Int. j. adv. multidisc. res. stud. 2023; 3(4):658-661

Received: 13-06-2023
Accepted: 23-07-2023

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Efficiency Assessment of Optimizing the Urban Passenger Transport Schedule on Duplicating Stretches in the City of Gomel

Kravchenya Irina
Department of Road Transport and Traffic Management, Belarusian State University of Transport, Gomel, Republic of Belarus

Corresponding Author: **Kravchenya Irina**

Abstract
The article presents a new alignment technique of time intervals between consecutive vehicles of different routes on duplicating stretches, taking into account existing public transport network in attaining optimization of public transport schedule. The adjusting technique of urban passenger transport schedule allows to increase movement steadiness of consecutive vehicles of different routes on duplicating stretches, adjust traffic intervals for each route, shorten the traffic load on stations, reducing idle time and queue lengths of route vehicles in front of transport stops and also minimize waiting time for route vehicle by those passengers, who can be transported along several routes. Improving the bus schedule on duplicating stretches in Gomel is illustrated to demonstrate the adjusting technique of urban passenger transport schedule. The obtained optimization results may be used by Open Joint Stock Company "Gomeloblavtotrans" for improving the quality of public passenger transportation.

Keywords: Urban Passenger Transport, Scheduling Technique, Duplicating Stretches, Traffic Interval

1. Introduction

Accessibility and quality of urban passenger transport determine the real living standard and social climate, while reducing its attractiveness leads to the use of personal vehicles by passengers, which has a negative impact on the environmental situation of cities [1-7]. Therefore, the task of public transport efficiency improvement and development of activities on improvement of public transport operation through qualitative scheduling is an urgent challenge.

Schedule optimization is a proven strategy to improve service quality for public transport networks. However current research mostly optimizes schedule design using priori knowledge of users' routings and ignores the optimization of public transport schedules on duplicating stretches of route vehicles.

An efficient and rational schedule of urban public transport could provide: regularity of the route vehicle traffic; high-quality public service for passengers and travel with minimal waste of time; traffic of vehicles in accordance with passenger traffic on routes; coordination of the route vehicle traffic with the traffic of other types of passenger transport.

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.

2. Scheduling Technique of Route Vehicles on Duplicating Stretches

Scheduling technique of route vehicles on duplicating stretches [5-9] includes some steps:

- analysis of public transport network and determining a lot of duplicating stretches,
- calculation the optimal time intervals among arrivals of route vehicles and alignment this intervals among consecutive route vehicles on duplicating stretches,
- realization simulation model of urban passenger transport within simulation modelling system GPSS World,
- testing on the developed simulation model the optimization technique of route vehicle scheduling,
- analysis of the quality of adjusted schedule with route vehicles of different kinds included,
- determining the optimization efficiency for duplicating stretches.

3. Application of Scheduling Technique of Route Vehicles on Duplicating Stretches

To substantiate and test the scheduling technique of route vehicles on duplicating stretches [5-9], it is proposed to use it to optimize the bus schedule in the city of Gomel, Republic of Belarus.

The city of Gomel with about 530,000 inhabitants is the administrative center and the second-most populous city in Belarus. Currently, transportation of passengers in Gomel is carried out on 81 regular bus routes.

There were defined six duplicating stretches provided for buses movement of three or more routes (Table 1).

Duplicating stretches were ranked in descending order of the sum of stops and the number of routes.

Table 1: Parameters of duplicating stretches

Duplicating stretch	Bus routes	Transport stop amount	Sum of stops and routes	Length of duplicating stretch (km)
D_1 – "Institute "Gomelproject" – Ogorenko street"	№17, №18, №34	13	3 + 13 = 16	7,5
D_2 – "Railway station – First school"	№35, №55, №58	12	3 + 12 = 15	8,47
D_3 – "Railway station – "Gorelektrotransport""	№10a, №19, №43	10	3 + 10 = 13	4,94
D_4 – "Railway station – Cinema "October""	№1, №20, №52	8	4 + 8 = 12	4,47
D_5 – ""Medgorodok" – Technical University named after P.O. Sukhoi"	№16, №26, №33	8	4 + 8 = 12	3,39
D_6 – "Railway station – Palace of culture "Gomselmash""	№6, №8, №9	7	4 + 7 = 11	3,93

As a result of the traffic schedule optimization along six duplicating stretches, the traffic intervals of buses were aligned, total deviation value of intervals among consecutive buses from the optimal value has decreased.

Fig 1 and 2 show examples of schemes of bus traffic shift of the routes № 17, 18 and 34 at the transport stop "Institute "Gomelproject" for the first duplicating stretch D_1 in the period from 17.00 to 18.00 (Fig 1) and in the period from 15.00 to 16.00 (Fig 2).

