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MEASURES TO IMPROVE THE OPERATION OF PASSENGER TRANSPORT AND URBAN MOBILITY

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Abstract
The article discusses the types of urban electric transport used in Belarusian cities, gives a detailed classification and comparison of available vehicles. Various options for increasing the share of environmentally friendly transport through the use of electric buses and trolleybuses are considered, an assessment and a comparative analysis of the options are given. Features of planning of work of drivers and drawing up of the schedule taking into account safety requirements are considered.
Intensive growth in the level of motorization of the population, an increase in the number of business trips, the use of light vehicles with small volumes of freight, the emergence of "commercial" routes have led in recent years to a sharp increase in car flows in urban transport systems. In this regard, a whole range of tasks arises related to increasing the comfort of movement and the quality of life of citizens in general, which is possible by optimizing the operation of route (urban) passenger transport and increasing its attractiveness for users of all levels. Experimental and computational-theoretical studies were carried out, the direction to improve the work of route passenger (urban) transport of cities (on the example of Polotsk and Novopolotsk). Recommendations are given for further improving the operation of urban passenger transport systems according to alternative scenarios for the cities of Polotsk and Novopolotsk. An assessment is made of the possibility of achieving planned indicators for reducing greenhouse gas emissions from the implementation of the pilot project measures aimed at improving the quality and efficiency of the route passenger transport in these cities. A comparative analysis of the possibility of developing various types of electric route passenger transport is carried out. A map has been developed for reducing emissions of pollutants from vehicles with a change in the structure of mobility of the population and an increase in the share of use of route passenger transport, an increase in the speed of movement of route passenger transport.
A methodology for assessing the efficiency of urban passenger transport has been developed, including taking into account the development of electric vehicles, which made it possible to determine the need to purchase appropriate vehicles for organizing the movement of non-rail electric vehicles; create a base for their repair and maintenance; construction of traction substations (new or additional); construction of cable networks; train staff. Also, an algorithm has been developed for the implementation of the least costly activities at the initial stage with limited funding. The studies performed allowed us to formulate a concept and propose specific comprehensive measures aimed at improving the quality and efficiency of the route passenger transport in Polotsk and Novopolotsk, including optimizing the existing route network of route passenger transport.

Studies of the effectiveness of measures aimed at reducing delays in route passenger transport have been carried out, criteria and places of their application in Polotsk and Novopolotsk have been determined, as well as an assessment of the technical and economic indicators of the proposed options using the international CBA methodology (Cost Benefit Analysis).
A business model has been developed for the implementation of standard measures aimed at improving the quality and efficiency of the route passenger transport, has been proposed a set of measures to increase the attractiveness and efficiency of urban passenger transport.

Keywords: Urban electric transport, Environment, Tram, Trolleybus, Electric Bus, Hybrid bus, Duobus, Charging electric buses, Safety, Schedule, Workplan.

1. Introduction

The creation of a favorable urban space for life and work is impossible without a developed system of route passenger transport, which is a clear and well-coordinated mechanism that combines various types of transport and offers a decent and effective alternative to personal cars. It is known that the share of private car owners depends on a number of factors: cultural, economic, social. The growth of motorization, the increase in the number of privately owned cars, is a challenge to the route passenger transport, which must respond to it with a systematic approach and rational organization of work, responding in a timely manner to the changing situation.

In the conditions of a vague response to a changing situation, a certain kind of "vicious circle" arises, when the growth of motorization in the conditions of the existing street network leads to its overload, which inevitably leads to a deterioration of conditions for the movement of route vehicles, reduces the speed of route vehicles movement, worsens the quality of passenger transportation services, which, in turn, leads to the loss of passengers of fixed-route passenger transport, further reducing the number of route vehicles on routes (there is a superficial impression that the existing regular route is not needed, since fixed-route vehicles are not sufficiently filled, etc.), which further removes passengers from fixed-route passenger transport and determines their choice in favor of personal, which again leads to an increase in motorization and so this circle "closes", aggravating the problems of cities.

