Identification of key route indicators to compare different modes of transport

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Abstract. Key route indicators of transport are identified, revealing the main characteristics of the organization of routes that affect the rationality of the organization and the effectiveness of their work. A model has been developed that considers the structural and operational characteristics of vehicles, which makes it possible to determine not only the parameters of the vehicle's operation on the route, but also the parameters characterizing the driver's employment. The nomenclature of indicators is given, which makes it possible to objectively compare the parameters of the route operation when servicing it with various types of transport, with the help of which the operation of route No. 139 in Minsk is investigated.

1 Introduction

The issues of choosing the type of route passenger transport when servicing routes on the established route network have disturbed the minds of scientists over the past century. However, these issues were often solved by urban planners at the stage of forming the route network and were reduced to determining the amount of passenger traffic being mastered (often promising) and choosing between a bus, trolleybus, tram and subway[1, 2, 3, 4, 5, 6, 7, 8, 9]. It is known that the trolleybus, tram and subway made it possible to master high passenger flows, however, it required the construction of a contact network, a contact network and a rail track, as well as all the necessary underground infrastructure for the subway. To date, the development of new types of electric transport makes the process of choosing a type of transport for servicing a direction or route more flexible and does not always require the creation of infrastructure geographically distributed along the length of the route, but allows its point placement, etc. [10, 11, 12, 13, 14, 15, 16,17, 18, 19, 20]. However, the issue of comparing the performance indicators of the urban passenger transport route remains open to assess its performance in organizing the operational work of a route passenger transport enterprise [21, 22]. To develop an approach, it is advisable to determine the nomenclature of key indicators that will allow us to assess the rationality of using productive time when working vehicles on the route and the degree of use of drivers' working time.

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2 Methods

From the point of view of the organization of the operational work of the enterprise of route passenger transport, it is advisable to present the model of the driver's work on the route of urban passenger transport through the duration of the driver's working time, since in this case both the parameters of the vehicle's operation on the route and the parameters determining the driver's employment and driver's remuneration for servicing this route on this route will be taken into account. the vehicle [23, 24, 25, 26].

Based on this approach, the duration of the driver's work shift t_{cm}, when working on a route with terminal stations A and B, can be represented as a model (1):

$$t_{\text{cm}} = t_{\text{pv}} + t_{\text{zv}} + t_{\text{nrn}} + t_{\text{nrk}} + n_{\text{AB}}(t_{\text{AB}} + t_{\text{ctoB}}) + n_{\text{BA}}(t_{\text{BA}} + t_{\text{stoA}}) + t_{\text{stdA}} + t_{\text{stdB}} \text{ , h, (1)}$$

where t_{pv} – the preparatory time for the acceptance of the vehicle, preparation for work (h);

t_{zv} – the final time for the completion of work, delivery of the vehicle (h);
t_{nrn} – the duration of the zero trip at the beginning of the shift (h);
t_{nrk} – the duration of the zero trip at the end of the shift (h);
n_{AB}, n_{BA} – the number of trips in the direction A→B and B→A;
t_{AB}, t_{BA} – duration of trips in the direction A→B and B→A;
t_{stoB}, t_{stoA} – the duration of mandatory parking on A and B (h);
t_{stdB}, t_{stdA} – the duration of additional parking on A and B (h).

At the same time, the duration of t_{pv}, t_{zv} is determined by the time determined, as a rule, by the experience of the enterprise of route passenger transport. This is the time required to receive and complete the necessary documentation, undergo a pre-trip medical examination, accept the vehicle at the beginning of work, including equipment, equipment, checking the technical condition of the vehicle at the beginning of work, as well as transfer or disassembly of the vehicle at the end of work.

An analysis of the operation of routes in Minsk shows that the largest share of $t_{см}$ is the time used to perform surfactant, n_{AB}, n_{BA} trips in the AB and VA directions (according to research data from 73.5% to 79.9% on various routes), the share t_{pv} и t_{zv} ranges from 4.8% to 5.3%, the share t_{nrn} и t_{nrk} is from 4.6% to 13.1%, the share of time spent on inter-route parking t_{stoA}, t_{stoB}, t_{stdA}, t_{stdB} ranges from 7.1% to 10.3% for buses, trolleybuses, trams at terminal stations, while for electric bus routes this value reaches 20.4%.

