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ANALYSIS OF THE RESULTS OF A PILOT STUDY OF PROBLEMS EXISTING IN PASSENGER TRAFFIC BY URBAN PASSENGER TRANSPORT

АНАЛИЗ РЕЗУЛЬТАТОВ ЭКСПЕРИМЕНТАЛЬНОГО ИССЛЕДОВАНИЯ ПРОБЛЕМ В ПАССАЖИРСКИХ ПЕРЕВОЗКАХ ГОРОДСКИМ ПАССАЖИРСКИМ ТРАНСПОРТОМ

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Abstract. The paper presents problems existing in passenger traffic by urban passenger transport, as well as the analysis of factors hindering the development of bus routes.

There have been studied both quantitative and qualitative indicators of a deterioration in the quality of passenger service by urban buses in the city of Kutaisi. For a comprehensive study of the issue using the time-table method of field observations, an experimental study of the passenger flow was carried out. Based on the system analysis, an assessment was made of the indicators of redistribution of passenger flows by bus and minibus routes: the number of motive power on the routes, in accordance with the percentage of coincidence of the parameters of traffic regimes with the transport schemes.

A list of measures has been drawn up, the integrated implementation of which will facilitate the development of a safe and convenient city–class bus route system.

Аннотация. Рассмотрены проблемы, существующие в пассажирских перевозках городского пассажирского транспорта, проведен анализ факторов, препятствующий развитию автобусных маршрутов.

Были изучены как количественные, так и качественные показатели качества обслуживания пассажиров городскими автобусами в городе Кутаиси.

Для всестороннего изучения проблемы с использованием метода полевых наблюдений с использованием временной таблицы было проведено экспериментальное исследование потока пассажиров. На основе системного анализа была проведена оценка показателей перераспределения пассажиропотоков по маршрутам автобусов и микроавтобусов.

Был составлен перечень мер, интегрированное внедрение которых будет способствовать созданию безопасной и удобной системы маршрутных автобусов городского класса.

Keywords: urban public transport, passenger, pilot studies, passenger flow, diagram.

Ключевые слова: городской общественный транспорт, пассажирские, пилотные исследования, пассажирский поток, схема.

Analysis of the processes, which have been taking place in recent years in public transport in a number of cities, revealed that a rising trend of passenger traffic by M_2 category vehicles (minibuses) in the field of the local regular urban passenger transport, has significantly slowed development of routes for M_3 category vehicles (urban buses) [1]. The formation of this process has both objective and subjective preconditions, in particular:

1. As the objective precondition, it could be considered that in the 1990s, the municipal passenger transport enterprises were unable to renew the bus depot owing to the lack of adequate financial resources, which gave rise to problems of administering the outdated bus depot, such as:

–increasing the number of service delays and failureson the routes caused by a technical malfunction of buses;

–low level of a technical readiness of the bus depot;

–the insufficient number of buses to complete motive power on the routes;

–low level of the operational management of motive power operation, etc.

In most cases, the existing bus depot could not meet the increased demand for passenger transportations by both quantitative and qualitative indicators. Therefore, the municipal authorities of cities were forced to use new models of mini–buses in urban transport, which were purchased by physical and private legal entities..

In parallel to the formation of this process, three types of bus routes were introduced in the field of urban transport service:

–routes, on which there are running both the city class buses and mini-buses in a certain proportion;

–duplicated mini-bus routes, whose transport patterns are fully or largely coinciding with transport patterns of the bus routes;

–the so called “alternative mini-bus routes”, whose transport patterns include powerful collecting points of passenger traffic flows for achieving high profitability of route.

2. As the subjective precondition, it could be considered that as a result of the reduction in the number of bus routes with assistance from municipal bodies, the number of the so-called "alternative mini-bus routes", which was preceded by tendency towards a growth in the demand for passenger traffic by new mini-buses. There has been created the real competition situation between the city-class buse and minibuse services, which had also dramatically escalated by the fact that, under conditions of almost equal incomes, due to the low operating costs of mini-buses (almost 3,0

times less in comparison with the large buses), the services rendered by them became profitable, and consequently the field of interest to business as well.

Facilitating the development of the mini-bus routes in the segment of the city-class bus services resulted in the negative events, such as:

1. Drastic reduction in the number of passenger transports by the city-class buses and an increasein the level unprofitableness of routes;

2. Further increase in the the level unprofitableness during the seasonal period of small passenger traffic flows (such periods can be attributable to some months of hot and cold climatic seasons);

3. Declining economic performance of bus services due to misallocation of motive power running on the routes and between the routes;

4. With a downward trend in incomes, refusal of financing for purchasing the new expensive city-class buses by municipal bodies of a number of cities, and so on.