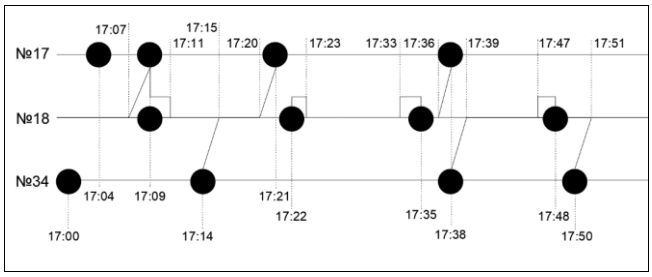


Fig 1: The scheme of bus traffic shift of the routes № 17, 18 and 34 at the transport stop "Institute "Gomelproject" for rush hours

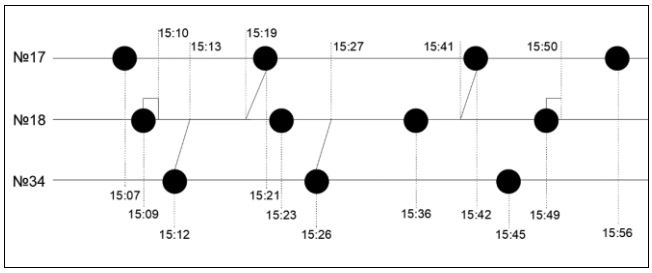


Fig 2: The scheme of bus traffic shift of the routes № 17, 18 and 34 at the transport stop "Institute "Gomelproject" for the period between rush hours

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:

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

$|I^*_{Dr} - I_i|$ – 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:

$$FD^*_r = D^0_r(I) - D^*_r(I)$$

Where:

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

$D^*_r(I)$ is deviation between consecutive route vehicles from optimal value after optimization.

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;

$$T_{Wi} = I_i \lambda_i$$

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

The value ΔT_W determines the amount of reduction in the waiting time for passengers of vehicles on the routes of duplicating stretch D_r.

The value t_p determines the average waiting time by one passenger of the vehicle for the routes of duplicating stretch D_r.

Performance evaluation of the adjusted schedule by six duplicating stretches is presented in Table 2 (for interval between rush hours) and Table 3 (for rush hours).

Table 2: Optimization result of the schedule by six duplicating stretches for the period between rush hours

DS	Before optimization		After optimization		$FD_r(I)$, minute	$FD_r(I)$, %	Δt_p, minute	ΔT_W, %
	$D^0_r(I)$, minute	t^0_p, minute	$D^*_r(I)$, minute	t^*_p, minute				
D_1	56	3,57	47	3,17	9	16,07	0,4	11,20
D_2	71	7,95	42	5,05	9	40,85	2,9	36,48
D_3	59	11,98	31	8,08	28	47,46	3,9	32,55
D_4	83	7,4	70	5,8	13	15,66	1,6	21,62
D_5	95	6,75	82	5,8	13	13,68	0,95	14,07
D_6	70	7,54	61	6,88	9	12,86	0,66	8,75
Result	434	7,53	333	5,80	101	24,43	1,74	20,78

Table 3: Optimization result of the schedule by six duplicating stretches for rush hours

DS	Before optimization		After optimization		$FD_r(I)$, minute	$FD_r(I)$, %	Δt_p, minute	ΔT_W, %
	$D_r^0(I)$, minute	t_p^0, minute	$D_r^*(I)$, minute	t_p^*, minute				
D_1	82	4,65	68	3,58	14	17,07	1,07	23,01
D_2	77	8,83	53	6,1	24	31,17	2,73	30,92
D_3	72	7,27	48	6,18	24	33,33	1,09	14,99
D_4	87	5,83	63	3,9	24	27,59	1,93	33,10
D_5	127	4,85	103	3,65	24	18,90	1,2	24,74
D_6	62	8,3	49	6,9	13	20,97	1,4	16,87
Result	507	6,62	384	5,05	123	24,84	1,57	23,94

3. Research Results

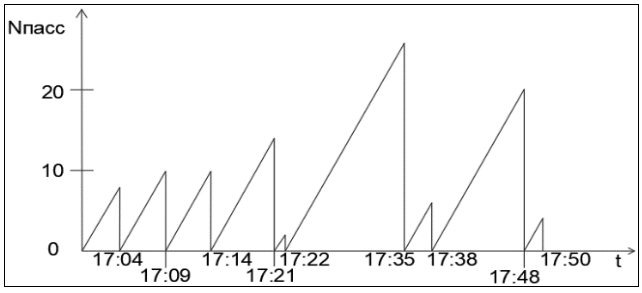
Based on the results of the optimization, the following conclusions can be drawn.