Based on the model of the vehicle driver's work on the route, in order to assess the operation of the urban passenger transport route, it is proposed to allocate the following range of indicators:

1. The number of trips in the forward and reverse directions (allows you to quickly assess whether the travel intervals according to the schedule have changed depending on the type of transport used, considering the technology of the vehicle on the route) [27, 28, 29, 30].
2. The duration of trips on the route in the forward and reverse directions (allows you to assess the impact of the mode of transport on the technical speed and characteristics of movement along the route under consideration).
3. The duration of parking and shifts (objectively shows how the unproductive time spent by vehicles at the end stations of the route varies depending on the chosen mode of transport).
4. Preparatory and final time (despite the fact that this indicator for one vehicle is normalized by law, it is objective for the route due to the different duration of this time depending on the type of release according to the schedule and also depends on the number of these releases) [30, 31, 32].

5. The duration of zero trips (shows how long how much unproductive time varies depending on the type of transport and the number of releases required to maintain the route with the same traffic intervals).

6. The duration of breaks for rest and meals (a reference indicator that does not affect paid working hours, but reflects the efficiency of using the route time as a whole) [33, 34].

7. The number of vehicles by type of issue — single-shift, double-shift, discontinuous (shows how many vehicles of different types of transport are needed to maintain the route with the maintenance of the same traffic intervals) [35, 36, 37].

8. The number of working shifts of drivers (shows how many drivers are needed to maintain the route).

9. The working time fund is common, for one productive trip, for one driver, for one vehicle (objective indicators of the efficiency of using the "human resource" when servicing the route by various modes of transport) [38].

10. Productive mileage (for trips in the forward and reverse directions), unproductive mileage (zero), total mileage allows you to assess whether the mileage of vehicles varies depending on the selected type of transport [39].

11. The average speed of the message (shows whether the passenger's travel time varies depending on the type of transport) and the average operating speed (reflects the effectiveness of the organization of operational work on the route).

3 Results and Discussions

The calculation results performed for route No. 139 in Minsk are summarized in Table 1.

Table 1. Technical characteristics of some energy storage devices

The name of the indicator	Bus	Electro-bus	Changing the indicator	
			Abs	Vs
Number of direct trips	83	82	–1	–1,2%
The number of trips in the opposite direction	83	82	–1	–1,2%
Duration of direct trips, min.	2255	2228	–27	–1,2%
Duration of trips in the opposite direction, min.	2241	2214	–27	–1,2%
Duration of stops and shifts, min.	513	1345	**+832**	**+162,2%**
Preparatory and final time, min.	290	330	+40	+13,8%
Duration of zero trips, min.	90	140	+50	+55,6%
Duration of breaks for rest and meals, min.	387	393	+6	+1,6%
Number of vehicles	6	7	+1	+16,7%
on issues of the same	1	1	0	0,0%
name on double-shift issues	5	5	0	0,0%
on discontinuous issues	0	1	+1	∞
Number of work shifts (number of drivers)	11	12	+1	+9,1%
Working time fund, min.	5389	6257	+868	+16,1%
Working time fund, attributable to	32,5	38,2	**+5,7**	**+17,5%**
for one productive trip, min.	89,8	104,3	**+14,5**	**+16,1%**
Working time fund, part	8,17	8,69	+0,52	+6,4%

of the working time Fund, attributable to	14,97	14,90	-0,07	-0,5%
per driver,	1278,2	1262,8	–15,4	–1,2%
whose Working time Fund is attributable to	26,4	30,8	+4,4	+16,7%
per vehicle, h	1304,6	1293,6	–11	–0,8%
Productive mileage, km	17,06	17,06	0	0,0%
Unproductive mileage (zero), km	14,23	**12,11**	–2,12	–14,9%

It can be seen from Table 1 that when transferring the route to electric bus service:

– the daily total mileage decreased by 11 km (due to a decrease in the number of trips per turnaround trip) while the unproductive mileage increased by 4.4 km;

– the duration of the vehicle's stay at the end stations during stops and shifts increased by 832 minutes (+162.2%);

– the daily duration (total) of drivers' working time along the route increased by 14.5 hours (+16.1%);

– the average speed of the message along the route has not changed;

– the average operating speed of the vehicle on the route decreased by 2.12 km/h from 14.23 km/h to 12.11 km/h (-14.9%).