In the current situation, it is necessary to take all possible measures and use any available means to break the "vicious circle" and improving the organization of the work of route passenger transport in cities. The concept of sustainable mobility has become highly relevant today. It is worth noting that in this regard, the concept of "mobility" is used in combination with the concept of "sustainability". This suggests that it is no longer enough for people to simply move from one point to another. This movement must meet a number of requirements, such as convenience, accessibility, speed, safety, reliability, environmental friendliness (the corresponding CO_2 emissions per passenger-kilometer are always lower for public transport compared to cars). Moreover, these requirements must be met constantly in time, and not be of a one-time or episodic nature. Therefore, the issues of improving transport services and choosing the type of transport are relevant for many cities. At the same time, it is necessary to take into account the capabilities of vehicle manufacturers, national specifics and legislation, the physical and financial capabilities of cities for transformation, restrictions, the level of return on investment, the tendency to build green transport systems. The studies were conducted in 2017–2018 on the basis of the information available at that time and in many positions they have not lost their relevance at the time of publication.

2. Methodology

The research was initiated in the form of studying the proposed technical solutions in the field of route passenger transport, affecting the issues of infrastructure and vehicles, their technical equipment. Methodologically, research is divided into three related groups: vehicles and technical issue, route network, organization of transportation.

2.1. Vehicles and technical issue

Currently, the Republic of Belarus has established its own production of trams, trolleybuses, trolleybuses-electric buses and electric buses. Various types of urban electric transport are known and widely used in world practice:

1. Tram is the oldest type of electric transport, vehicles which move on the track.
2. Trolleybus is a type of electric transport, vehicles which move on roads and are driven by electric motors that receive electrical energy from the laid contact wires. Trolleybuses in the classic and known to the consumer representation are vehicles with feeding in motion — IMF (in-Motion-Feeding). If to obtain electricity on some parts of the route is not used contact network, and autonomous on-board energy source, charging from the contact network, such trolleybuses can be considered as trolleybuses-electric buses with dynamic charging — IMC (in-Motion-Charging).
3. Hybrid bus is a type of transport whose vehicles move on roads and are driven by the combined work of an internal combustion engine and an electric motor.
4. Electric bus — it is a type of electric transport, vehicles of which move on roads, are driven by electric motors, which receive electric energy from an autonomous onboard source (charging of the onboard source occurs during the stay of the electric bus at special charging stations and requires a certain time).

Recent years have been characterized by rapid development of electric transport, manufacturers of route vehicles with electric drive also continue to develop this direction and offer customers new solutions. The emergence of new models and modifications of vehicles has led to the fact that within the same scheme according to the existing classification there were vehicles with significant differences in parameters determining their operational properties and qualities, requirements for charging infrastructure and, as a consequence, characterizing the possibility of using vehicles on regular routes of a certain configuration and length.

Thus, the existing classification at the moment turned out to be very stingy and, in the opinion of the authors, there was a need to create an extended classification. In the extended classification proposed by the authors, in addition to the designation of the scheme, the concept of a category with a digital designation is introduced, while the higher the value of the category, the greater the margin of autonomous travel the vehicle has.

For trolleybuses built according to the IMF scheme, two categories are provided:

- IMF-0 — no reserve of autonomous travel;
- IMF-1 — an autonomous power reserve of up to 1 km (as a rule, this is an emergency mode).

For trolleybuses built according to the IMC scheme, three categories are provided:

- IMC-1 — a reserve of autonomous travel from 5 to 15 km;
- IMC-2 — autonomous range from 15 to 31 km;
- IMC-3 — autonomous range from 31 to 51 km.

For electric buses built according to the OC scheme, four categories are provided:

- OC-1 — a reserve of autonomous travel from 3 to 5 km;

- OC-2 — autonomous range from 5 to 13 km;
- OC-3 — autonomous range from 13 to 21 km;
- OC-4 — autonomous range from 21 to 51 km.

For electric buses built according to the ONC scheme, two categories are provided:

- ONC-1 — a reserve of autonomous travel up to 170 km (equal to the duration of one working shift);
- ONC-2 — autonomous range from 170 to 250 km (equal to duration of one working day with restrictions);
- ONC-3 — autonomous range from 250 to 350 km (equal to the duration of one working day).

