bus; route; busstop; passenger

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COORDINATION OF THE WORK OF BUSES IN CITY ROUTES

Summary. The paper studied the work of bus routes passing through a street. Optimality criterion was chosen for the development of appropriate models of effective work of buses on the land. The paper proposes a new model costing time passengers at bus stops. A method of technique was developed to coordinate the buses running on the combined section of route.

КООРДИНАЦИЯ РАБОТЫ АВТОБУСОВ НА ГОРОДСКИХ МАРШРУТАХ

Аннотация. В статье изучена работа автобусных маршрутов проходящих по одной улице. Выбран критерий оптимальности для разработки целесообразной модели эффективной работы автобусов по рассматриваемому участку. В статье предложена новая модель оценки затрат времени пассажиров на остановках. Разработана методика координации работы автобусов работающих на совмещенном участке маршрута.

1. INTRODUCTION

The current period of the city public passenger transport is accompanied by its own problems. One of these problems is to achieve operating efficiency of the buses on the routes. At present, city bus transports are characterized with the tension of competitive environment. It is related with the formation of market relations in the transport sector of large cities of post soviet states. The problems arose in the compliance with traffic regularity on the bus routes of various companies of which certain parts concur with. By breaking the rules of traffic safety, traffic graphic of a bus and by frequent changing of traffic speed, drivers try to pick up more passengers. Consequently, passengers are dissatisfied with the quality of public transport. Low quality of service in public transport strengthens the trend for usage of individual automobiles that this in its turn increases the problems of street-road network of which have been already loaded.

The density of route network in Baku is 0,942 km/km^2 [1]. Besides this, the coefficient of the route is very high. The traffic intensity of route buses is more than 200 pieces/hours in some streets. As a result of this, in stop points of the buses queues, even traffic congestions appear, it creates serious impediments for the operation of general transport flow. There are such stop points in Baku that more than 15 route buses of which large part of their roads passes over there. Thus, the solution of the arose problems necessitates the coordination of traffic of buses in these parts of routes. The coordination of traffic will result in strengthening of traffic regularity. This means providing of high quality service for passengers.

Therefore, we consider two questions: establish work regimes that ensure time waste of passengers and increase parking capacity of stop points. It is also obvious that for analysis should consider other types of public transport [4].

2. ASSESSMENT OF LOSS OF TIME OF PASSENGERS

The supposition to get on the bus may be defined as follows when passengers of bus route number *k* comes to bus stop number *z*:

$$p_z = \frac{t_{stop,k}}{\dot{I}_k} \tag{1}$$

Here $t_{stop,k}$ is stop time of the bus of route number *k* at stop point; $\dot{I}_k$ is a traffic interval of the buses in route number k .

According to Bernoulli's equation, the supposition to get on is as follows when passengers of S number out of S number passengers of route number k come to the bus stop:

$$P_{s,S} = C_S^s p_z^s q^{S-s} \tag{2}$$

The most supposed value of S will be whole number within $Sp + p - 1 \le s \le Sp + p$ interval.

It is seen from the above-mentioned formulae that value of S increases with the decrease of traffic interval of a bus. With the help of modern automation techniques one may calculate the number of passengers getting on via stop points and rails in every bus route. So, it is possible to define the number of passengers getting on and not getting on the bus when coming to stop point.

With regard to all routes passing through certain stop point during t period after m number buses comes to the stop point, the passengers remaining at the stop may be defined as follows:

$$A_t = A_{t-1} + C_{t-1;t} - (\sum_{j=1}^{m} b_j - \sum_{j=1}^{m} s_j) \tag{3}$$

Here A_{t-1} - is the number of passengers waiting at the stop from $t-1$ period, $C_{t-1;t}$ - is the number of passengers coming to the stop during $t-1;t$ interval; $\sum_{j=1}^{m} b_j$ - is the number of passengers getting on the bus No. j during t moment; $\sum_{j=1}^{m} s_j$ - is the number of the passengers coming to the stop during t moment and getting on j bus. $j = 1...m$ is the number of passengers coming to the stop at t moment.

Taking the capacity and structure of bus stops in Baku into consideration, the desirable maximal number of buses coming to the stop at the same time is 3 (in fact, this figure is considerably high).

For the stop through which passes n number route, we may write:

$$A_t = \sum_{i=1}^{n} a_{i,(t)} \tag{4}$$

$$A_{t-1} = \sum_{i=1}^{n} a_{i,(t-1)} \tag{5}$$

$$C_{t-1;t} = \sum_{i=1}^{n} c_{i,(t-1;t)} \tag{6}$$

Here $a_{i,(t)}$ - is the number of passengers waiting for route No. i during t moment and $a_{i,(t-1)}$ is the number of passengers waiting for route No. i during t - 1moment and $c_{i,(t-1;t)}$ - is the number of passenger coming to get on the bus of route No. i during $t-1;t$ interval.