The waiting time for passengers of route vehicles decreased for the first duplicating stretch D_1 "Institute "Gomelproject" – Ogorenko street" by 11,2% (for interval between rush hours) and 23% (for rush hours), for D_2 "Railway station – First school" – 36,5% and 30,9%, for D_3 "Railway station – "Gorelektrotransport"" – 32,6% and 15%, for D_4 "Railway station – Cinema "October"" – 21,6% and 33,1%, for D_5 ""Medgorodok" – Technical University named after P.O. Sukhoi" – 14,1% and 24,7%, for D_6 "Railway station – Palace of culture "Gomselmash""– 20,8% and 23,9%.

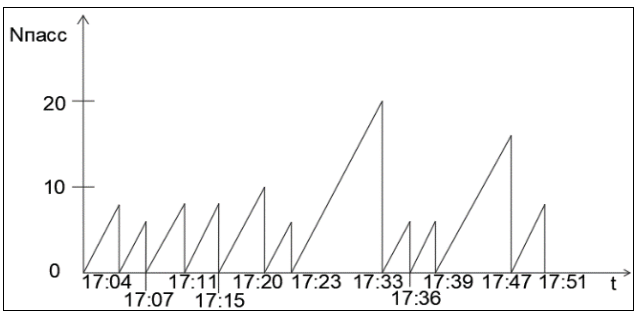
The waiting time for passengers of route vehicles by six duplicating stretches decreased by 20, 78% (for interval between rush hours) and 23, 94% (for rush hours).

The efficiency of the optimized schedule for the six duplicating stretches is 23, 43 % (for interval between rush hours) and 24, 84 % (for rush hours).

Fig 3 shows an example of diagrams of passengers waiting for route vehicles at the transport stop "Institute "Gomelproject" in the period from 17.00 to 18.00 for the first duplicating stretch D_1 before (Fig 3, *a*) and after optimization (Fig 3, *b*).



a) With the existing bus schedule



b) With the bus schedule after optimization

Fig 3: Diagrams of passengers waiting for route vehicles at the transport stop

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 were aligned,
- Passengers' waiting time for route vehicle arrival, average queuing time and queue length for route vehicles, load factor of transport stop by vehicles were reduced.

4. 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.

Improving the bus schedule on duplicating stretches in the city of Gomel was conducted to illustrate the effectiveness of the scheduling technique of route vehicles on duplicating stretches.

Experimental research has shown the applicability of the developed technique in practice.

5. References

1. Azemsha SA. Parameters of automobilization in the Republic of Belarus and their impact on greenhouse gas emissions. Ecologica. 2019; 94:217-223.
2. Cao Zh, Ceder A. Autonomous shuttle bus service timetabling and vehicle scheduling using skip-stop tactic. Transportation Research Part C: Emerging Technologies. 2019; 102:370-395.
3. Liu T, Ceder A. Integrated public transport timetable synchronization and vehicle scheduling with demand assignment: A bi-objective bi-level model using deficit function approach. Transportation Research Part B: Methodological. 2018; 117:935-955.
4. Wu W, Liu R, Jin W, Ma Ch. Stochastic bus schedule coordination considering demand assignment and rerouting of passengers. Transportation Research Part B: Methodological. 2019; 121:275-303.
5. Lebid I, Luzhanska N, Kravchenya I, Medvediev I, Kotyra A, Droździel P, *et al.* Optimization of public transport schedule on duplicating stretches. Mechatronic Systems 1: Applications in Transport, Logistics, Diagnostics, and Control. 2021; Chapter 18:209-220.
6. Azemsha S, Kravchenya I, Vovk Y, Lyashuk O, Vovk I. Scheduling technique of route vehicles on duplicating stretches. Scientific Journal of Silesian University of Technology. Series Transport. 2021; 113:5-16.
7. Azemsha SA, Kravchenia IN. Efficiency assessment of optimizing the schedule of urban passenger transport on duplicate sections. The Russian Automobile and Highway Industry Journal. 2021; 18(1):72-85.
8. Kravchenya IN, Podkolzin AM. Optimization of public transport schedule of different routes on duplicating stretches. Organization and road safety. 2019; 2:54-61.
9. Lebid I, Kravchenya I, Luzhanskaya N, Medvedev E. Optimization technique of public transport schedule of different routes on duplicating stretches. Prospects for the development of mechanical engineering and transport, 2019, 176-177.

10. Kravchenya IN. Optimization of Urban Passenger Transport Schedule on Duplicating Stretches in the City of Rechitsa. International Journal of Engineering Inventions. 2022; 11(12):124-127.
11. Taha Hamdy A. Operations research: An introduction. 10th edn. USA, Upper Saddle River, 2017, p815.
12. Kravchenya IN, Burduk EL, Alymova TV. Mathematical modeling. Linear and nonlinear programming, network planning and management: A training manual. Belarus, BelSUT, 2014, p112.