The proposed categories are formed based on the solutions offered by manufacturers and the established practice of using route vehicles with electric drive on regular routes. The emergence of new solutions that will require the introduction of additional categories in the classification under consideration is not excluded.

The infrastructure elements necessary to provide traction of trolleybuses and charging of electric buses of various versions are given in table 1.

Table 1: Infrastructure required to provide traction for IMF trolleybuses, IMC trolleybuses, duobuses and charging electric buses of various versions

Name, Value	IMF	IMC	Duobus	OC	ONC
Traction substation	+	+	+	+	+
Cable network	+	+	+	+	+
Contact wires	+	+/–	+/–	–	–
Charging stations on the line	–	–	–	+	–
Charging stations in the depot	–	–	–	+	+

2.2. Route network

In order to obtain reliable information about the route network, formed passenger flows and correspondence, various field studies and experiments were carried out on it. They were carried out by examining the operation of transport systems, objective and expert assessments, measurements, including using the analysis of video recordings and GPS tracks.

To perform an analysis of the route network, all routes were classified according to geographical, topographic features, route topology and purpose. The areas of duplication of routes performed by vehicles of different capacity classes have been identified, the degree of duplication of routes has been established. Urban and suburban areas were zoned according to territorial and (or) functional characteristics.

During the survey of stopping points, the general planning parameters of the road network, planning parameters of elements and equipment of stopping points, approaches and pedestrian connections, the presence of systemic interference for the movement of route vehicles, the presence of interference and inclusive barriers were studied. The main shortcomings identified include the absence of entry pockets on streets with high traffic intensity, the absence of landing pads, the discrepancy between the level of the landing pad and the floor level of the vehicle, barriers when using vehicles of the M2 category (commercial minibuses). When conducting passenger traffic studies, a continuous and selective method was used. The places of gravity, passenger-forming points, places of intensive passenger exchange were determined. In the selective method, a capacity score was used (with a differentiated scale from 1 to 6 points for vehicles of different capacity classes), the date, time, route number, vehicle registration plate, number of passengers entering and exiting, occupancy were recorded. According to the results of the study, the volume of passenger traffic on certain sections of the route network was clarified, dependencies were built reflecting the unevenness by time of day, by directions and by days of the week.

2.3. Organization of transportation

All routes were classified according to the purpose of the route, according to the frequency of movement (high-frequency with a frequency of more than 6 flights per hour, medium-frequency with a frequency of 3 to 6 flights per hour, low-frequency with a frequency of up to 3 flights per hour). The schedule has been studied for each route and graphical trips charts have been compiled. It was established by what capacity buses each route is served by. Trends and dependencies were identified. In particular, it was found that passenger capacity does not always correlate with the frequency of traffic on the route, which is abnormal and should become a trigger for making decisions on the reorganization of the route network. Separate studies were conducted to study the time of disembarkation and boarding of passengers. It is established that this time increases when the bus class does not match the capacity of passenger traffic, with an increase in the degree of filling of the vehicle, when using vehicles with a high floor level. A study of the speed of route vehicles with details on the stages was carried out. The factors that affect the speed of movement are established: the type of transport, the number of intersections with traffic light regulation, lack of coordination, green wave, the number of unregulated pedestrian crossings, artificial irregularities, the presence of level crossings, unregulated objects with high traffic intensity, the presence of a narrow carriageway, the presence of randomly parked cars in unauthorized places.

