig. 2, the route scheme of the town of Ruse is indicated.

4. ASSESSMENT OF THE REGULARITY OF THE MASS URBAN PASSENGER TRANSPORT MOVEMENT IN RUSE

As a criterion for the quality of the transport service, the regularity of the movement of the transport vehicles (TV), influencing the waiting time of the passengers at the stops, is used.

To assess the regularity of traffic, we have selected ten of the busiest stops of the UPT in Ruse: Skobelev, SBA, GTI, Olymp, Rousse Mall, Third Polyclinic, Printed Circuit Board, Technopolis, Aphrodite, and Yordan Yovkov. The study was conducted by observation and chronometric measurements over a period of time of 5 working days in a period between 8:00 and 9:00 o'clock.

Fig. 2. Route scheme of trolley bus and bus transport in Ruse

In Table 2, the basic numerical characteristics (average and standard deviation), the confidence interval of the mean, guaranteed by probability γ=0,95 for the actual driving range, as well as the scheduled time interval and the delay of the ten stops are presented. They are calculated as follows:

- average value: $$\bar{X} = \frac{\sum_{i=1}^{n} xi}{n} \qquad (1)$$

- adjusted standard deviation: $$S = \sqrt{\frac{\sum_{i=1}^{n}\left(xi - \bar{X}\right)^2}{n-1}} \qquad (2)$$

- average confidence interval: $$I = \left(\bar{X} - \frac{s}{\sqrt{n}} t_{\frac{1+g}{2};n-1} ; \bar{X} + \frac{s}{\sqrt{n}} t_{\frac{1+g}{2};n-1}\right) \qquad (3)$$

where $t_{\frac{1+g}{2};n-1}$ is a two-sided quantum of the Student's distribution $n-1$ degrees of freedom, which guarantees with probability γ.

For each stop, a Student test has been conducted for the significance of the time difference between the "Actual Runway Interval" and "Scheduled Time Interval". A major statistical hypothesis H_0 is proposed – the difference is statistically insignificant against the alternative hypothesis H_1 – the difference is statistically significant:

$$H_0: \overline{X}_{real} - \overline{X}_{schedule} = 0$$
$$H_1: \overline{X}_{real} - \overline{X}_{schedule} \neq 0.$$

Table 2

Basic numerical characteristics of time slots and actual execution

Station	Average value $\overline{X}$	Standard deviation s	Confidence interval of the difference $\gamma = 0{,}95$
Station Skobelev			
Actual movement range, s	155.43	134.51	(97,26;213,60)
Scheduled time interval, s	153.91	128.97	(98,14;209,68)
Station SBA			
Actual movement range, s	198.24	192.13	(99,44;297,02)
Scheduled time interval, s	176.47	197.38	(74,98;277,95)
Station GTI			
Actual movement range, s	196.94	138.5	(128,06;265,81)
Scheduled time interval, s	206.67	147.29	(133,42;279,91)
Station Olimp			
Actual movement range, s	194.11	133.37	(125,54;262,69)
Scheduled time interval, s	211.76	197.99	(109,96;313,56)
Station MALL Rousse			
Actual movement range, s	171.31	126.12	(110,52;232,10)
Scheduled time interval, s	164.21	136.88	(98,23;230,18)
Station of the third polyclinic			
Actual movement range, s	155.21	115.98	(105,06;205,37)
Scheduled time interval, s	166.95	176.28	(90,72;243,18)
Station printed circuit boards			
Actual movement range, s	211.66	148.94	(129,18;294,14)
Scheduled time interval, s	204.00	169.40	(110,18;297,81)
Station Technopolis			
Actual movement range, s	182.21	130.98	(119,07;245,34)
Scheduled time interval, s	189.47	173.50	(105,84;273,10)
Station Aphrodite			
Actual movement range, s	130.00	104.74	(90,88;169,11)
Scheduled time interval, s	156.00	174.46	(90,85;221,14)
Station Yordan Yovkov			
Actual movement range, s	131.61	135.42	(81,93;181,28)
Scheduled time interval, s	116.12	100.32	(79,33;152,92)

For a statistical check on the hypothesis that the difference between the average $\overline{X}_1 - \overline{X}_2$ is equal to a given number d_0 (in this case d_0=0) the following criterion is calculated

$$t = \frac{|\ \overline{X}_1 - \overline{X}_2 - d_0\ |}{s^* \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}},\ s^* = \frac{(n_1+1)s_1^2 + (n_2+1)s_2^2}{n_1 - n_2 - 2}. \quad (4)$$

If $t < t_{1-\frac{a}{2};n_1+n_2-2}$ it is assumed that the difference is not statistically different from d_0.

Otherwise, if $t > t_{1-\frac{a}{2};n_1+n_2-2}$ the assertion of a statistically significant difference is accepted.

$t_{1-\frac{\alpha}{2};n_1+n_2-2}$ again, is a two-sided quantum of the Student's distribution with $n_1 + n_2 - 2$ degrees of freedom with level of significance α.

The verification was carried out at a level of significance α=0.05.

Tests are done using the software IBM SPSS 16 [11, 12] and the results are shown in Table 3.