Considering that the time spent by the vehicle at the terminus of the route during inter-trip parking is unproductive, a separate study and comparison of the duration of parking times of various modes of transport is of particular interest in this regard. Using the example of route No. 139 in Minsk, the distribution of the duration of parking at the end stations during the maintenance of the route by diesel buses (Figure 1) and electric buses with ultrafast charging (Figure 2) is constructed.

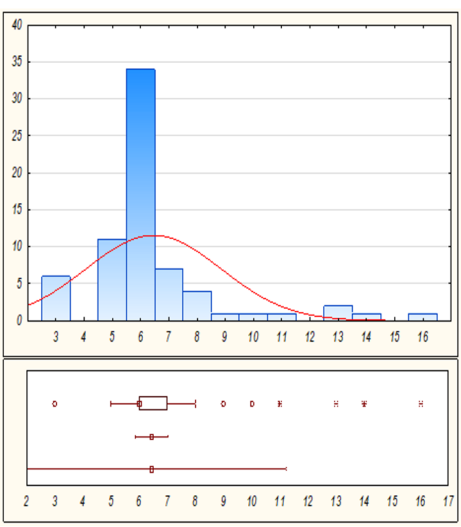

Fig. 1. Allocation of parking time at the end stations of route No. 139 for diesel bus service (avg = 6,435; med = 6; var = 5,69; st.dev = 2,39)

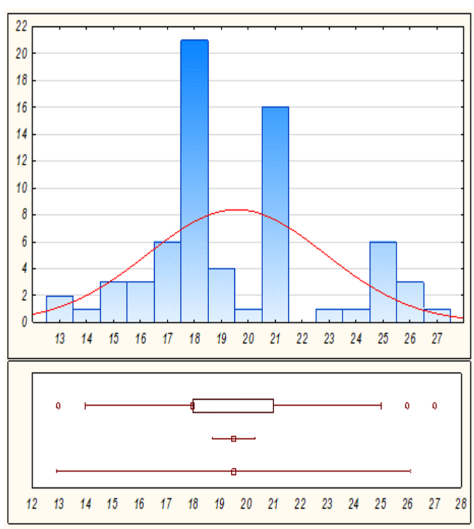

Fig. 2. Allocation of parking time at the end stations of route No. 139 for electrobus service (avg = 19,52; med = 18; var = 10,75; st.dev = 3,28)

Fig. 3. Unproductive inter-trip parking time at the terminal station while charging at the charging station [photo by authors]

From the comparison, it can be seen that the average duration of inter-trip parking when transferring the route to electric bus service increased by 13.1 minutes (from 6.4 minutes to 19.5 minutes).

4 Conclusions

The developed nomenclature of indicators makes it possible to compare the parameters of the operation of routes when servicing them by various modes of transport and objectively assess the impact of the type of transport and its design characteristics on the efficiency of using working time and, as a result, the organization of operational work. The considered example for route No. 139 in Minsk is quite objective and indicative, the results obtained make a significant contribution to the issue of studying the productivity of using drivers' working hours. Also, with the help of the proposed methodology, other types of transport (tram, trolleybus) that have not been considered in this article can be investigated.

References

1. Semchenkov, S.S. & Kapski, D.V. (2022). *Reduction of unproductive costs of route passenger transport by the sectoral method*. Bulletin of Polotsk State University. Series B. Industry. Applied sciences technologies (85–90). Novopolotsk: PGU.
2. Schneider Lars (2015). Operational planning in local public transport: goals, methods, concepts. Berlin: Springer-Verlag Berlin Heidelberg.
3. Semchenkov, S.S. & Kapski, D.V. (2022). *Management of the mode of operation of route passenger transport by the sectoral method.* Bulletin of Polotsk State University. Series B. Industry. Applied sciences technologies (59–63). Novopolotsk: PGU.
4. Semchenkov, S.S. & Kapski, D.V. (2022). *Improving the efficiency of the enterprises of route passenger transport in modern conditions.* Science and Technology news, 16–26. Minsk: BNTU.