The following models were used to determine the parameters of transport processes:

- passenger travel time t_{ptt}, which includes the time of approach to the stopping point t_{apr}, waiting time t_{wait}, time on the move t_{move}, transfer time $t_{transfer}$ (if applicable), t_{fin} final travel time from the stopping point to the destination, see equation (1)

$$t_{ptt}=t_{apr}+t_{wait}+t_{move}+t_{transfer}+t_{fin} \qquad (1)$$

- turnaround time T_{tt}, depending on the time for mandatory technological stopping T_{tsA} at the conditional station A of the route, time for stopping for the sanitary needs of the driver T_{ssA} at the conditional station A of the route, time for movement T_{mAB} from the conditional station A to the conditional station B, time for mandatory technological stopping T_{tsB} at the conditional station B of the route, time for stopping T_{ssB} for the sanitary needs of the driver at the conditional station B of the route, time for movement T_{mBA} from the conditional station B to the conditional station A, see equation (2)

$$T_{tt}= T_{tsA}+T_{ssA}+T_{mAB}+T_{tsB}+T_{ssB}+T_{mBA} \qquad (2)$$

- the number of vehicles on the route n, depending on the hourly capacity of passenger traffic Q in the most loaded stage, the passenger capacity q of the vehicles used, operating ratio of passenger capacity γ (sets the service level), turnaround time T_{tt}, see equation (3)

$$n = \frac{q\gamma T_{tt}}{60Q} = \frac{q\gamma(T_{tsA}+T_{ssA}+T_{mAB}+T_{tsB}+T_{ssB}+T_{mBA})}{60Q} \qquad (3)$$

The solution of the optimization problem from the point of view of the organization of transportation as an objective function should be used n → min. Solving in various ways, optimizing values *Ttt*, minimizing them, setting the level of service $\gamma \leq 0{,}80$.

3. Analysis and Results

The possibilities of using different types of urban electric transport in the cities of Belarus proposed to evaluate on the example of the Polatsk agglomeration (cities of Polatsk and Navapolatsk). This route can be chosen bus route No. 4 "Marynenka–Baravukha-3" in the city of Polatsk. The main parameters of route No. 4 when using different types of urban electric transport are given in table 2.

Table 2: Comparison of parameters of route No. 4 in Polatsk at service by vehicles of various types of city electric transport

Name, Value	Quantity of vehicles		Min. turnaround time, min.	Average operating speed, km/h	The length of sections, km	
	On the line	Total			with contact network	without contact network
Scenario 1. Service by single 12m length class vehicles						
IMF	12	15	90	16,79	25,19	0
IMC (LTO w/extra rapid charge)	12	15	90	16,79	3,20*	21,99
IMC (LFP)	12	15	90	16,79	12,00*	13,19
OC	14	18	100	15,11	0	25,19
Scenario 2. Service by articulated 15m length class vehicles						
IMF	9	11	90	16,79	25,19	0
IMC (LTO w/extra rapid charge)	9	11	90	16,79	3,20	21,99
IMC (LFP)	9	11	90	16,79	12,00*	13,19
OC	10	13	100	15,11	0	25,19