Loss of time of passengers during every $t-1;t$ interval:

$$T_{lost(t-1;t)} = t \cdot \sum_{i=1}^{n} a_{i,(t-1)} + \frac{t}{2} \cdot \sum_{i=1}^{n} c_{i,(t-1;t)} \rightarrow \min \tag{7}$$

3. ANALYSIS OF BUS STOPS

As a result of investigations [2] carried out in the USA, the following formula has been put forth to find out launch capacity of bus stops:

$$B_S = N_{eb} B_{bb} = N_{eb} \frac{3600 \cdot \frac{g}{C}}{t_c + \frac{g}{C} \cdot t_d + z_a \cdot c_v \cdot t_d} \tag{8}$$

Here N_{eb} is the number of places designated for buses at stop; B_{bb} - is the launch capacity of one stop point; g -lighting period of green light; C - length of settlement cycle of traffic lights; t_c - time when the bus leaves the stop; t_d -time during which bus is at the stop; z_a - supposition on the increase of queues before the stop; c_v - variations of incoming intervals.

t_d, c_v and $\frac{g}{C}$ correlation varies in great interval depending on different factors such as traffic schedule and capacity of bus, number of passengers at stop and may be defined as a result of investigation of every stop points. The values of z_a and t_c parameters have been determined as a result of investigations conducted in the cities of the USA. However, street-road and route network of every city may be adjusted to the local conditions taking into consideration their characteristics. The observations made in bus routes in the investigated areas of Baku and the calculations conducted with this technique shows that the number of buses passing through the stops does not differ very much from launch capacity of stops. Thus, reconsidering the work regimes of bus routes of which certain parts concur with one another, the quality of service may be improved.

4. COORDINATION OF THE WORK OF BUSES RUNNING ON THE COMBINED SECTION OF ROUTE

The model suggested for minimization of loss of time of passengers may be accepted as a major criterion for the coordination of the work of buses. If possible, the combined work regime ensuring minimum value of loss of time of passengers should be applied. According to the suggested criterion, all stop points that concur with one another should be controlled. On the basis of the control, start and end stops of road on which combined work will be implemented should be defined. Then, as a first step traffic intervals of buses should be adjusted. In further steps, in the area that concur traffic intervals shall be optimized by sliding. In traffic schedules together with start and end points, beginning and end of the area concurring with other routes and in which the work regimes are combined shall be specifically noted.

For two routes, the question may be solved by incoming of one bus to the stop between two consecutive buses of other routes. If buses of many routes come to the stop at different intervals, the solution of the question may be achieved by grouping of bus routes according to their intervals and adjusting them to each other, because combination of the work of all routes is very complicated. Bus routes may be classified into 3 or 4 groups. For example, the solution of the question may be started by including routes of which intervals are 4-6 minutes into I group, routes within 6-10 minutes interval into II group, routes within 10-14 minutes interval into III group and etc,. In order to simplify the solution of the question it is effective to consider the group into which more routes are included.

For instance, the number of routes included into III group is more than other groups. First of all, we identify the traffic intervals of the routes as $\dot{I}_{III}$ (minute). If the number of bus routes running within this interval is n_{III}, the schedules should be made ensuring that their buses come with $\frac{\dot{I}_{III}}{n_{III}}$ (minute) difference from the stop in the beginning point of the area in question. In this case, the supposition of buses of n_{III} route on coming to the stops in the area in which route buses concur with will considerably fall. The generally accepted interval should be defined in such a form so that to be possible to be divided into the number of routes which will run on such interval $\frac{\dot{I}_{III}}{n_{III}} \in N$. If it is not possible, it is necessary to change the composition of the groups and increase their number.

In further steps, for other groups traffic schedules are adjusted in analogical method and it is not allowed for route buses in such groups to come to the stop point at the same time. If there is common divisor for traffic intervals of the routes of the discussed two groups, then it is possible to combine the work of these two groups and achieve all buses of these groups to come to the stops at different times (Fig. 1).

