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QUALITY ASSESSMENT OF SCHEDULE OPTIMIZATION OF URBAN PASSENGER TRANSPORT ON DUPLICATING STRETCHES

ОЦЕНКА КАЧЕСТВА ОПТИМИЗАЦИИ РАСПИСАНИЯ ГОРОДСКОГО ПАССАЖИРСКОГО ТРАНСПОРТА НА ДУБЛИРУЮЩИХ УЧАСТКАХ

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Abstract. *The article presents the optimization problem of public transport schedule in response to the improvement in passenger service quality. Using scheduling technique of route vehicles on duplicating stretches allows to determine the optimal vehicle traffic intervals for each route, taking into account duplicating stretches; coordinate the movement of route vehicles on duplicating stretches; reduce waiting time for route vehicles for those passengers who can be transported using several route options; increase uniformity of vehicle occupancy, which reduces the number of passengers in the cabin and reduces the risk of COVID-19 transmission. Parameters for evaluating the quality of schedule optimization of route vehicles on duplicating stretches are proposed.*

Keywords: *urban passenger transport, quality assessment of schedule optimization, scheduling technique, duplicating stretches, traffic interval.*

Introduction.

The main role of urban passenger transport is to ensure the sustainable development of cities. In particular, compared with individual vehicles, urban public transport significantly increases the safety of transportation and provides considerable savings of natural and financial resources [1]. It makes the task of improving the schedule of passenger transport actual. A lot of articles are devoted to the scheduling methodology of passenger transport [2 – 4].

When scheduling, the impact of compatible travel stretches of route vehicles is more often ignored, which is significant weakness for urban passenger transport services. If there are several routes servicing the same stretch, it is necessary to coordinate traffic schedules of different routes on compatible or duplicating stretches of their traffic [5, 6].

Servicing of duplicating stretches causes some problems: transport queues at the transport stops, irregular intervals of traffic vehicle, increasing passengers' waiting time which leads to discomfort while travelling, uneven occupancy of vehicles and, as a consequence, overflow of some of them, which leads to an increased risk of infection with COVID-19.

To solve these problems the scheduling technique of route vehicles on duplicating stretches was created [5 – 9]. The problem of the improvement in passenger service quality and efficiency of urban public transport is to align the schedules of different routes on duplicating stretches, thereby contributing to more regular traffic interval and vehicle occupancy. It would appear to be possible to achieve abovementioned coherence in vehicle schedule of different routes through the primary coordination of traveling time through "basic" transport stops with further calculation of the traveling time through the other transport stops of the route.

Statement of basic materials.

An important step is quality assessment of schedule optimization of route vehicles on duplicating stretches using the scheduling technique developed in the articles [5 – 9].

The quality of schedule optimization for set of duplicating stretches is determined by the following parameters.

Objective function for the duplicating stretch $D_r(I)$ can be written down in the following format:

$$D_r(I) = \sum_{i=1}^{N_D} | I_{Dr}^* - I_i \ | + \sum_{i=1}^{N_{M1}} | I_{MD1}^* - I_i \ | + \ldots + \sum_{i=1}^{N_{Mk}} | I_{MDk}^* - I_i \ | \to \min \tag{1}$$

$| I_{Dr}^* - I_i \ |$ – deviation value of intervals between route vehicles from the optimal value for the duplicating stretch,

$| I_{MDk}^* - I_i \ |$ – deviation value of intervals between route vehicles from the optimal value for the routes on the duplicating stretch.

The efficiency of optimizing public transport schedules on duplicating stretches is calculated:

$$F_r^* = D_r^0(I) - D_r^*(I), \tag{2}$$

where $D_r^0(I)$ is deviation between consecutive route vehicles from optimal value before optimization,

$D_r^*(I)$ – deviation between consecutive route vehicles from optimal value after optimization.

Determining the values of objective function for group of duplicating stretches before $D_G^0(I)$ and after $D_G^*(I)$ optimization:

$$D_G(I) = \sum_{i=1}^{N_G} | I_G^* - I_i \ |. \tag{3}$$

Comparison of objective function values for a group of duplicate plots before $D_G^0(I)$ and after $D_G^*(I)$ optimization:

$$D_G^*(I) \le D_G^0(I). \tag{4}$$

If the inequality is not met, it is necessary to return to optimization stages on each of the duplicating stretches of the group GD_k. Determination of optimization efficiency for group of duplicating stretches GD_k

$$FG_k = \sum_r FD_r. \tag{5}$$

The efficiency of schedule optimization is achieved by reducing the waiting time for public transport passengers. The waiting time for passengers of vehicles at the transport stop is defined as

$$T_{Wi} = I_i \lambda_i, \tag{6}$$

where λ_i is the intensity of arrival of passengers using vehicles of duplicating stretch.

Figure 1 shows an example of diagrams of passengers waiting for route vehicles at the transport stop before optimization (Fig.1, *a*) and after optimization (Fig.1, *b*).