* It is necessary to build a contact wired

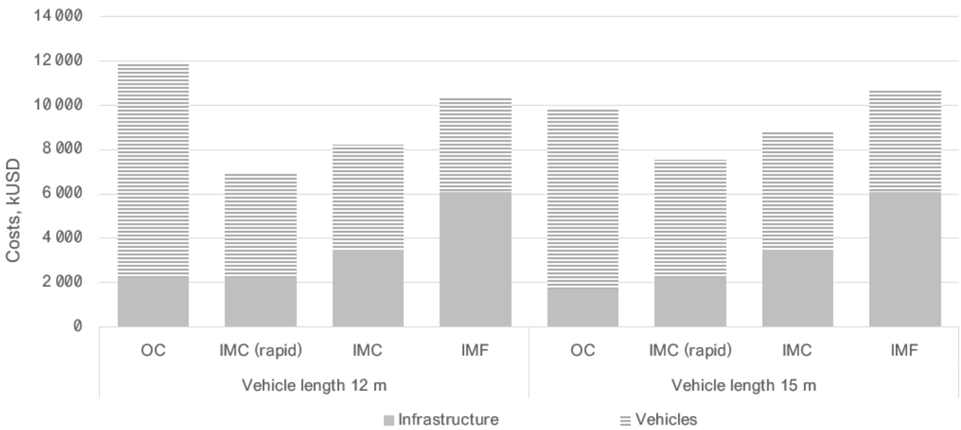

Figure 1: **Total investments for Route No. 4 in Polatsk**

Route 4 runs along Marynenka street, Pyatrusya Brouka street, Yubileynaya street, Kastrychnickaya street, Hogal' street, Kammunistychnaya street, Efrosinnya Polatsk street, Kasmonautau street, Valagodskaya street. The length of the route is 25.19 km, the bus work time in the forward direction and in the reverse direction is 40 minutes. The Current schedule provides for 124 trips, including 62 trips in the forward and 62 trips in the reverse direction. The route works from 05:00 to 00:45. The highest frequency of traffic on the route from 6 to 8 hours and from 16 to 18 hours, when 9 vehicles are used for passenger service at the same time. In the consolidated calculations, it is assumed that the depot for electric transport will be located in the existing bus fleet No. 2 on Budaunichaya street.

The assessment of the possibility of using different types of urban electric transport in Navapolatsk was carried out on the example of the bus route No. 4 "Padkasteltsy–Hospital town".

The route № 4 is for Moladzewa Street, Ktatarava Str., Slabadskaya Str., Haidara str. in forward direction and Haidar Str. and Moladzewa Street in the reverse direction. The length of the route is 14.92 km, the bus travel time in the forward direction is 25 minutes, in the reverse direction — 24 minutes. The current schedule provides for the implementation of 106 trips (53 trips in the forward and reverse directions). The route works from 08:24 to 23:52. The highest frequency of traffic on the route from 17 to 19 hours, when 5 vehicles are used simultaneously for passenger service. In consolidated calculations it was accepted that depot for electric vehicle will be located on the terminal station "Padkasteltsy".

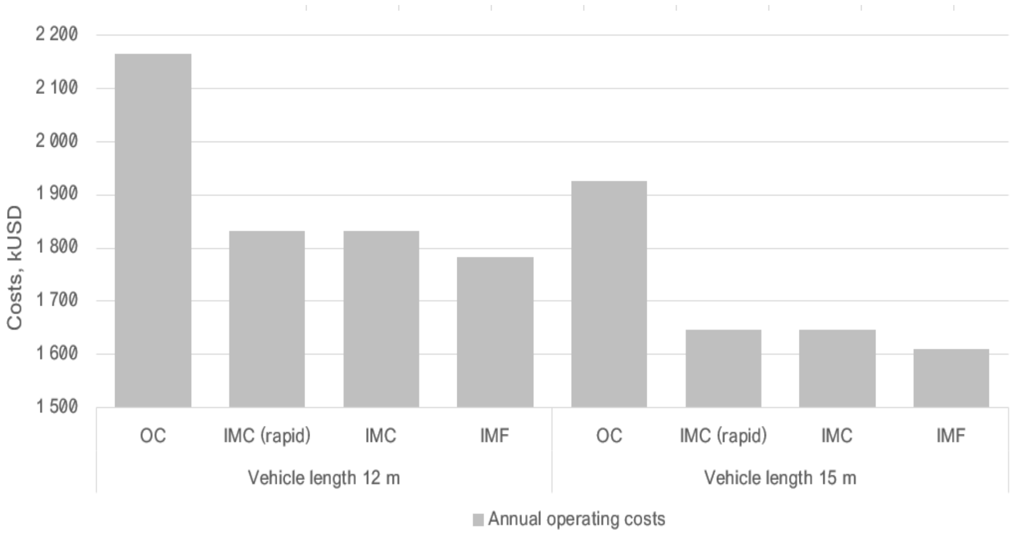

Figure 2: **Annual operating costs for Route No. 4 in Polatsk**

The main parameters of the route when using different types of urban electric transport are given in table 3. The total investments are summarized (figure 3). When calculating the total investments in infrastructure and vehicles, the costs of contact wires, traction substations, charging stations and the vehicles themselves required for work on the route are taken into account. The costs of the cost of design, contract work, to create a base for maintenance and repair of vehicles at the transport enterprise were not taken into account.

An overview of annual operating costs is shown in Figure 4. Let us consider separately the problems of traffic organization, transportation organization and traffic safety arising from the operation of some types of non-rail electric transport. Trolleybuses IMC, IMF, duobuses favorably differ from electric buses OC, which have a limited working reserve and require periodic stops to charge the drives. This stop occurs at each terminal station and its duration is about 10 minutes.