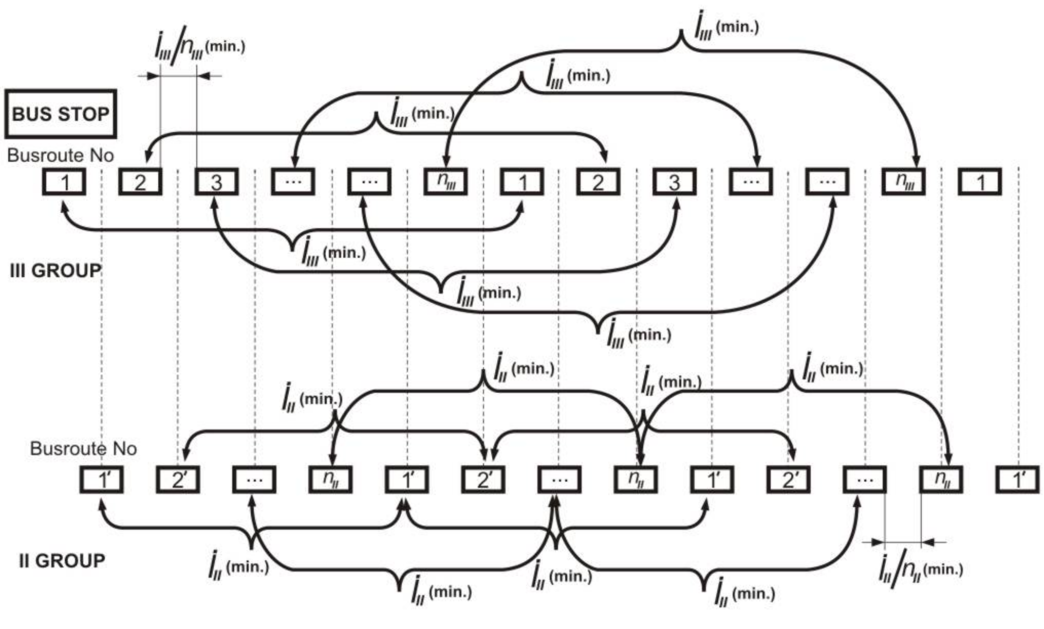

Fig. 1. Coordination of the work of bus groups having different interval (I variant)
Рис. 1. Координация работы автобусных групп имеющих различные интервалы (I вариант)

If the number of buses having short interval comprises majority, then the probability of buses of routes being under different groups to come to the stops at different times reduces. This case may be described as in Fig. 2.

In the Fig. 1 and 2: $1,2,3,...,n_{III}$ shows the number of bus routes including into III group and $1',2',3',...,n_{II}$ including into II group.

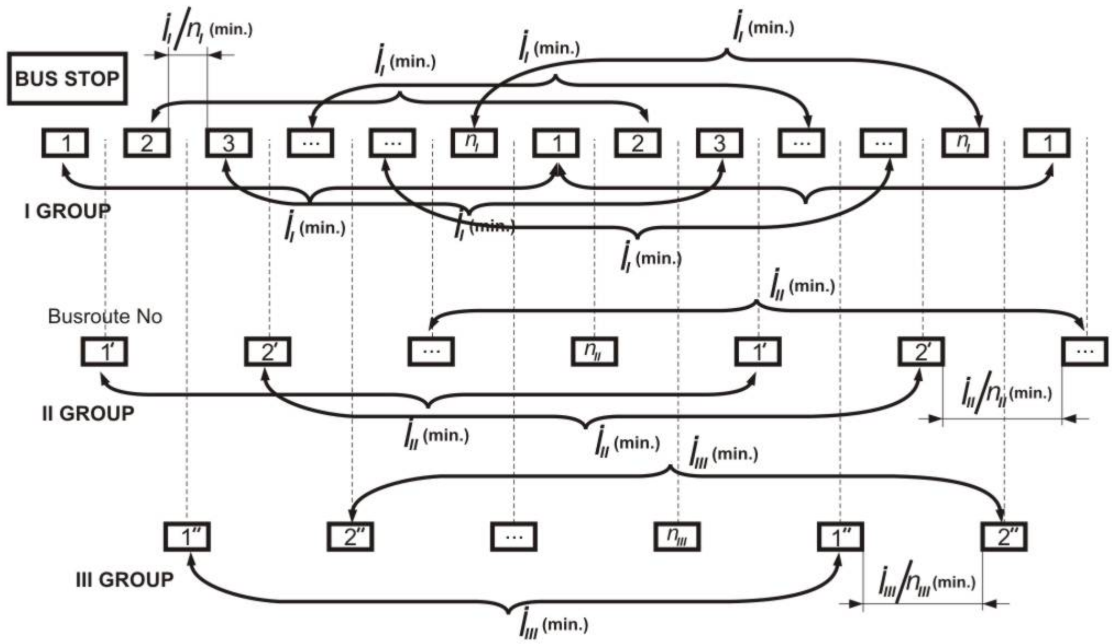

Fig. 2. Coordination of the work of bus groups having different interval (II variant)
Рис. 2. Координация работы автобусных групп имеющих различные интервалы (II вариант)

5. CONCLUSION

If the shortest interval is 6 minutes and the number of the routes under the group is 6, then the time limit among the buses if the group coming to the stops consecutively will be a minute. If taking into consideration from the traffic schedule of the bus on stop that directions are not in great numbers, in such case the work of this group may be combined with the work of at least of one of other groups.

By application of the suggested technique it is possible to improve the organization of the work in any case, because in the worst case the maximal number of the buses coming to the stop at the same time will be relevant to the maximal number of the organized groups.

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