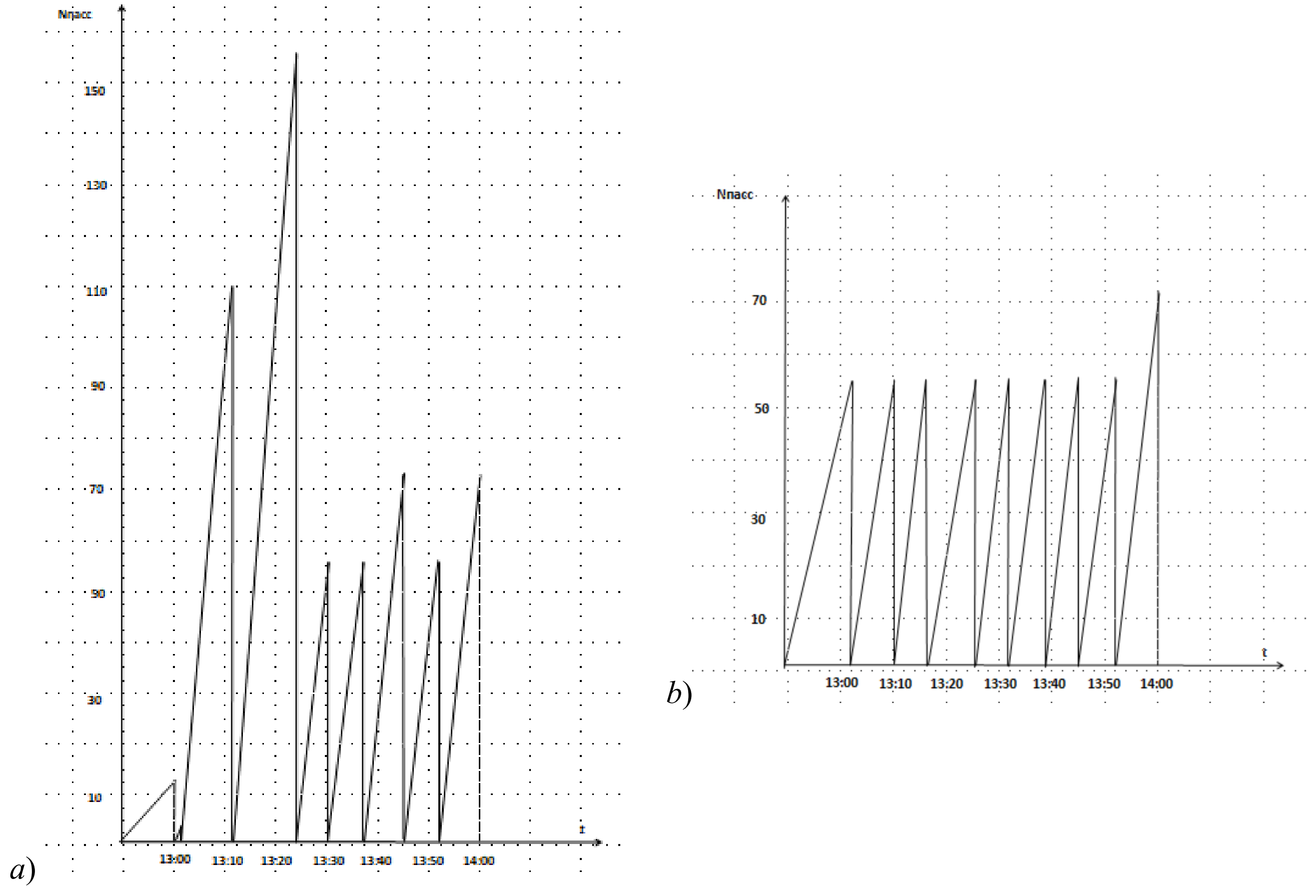

Fig. 1 Diagrams of passengers waiting for route vehicles at the transport stop
Authors` development

Environmental losses from forced downtime of route vehicles in front of the transport stop are calculated:

$$E_i^S = \sum_{j=1}^{n} q_{ij}^S \, S \, K, \tag{7}$$

where q_{ij}^S is specific emissions of the i-th substance when stopping (braking, acceleration) of j–th route vehicle (grams per transport stop),
S – the specific number of traffic stops (stops per vehicle),
K – the emission correction factor depending on the speed of route vehicle.

Emission values for following pollutants are calculated for each transport stop: carbon monoxide (CO), nitrogen oxide (NO), volatile organic substances (VOC), solid particles (PM) and fuel.

As a result of the traffic schedule optimization on the duplicating stretches

– the traffic intervals of vehicles for each route separately and for duplicating stretches are aligned,
– passengers’ waiting time for route vehicle arrival, average queuing time and queue length for route vehicles, load factor of transport stop by vehicles are reduced.

Conclusions.

While optimizing the existent schedule, particular attention is paid to reduce transport delays; due to lack of forced idle time of route vehicles in front of transport stop (waiting for an opportunity to drive to it) and subsequent accelerations, there is also the effect of reducing economic (additional fuel consumption) and environmental (from emissions of air pollutants) losses.

Experimental researches have shown the applicability of the developed technique in practice.

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Аннотация. *Одним из показателей качества обслуживания населения городским пассажирским транспортом является регулярность движения, которая напрямую зависит от грамотно составленного расписания маршрутных транспортных средств. При составлении расписания пассажирского транспорта необходимо, чтобы оно обеспечивало: проезд пассажиров с минимальными затратами времени; движение маршрутных* *транспортных средств в соответствии с пассажиропотоками на маршрутах; регулярность движения; координацию движения маршрутных транспортных средств с движением других видов пассажирского транспорта.*

В статье предложены параметры для оценки качества оптимизации расписания городского пассажирского транспорта по множеству дублирующих участков.

Ключевые слова: *городской пассажирский транспорт, оценка качества оптимизации расписания, методика оптимизации расписания, дублирующий участок, интервал движения.*

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