Over the past ten years, under conditions of a dramatic increase in the number of private cars and a high intensity of their use, there have been created the hard-to predict situations of loading the urban transport network with road transport, which had created additional problems for the good functioning of public transport, particularly regarding the bus routes [2].

Similar problems are reported in Kutaisi city transport. The city of Kutaisi is an administrative center of the Imereti region of Georgia with a population of 182 thousand people. Currently, local urban regular passenger traffics are fully operated by licensed private carriers. There are 42 mini-bus and 10 city-class bus routes in the routing system, and 165 mini-buses and 67 buses run daily on the lines.

In order to assess problems existing in urban transport and work out relevant recommendations for addressing them, in 2016-2017, the authors of this paper explored the existing transport system, and the factors hindering development of the route system for the city-class buses, for which it has become necessary to study the real indicators passengers traffic flows, as well as to assess quantitatively the allocation of passenger traffic flows between the bus and mini-bus routes.

At the initial stage, the studies of passenger traffic flow were carried out using a table method of full field observations. Then, the periods of stable passenger traffic flows were distinguished both by the months of the seasons and weekdays. It has been established that further studies can be carried out during the periods of stable passenger traffic flows, when the non-uniformity factor of passenger traffic flow equals to 1.0 or varies within the interval close to 1,0. Results of this type of analysis allow us for designing an optimal experiment [3].

To choose the month of the season to be studied, we use the seasonal non-uniformity factor of passenger traffics, which is determined by the formula for the *i*-th month of the year, as follows:

$$K_{s.u}.i = \frac{P_{m.i} \cdot n_1}{P_r \cdot n_{m.i}} \quad (1)$$

where $P_{m.i}$ — the volume of passenger traffic in the *i*-th month;

P_r — the volume of passenger traffic during the year;

$n_{m.i}$ — the number of calendar days in the month.

According to the carried out studies, the average number of passenger traffic in the city of Kutaisi was 32,122 million (mln) per year, whose monthly distribution is shown in Table 1.

Since the value of the seasonal non-uniformity factor of ki = 1,011 is the closest to 1,0, therefore, April may be considered to be a stable month for the study of passenger traffic flow. In

addition, for choosing the type and number of motive power on the routes to be designed, the studies should be carried out in the most tense month of passenger traffic flow, in this case this month is October. As shown in Table 1, we have the lowest value of passenger traffic in the month of August, therefore, in order to assess the level of the operability of routes during this month, the studies should be carried out in August as well.

Table 1

No	*Month of the year*	*Number of transported passengers by month of the year, P_i*	*Number of days in the months of the year, n_i*	*Non-uniformity factor of passenger traffic flows by month of the year K_i*
1	January	2,498	31	0,919
2	February	2,366	28	0.963
3	March	2,534	31	0,932
4	April	**2,676**	30	**1,017**
5	May	2,968	31	1,092
6	June	2,842	30	1,080
7	July	2,743	31	1,042
8	August	**2, 481**	31	0,912
9	September	2, 925	30	1,112
10	October	**2,953**	31	1,032
11	November	2,833	30	1,037
12	December	2,823	31	1,038

The calendar weekdays should also be chosen for conducting the studies in the specified months.

It is recommended that studies should on a one working day and one non-working day [4]. The working day is chosen by the non-uniformity factor of passenger traffic flows on weekdays ($K_{k.u.i}$), which is calculated by the formula:

$$K_{k.u.i} = \frac{n_{m.i} \cdot \sum_{j=1}^{m} P_{w.t.J}}{m_J \cdot P_{m.i}} \quad (2)$$

where $P_{w.t.J}$ — the volume of passenger traffic on a *j*-th weekday of the *i*-th month;

m_J — the number of *j*-th weekdays of the *i*-th month to be studied.

The volume of passenger traffic ($n_{m.i} = 30$) in the month of April was 2,676 mln passengers ($P_{m.i}$), including the volume of passenger traffic by weekday ($P_{m.i}$) thousand passengers, was redistributed as follows (Table 2):

Table 2

Weekdays	*1st week*	*2nd week*	*3rd week*	*4th week*	m_j	$\sum_{j=1}^{m} P_{днj}$	$K_{ннj}$
Monday	102	101	99	103	4	405	1,13
Tuesday	98	96	97	99	4	389	1,09
Wednesday	98	98	99	99	4	394	1,09
Thursday	102	103	100	102	4	407	1,12
Friday	97	99	98	98	4	392	1,11
Saturday	85	88	86	88	5	347	0,77
Sunday	83	85	86	89	5	342	0,76

$K_{k.u.i}$ is the value of factor closest to 1,0 on Tuesday, which we choose as a working day for studying the passenger traffic flow. As a non-working day can be chosen Saturday. To achieve a high level of reliability of the results of studies, it has been considered to be appropriate that at the initial stage of studies, the number of weekdays under observation can be increased to three (Tuesday, Friday and Saturday). On Friday considerable strain is placed on the several main routes, which should be taken into account for establishing the adaptive management conditions of the routes.