5. Semchenkov, S.S. & Kapski, D.V. (2021). Improving the efficiency of the route passenger transport using the sectoral method. Transport and transport systems: design, operation, technologies, 170–185. Minsk: BNTU.
6. Semtchenkov, S., Kapski, D., & Czerepicki, A. (2022). WUT Journal of Transportation Engineering, **(134):** 17–33.
7. Lobashov, A.O. (2022) Planning for sustainable urban mobility Minsk: BNTU
8. Kapski, D.V., Kot, Ye.N. & Semchenkov, S.S. (2020). Some issues of a systematic approach to planning the work of drivers of urban passenger transport. Socio-economic problems of development and functioning of transport systems of cities, 269–280. Yekaterinburg: AMB.
9. Semchenkov, S.S. & Sedyukevich, V.N. (2014). Preparation of daily work orders for drivers of vehicles when transporting passengers in regular traffic. Improving the organization of road traffic and transportation of passengers and cargo: collection of scientific papers, 286–292. Minsk: BNTU.
10. Semchenkov, S.S. & Kapski, D.V. (2022). Development of rational work schedules for drivers of route passenger transport using the sectoral method. Bulletin of Polotsk State University. Series B. Industry. Applied sciences technologies, 64–72. Novopolotsk: PGU.
11. Abdurazzokov, U., Sattivaldiev, B., Khikmatov, R., Ziyaeva, S. (2021a). E3S Web of Conferences, **264**, 05033. https://doi.org/10.1051/e3sconf/202126405033
12. Abdurazzokov, U., Sattivaldiev, B., Khikmatov, R., Ziyaeva, S. (2021b). E3S Web of Conferences, **264**, 05033. https://doi.org/10.1051/e3sconf/202126405033
13. Dashdamirov, F., Abdurrazzokov, U., Ziyaev, K., Verdiyev, T., Javadli, U. (2023). E3S Web of Conferences, **401**, 01070. https://doi.org/10.1051/e3sconf/202340101070
14. Faizullaev, E. Z., Rakhmonov, A. S., Mukhtorjanov, U. M., Turdibekov, S., & Nasirjanov, Sh. I. (2023). E3S Web of Conferences, **401**, 03022. https://doi.org/10.1051/e3sconf/202340103022
15. Fayzullaev, E., Tursunbaev, B., Xakimov, S., & Rakhmonov, A. (2022, June). AIP Conference Proceedings, **2432(1),** 030099, AIP Publishing. https://doi.org/10.1063/5.0089596
16. Fayzullayev, E., Khakimov, S., Rakhmonov, A., Rajapova, S., & Rakhimbaev, Z. (2023). E3S Web of Conferences, **401**, 01073. https://doi.org/10.1051/e3sconf/202340101073
17. Ikromov, A. (2023). Components modifying methods with the using of energy technologies. In AIP Conference Proceedings, **2612(1),** 060037. https://doi.org/10.1063/5.0115559
18. Kasimov, O. (2023). E3S Web of Conferences, **401**, 02033. https://doi.org/10.1051/e3sconf/202340102033
19. Kasimov, O., & Tukhtamishov, S. (2023). Mathematical model of braking process of car. E3S Web of Conferences, 401, 02034. https://doi.org/10.1051/e3sconf/202340102034
20. Keldiyarova, M., Ruzimov, S., Bonfitto, A., & Mukhitdinov, A. (2022, October). Comparison of two control strategies for range extender hybrid electric vehicles. In 2022 International Symposium on Electromobility (ISEM) (pp. 1-6). IEEE.
21. Khakimov, S., Fayzullaev, E., Rakhmonov, A., & Samatov, R. (2021). Variation of reaction forces on the axles of the road train depending on road longitudinal slope. E3S Web of Conferences, 264, 05030. https://doi.org/10.1051/e3sconf/202126405030