Table 3

Student's test of significance of the time difference between "Real-time traffic" and "Scheduled time interval"

Station			Mean	95% Confidence interval of the difference		Sig.(2-tailed)
				Lower	Upper	
Skobelev	Pair 1	Real time—schedule time	1,52174	-56,25452	59,29799	0,957
SBA	Pair 1	Real time—schedule time	21,76471	-88,58714	132,11656	0,681
Stif	Pair 1	Real time—schedule time	-9,72222	-109,65946	90,21501	0,840
Olympus	Pair 1	Real time—schedule time	-17,64706	-98,36102	63,06690	0,649
Mall Rousse	Pair 1	Real time—schedule time	7,10526	-80,54114	94,75167	0,867
Third Polynik	Pair 1	Real time—schedule time	-11,73913	-77,23596	53,75770	0,714
Printed circuit boards	Pair 1	Real time—schedule time	7,66667	-46,01288	61,34622	0,764
Technopolis	Pair 1	Real time—schedule time	-7,26316	-99,56594	85,03963	0,871
Aphrodite	Pair 1	Real time—schedule time	-26,00000	-81,65009	29,65009	0,347
Yordan Yovkov	Pair 1	Real time—schedule time	15,48387	-44,10582	75,07356	0,600

Table 2 shows that at all stops, Sig.(2-tailed)> α=0.05, which means that the zero hypothesis is accepted, i.e., the difference in times between "Actual Runway Interval" and "Scheduled Time Interval" is statistically insignificant. Therefore, for the studied period, the duration of the time interval is as planned.

In order to investigate compliance with the traffic timetable, it is necessary to determine the values of delay or overtaking. Table 4 shows the average values of the delay in the timetable of the selected nodes of the city passenger transport in Ruse. No overrun of the schedule has been noted.

For each stop, a Student's test of the significance of the delay times has been conducted. The hypotheses and the level of significance are analogous to the previous one. The results are shown in Table 5.

Table 4

Interval evaluation and basic numerical characteristics of the delay

Numeric characteristics / Stops	Mean value - $\overline{X}$	Standard deviation - s	Confidence interval of the difference $\gamma = 0{,}95$
Skobelev	144.35	114.17	(94,97;193,71)
SBA	464,70	234,01	(344,38;585,02)
Stif	114,72	117,77	(56,15;173,29)
Olympus	172,94	177,33	(81,76;264,11)
Mall Rousse	198,15	217,47	(93,33;302,97)
Third polyclinic	165,50	173,21	(90,13;239,94)
Printed circuit boards	141,00	80,58	(96,37;185,62)
Technopolis	187,00	167,70	(106,16;267,83)
Aphrodite	244,66	145,69	(190,26;299,06)
Yordan Yovkov	139,35	149,70	(84,44;194,26)

When checking a statistical hypothesis with a two-sided critical area, for middle-level equality and a given number d, the criterion

$t_{watch} = \left| \frac{\overline{X} - d}{s} \right| \sqrt{n}$ is used. With $t_{watch} < t_{1-\frac{\alpha}{2};n-1}$ it is assumed that the average level is not statistically different from d. Otherwise, the difference is statistically significant.

$t_{1-\frac{\alpha}{2};n-1}$ is a Student's quantum with n-1 degrees of freedom at a level of significance α

From Table 5 for each stop, we have Sig.(2-tailed)<α = 0.05, which means that the zero hypothesis for statistical significance of the average delay times is rejected, i.e., all delay times are statistically significant. This means that for each stop the delay is a trend.

The least average delay is reported at the Stif station at 114.72 s and the biggest delay at the SBA station – 464.70 s.

Consequently, the general conclusion can be drawn that although the average time interval between two vehicles is observed, they are running late, which is different for the different stops.

5. CONCLUSION

1. Increasing the number of inhabitants of cities and modernization of motorways creates a number of problems. The speed of traffic significantly decreases, causing frequent traffic jams and road traffic accidents, hampering the movement of both individual transport and the vehicles servicing the mass urban passenger transport (MUPT) lines. Some of the most important conditions for high-quality passenger service such as safety, regularity of traffic, and reliability of the transport process are significantly deteriorating.
2. Maintaining and improving the quality of the MUPT transport service is essential to ensure its attractiveness and use as an alternative to the use of personal transport.

3. Regularity of traffic is an essential indicator of the quality of the transport service.
4. Research in the city of Ruse at the 10 busiest stops for an hour on shows that the difference in times between “Real-time traffic” and “Scheduled time interval” is statistically insignificant.
5. When examining delays, it is found that they are statistically significant. This means that the delay is a trend for every stop, which implies that it is necessary to plan more carefully the work schedule of the vehicles.

Table 5

Test of the significance of the delay times has been made

Delay stops	Test value = 0			
	t	df	Sig.(2-tailed)	Mean difference
Skobelev	6,063	22	0,000	144,34783
SBA	8,188	16	0 ,000	464,70588
Stif	4,133	17	0,001	114,72222
Olympus	4,021	16	0 ,001	172,941118
Mall Rousse	3,972	18	0,001	198,15789
Third polyclinic	4,570	22	0 ,000	165,04348
Printed circuit boards	6,777	14	0,000	141
Technopolis	4,860	18	0 ,000	187
Aphrodite	9,198	29	0,000	244,66667
Yordan Yovkov	5,183	30	0 ,000	139,35484

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