The volume of traffic selected for the studies and the part of the population under observation are of an imaginary nature, petaining to the whole population (total passenger traffic and the total population) [5].

A sufficient representativeness for the studies by sampling method was determined according to the following formula:

$$P_{res.} = \frac{t^2 \cdot w(1-w) \cdot P_0}{\Delta^2} \quad (3)$$

Δ — the maximum permissible error of the representativeness of samples;
t — multiplicity of error of the representativeness of samples;
$w(1-w)$ — the degree of variation in distribution.

According to the results of the study, it has been established that in order to use sampling method, it is enough to study just 3,8% of the annual passenger traffic or/and of the population.

The studies were carried out using a sampling method of field observations.

The task of identifying the object of the studies of passenger transports involves:

– Selection of city bus routes according to the high intensity of passengers traffic flows;

– Selection of city bus routes to be studied by the length of the transport scheme, km.

It is recommended to select the types of routes that cover at least 10 ... 15% of the entire route network.

Selection of the passenger traffic flow examination schedule was carred out on the basis of analyzing the bus route time tables on routes under study. The interval between bus services should not exceed 25 minutes [6], otherwise the route is considered to be a low-intensive route. A pilot study has revealed that the interval on city routes generally varies ranging from 4 to 6,5 minutes.

The studies were carried out by sampling technique with a method of field observations. In each bus the passengers were counted by one or two counter-controllers, who were directly near the bus door, but at least one counter-controller was on the main bus stops. Accounting of passengers was carried out on special-form cards, by their categories.

The routes to be studied were selected according to the convergence size of the transport schemes of the bus and mini-bus routes, the goal of which was to clarify the relationship between the number of passengers transported over the day by both types of transport, and to determine the size of the demand for passenger transports on them. For the purpose of solving this task, the routes were coupled according to the following scheme: the number 1 and number 5 (convergence of transport schemes — 67%); the number 2 and the number 6 (65%); the number 3 and the number 7 (50%); the number 4 and the number 8 (55%).

Taking the example of routes of the number 1 and number 5, Figure1 and Figure 2 illustrate the diagrams of the distribution of passenger traffic flows on Tuesday in the month of October during the period between 7 a.m. and 6 p.m. As the diagrams show, the distribution histogram for both routes varies with almost similar patterns. During this period, the number of passengers

transported by the number 1 bus route was 7460 passengers, and 6960 passengers by the number 5 mini-bus route. There was also studied the relationship between the numbers of passengers transported on both type of routes, which does not exceed 5% in favor of the bus routes. This result proves that the bus route face considerable competition from the mini-bus routes.

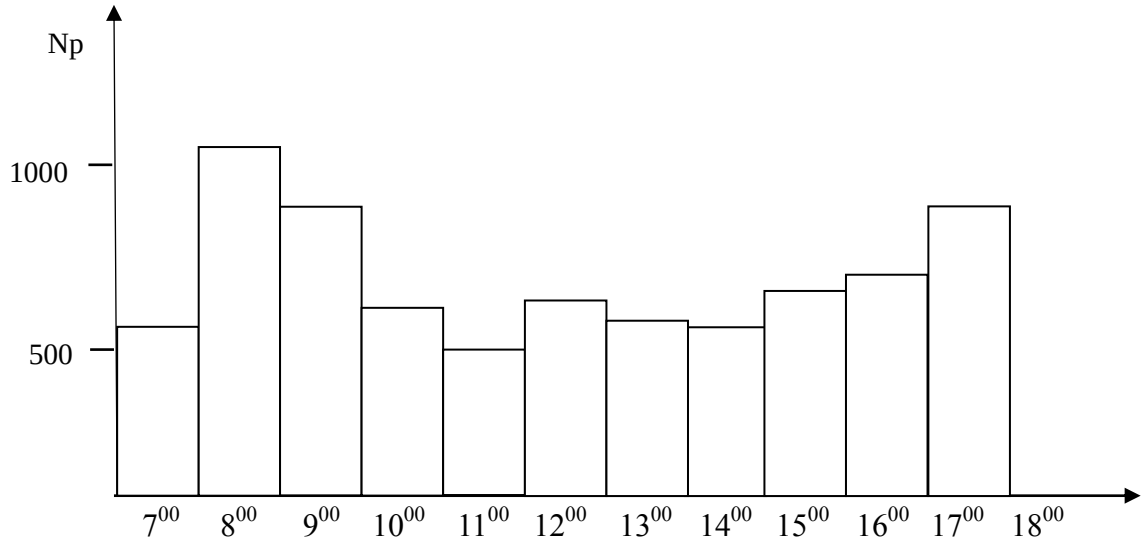

Figure 1. The diagram of distribution of passenger traffic flows on the bus route number **1**