22. Kulmukhamedov, Z., Khikmatov, R., Erbekov, S., & Saidumarov, A. (2022). Maximum temperature values of the engine and auto motor vehicles units in conditions of elevated ambient temperatures. In AIP Conference Proceedings, 2432(1), 030040. https://doi.org/10.1063/5.0093466
23. Kulmukhamedov, Z., Khikmatov, R., Saidumarov, A., & Kulmukhamedova, Y. (2021). Theoretical research of the external temperature influence on the traction and speed properties and the fuel economy of cargo-carrying vehicles. Journal of Applied Engineering Science, 19(1), 68–76. https://doi.org/10.5937/jaes0-27851
24. Kutlimuratov, K., Khakimov, S., Mukhitdinov, A., & Samatov, R. (2021). Modelling traffic flow emissions at signalized intersection with PTV vissim. E3S Web of Conferences, 264, 02051. https://doi.org/10.1051/e3sconf/202126402051
25. Mukhitdinov, A., Abdurazzokov, U., Ziyaev, K., & Makhmudov, G. (2023). Method for assessing the vehicle energy efficiency on a driving cycle. In AIP Conference Proceedings, 2612(1), 060028. https://doi.org/10.1063/5.0114531
26. Mukhitdinov, A., Ziyaev, K., Abdurazzokov, U., & Omarov, J. (2023). Creation of the driving cycle of the city of Tashkent by the synthesis method. In AIP Conference Proceedings, 2612(1), 060029. https://doi.org/10.1063/5.0126363
27. Mukhitdinov, A., Ziyaev, K., Omarov, J., & Ismoilova, S. (2021). Methodology of constructing driving cycles by the synthesis. E3S Web of Conferences, 264, 01033. https://doi.org/10.1051/e3sconf/202126401033
28. Nurmetov, K., Riskulov, A., & Ikromov, A. (2022). Physicochemical aspects of polymer composites technology with activated modifiers. In AIP Conference Proceedings, 2656(1), 020011. https://doi.org/10.1063/5.0106358
29. Yusupov, U., Kasimov, O., & Anvarjonov, A. (2022). Research of the resource of tires of rotary buses in career conditions. In AIP Conference Proceedings, 2432(1), 030073. https://doi.org/10.1063:/5.0089590
30. Yusupov, U., & Mukhitdinov, A. (2023). Evaluation of the influence of the longitudinal slope of carriage roads on the tire life. E3S Web of Conferences, 401, 03025. https://doi.org/10.1051/e3sconf/202340103025
31. Avdeychik, S., Goldade, V., Struk, V., Antonov, A., & Ikromov, A. (2020). The Phenomenon of Nanostate In Material Science of Functional Composites Based on Industrial Polymers. Theoretical & Applied Science, (7), 101-107.
32. Ziyaev, K., Omarov, J., (2024). Research of passenger traffic in public transport, AIP Conference Proceedings, 3045(1), 040030, DOI: 10.1063/5.0197314
33. Mukhitdinov, A., Yusupov, U., Tukhtamishov, S., Urinbayev, Q., (2024). Results of the study of the influence of an average longitudinal slope of routes on the life of tires in the quarry, AIP Conference Proceedings, 3045(1), 040041, DOI: 10.1063/5.0197301
34. Abdurazzoqov, U., Anvarjonov, A., (2024). State of transport system organization in developed cities, AIP Conference Proceedings, 3045(1), 040012, DOI:10.1063/5.0197302
35. Rustamov, K., Rustamova, N., Nazarov, A., & Abdukodyrova, M. (2024, March). The state of the transport services market and development trends. In AIP Conference Proceedings, 3045(1). AIP Publishing.
36. Juraboevich, R. K. (2020). Technical solutions and experiment to create a multipurpose machine. International Journal of Scientific and Technology Research, 9(3), 2007-2013.

37. Rustamov, K. (2023, June). Justification of the structures of a road-building machine and the application of repair processes performed by the MM-1 machine. In AIP Conference Proceedings, 2789(1). AIP Publishing.
38. Rustamov, K., & Rustamova, N. (2023, June). Determination of the main parameters of the mechanisms of a two-stage compressor and their kinematic analysis. In AIP Conference Proceedings, 2789(1). AIP Publishing.
39. Komilov, S., Rustamov, K. J., Akramova, L., Egamshukurov, P., & Tastanova, G. (2024). Development of mining operations in deep quarries using automobile and combined transport. In E3S Web of Conferences, 515(1), 03014. EDP Sciences.