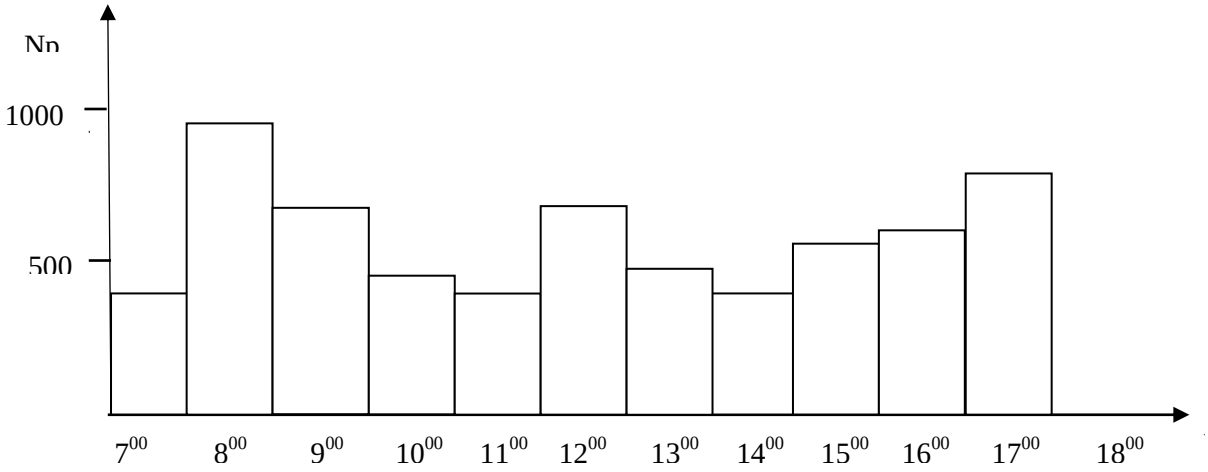

Figure 2. The diagram of distribution of passenger traffic flows on the mini-bus route number 2

The studies carried out have shown that

– Mini-buses accounted for nearly 65% of total passenger transports in Kutaisi city;

– The convergence size of the transort schemes of the main mini-bus routes and bus route schemes in Kutaisi City is more than 50%;

– The transport schemes of the main mini-bus routes are drawn so that they mostly cover the directions with high intensity of passenger flows;

– On some mini-bus routes, the number of motive power is purposfully increased, and consequently, the intervals between the bus services are reduced;

– Under conditions of the operation of outdated bus depot, the majority of the population (almost 65%) use more mobile and comfortable mini-bus services;

–To facilitate the functioning of the bus routes in Kutaisi City, there have been introduced special schedules for buses during the morning and evening hours, in particular: during the evening hours, during the priod of a sharp decrease in passenger flows between 7 p.m. and 9 p.m. and between 9 p.m. and 11 p.m., the number of motive power is reduced and the interval between the bus services is increased by 25…30 minutes. During the morning hours, between 6 a.m. and 8 a.m., the buses are bringing stage-by-stage to the route in accordance with passenger flow dynamics;

–Due to the correction of the number and operating modes of motive power in accordance with passenger flow dynamics during the morning and evening hours, it has become possible to save the existing city class buses, but measures undertaken are not sufficient to develop them.

Based on the foregoing, in order to develop the city-class bus routes, it is necessary to create a balanced route system, which requires the following types of activities:

1. Increasing the level of the effectiveness of using the city-class buses, through the development of the integrated transport schemes and by determining the traffic condition of buses on routes;

2. Determining the conditions of rational management of mini-buses in urban transport, as well as justifying the possibilities of their use for unexpected routes for the express and city class buses;

3. Reducing the convergence size of the bus and mini-bus route transport schemes to 30%;

3. Introduction of integrated routes of city-class buses maximally adapted to the indicators of the transport network (bus routes providing regular transport links between more than three quarters of the city);

4. Canceling duplicate routes;

5. Ensuring adaptive management of the type and number of the city-class buses during the period of small passenger traffic flows in the working days (which means the operative replacement of large-capacity buses by buses with medium or small capacity);

6. Ensuring adaptive management of routes of the city-class buses during the period of small passenger traffic flows in seasons;

7. Drawing the operational management schemes for alleviating the passenger traffic during peak hours, by bringing the backup buses at peak times;

8. Introduction of the effective monitoring and management mechanisms using intelligent information systems, and so on.

Integrated implementation of the above-mentioned activities will facilitate the development of a safe and convenient city-class bus route system.

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