Table 3: Comparison of parameters of route No. 4 in Navapolatsk at service by vehicles of various types of city electric transport

Name, Value	Quantity of vehicles		Min. turnaround time, min.	Average operating speed, km/h	The length of sections, km	
	On the line	Total			with contact network	without contact network
IMF	5	7	54	16,58	14,92	0
IMC (LTO w/extra rapid charge)	5	7	54	16,58	2,53*	12,39
IMC (LFP)	5	7	54	16,58	7,00	7,92
OC	7	9	67	13,36	0	14,92

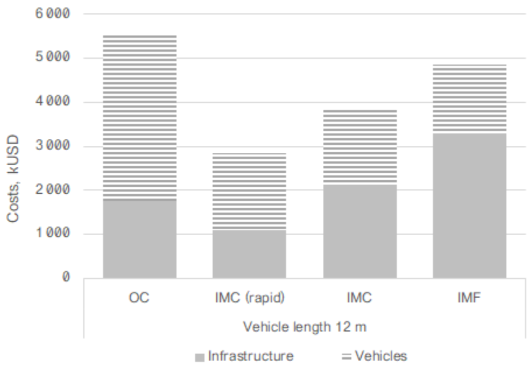

Figure 3: **Total investments for Route No. 4 in Navapolatsk**

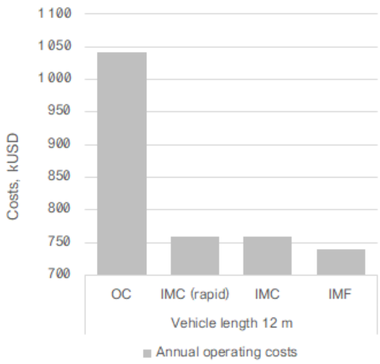

Figure 4: **Annual operating costs for Route No. 4 in Navapolatsk**

This fact introduces a number of restrictions in the technology of the organization of the movement of electric buses and in the order of scheduling.

Moreover, from the standpoint of economic efficiency, the use of electric buses with a travel interval of less than 10 minutes requires the construction of not one, but two or more charging stations at the final station, which are necessary for the stable functioning of the route.

Also, in case of delay, the stability of the system is violated. An delayed electric bus will occupy a slot in the schedule belonging to the next electric bus that operates on the same route. This will lead to him also starting to be late. Then the "domino principle" will work. Each subsequent electric bus will be late. From the point of view of the human factor and psychophysiology of the public transport driver, such violations of the traffic schedule will lead to the fact that drivers will begin to reduce delays by increasing the speed of traffic on routes. Experience shows that this will happen in those parts of the route where it is unsafe, and will lead to an increase in accidents.

At the same time, an alternative scenario provides for the development of tram. At the same time, tram depot already has the necessary base for the repair and maintenance of trams, as well as the trams themselves in the quantity necessary to work on new lines. The step-by-step plan of tram transportation is shown in Figure 5.

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4. Discussion

Returning to the problems of the Polatsk agglomeration, it should be noted that Navapolatsk enterprises form the largest petrochemical complex in Belarus, and this affects the environmental situation. Navapolatsk is one of the cities with the highest density of emissions of harmful substances. Mobile sources of emissions also play a negative role in the overall air pollution. In these circumstances, the increase in the share of environmentally friendly transport is particularly relevant.

The analysis of various variants of application of non-rail electric transport in table 4.

To organize the movement of non-rail electric transport, it is necessary to purchase vehicles, create a base for their repair and maintenance in bus fleets, construction of traction (and charging) substations, cable networks, training of personnel. The construction of a contact wires along the entire length of the route is required for IMF trolleybuses, and partially for IMC trolleybuses and duobuses. To organize the movement of electric buses, it is necessary to build charging stations in the depot and at the end stations (for electric buses OC).

Revealing the issues of complex optimization of costs for the maintenance of the route network by route passenger transport, it is necessary to return to the dependence (3). For service of route network, can use the author's sectoral methods.

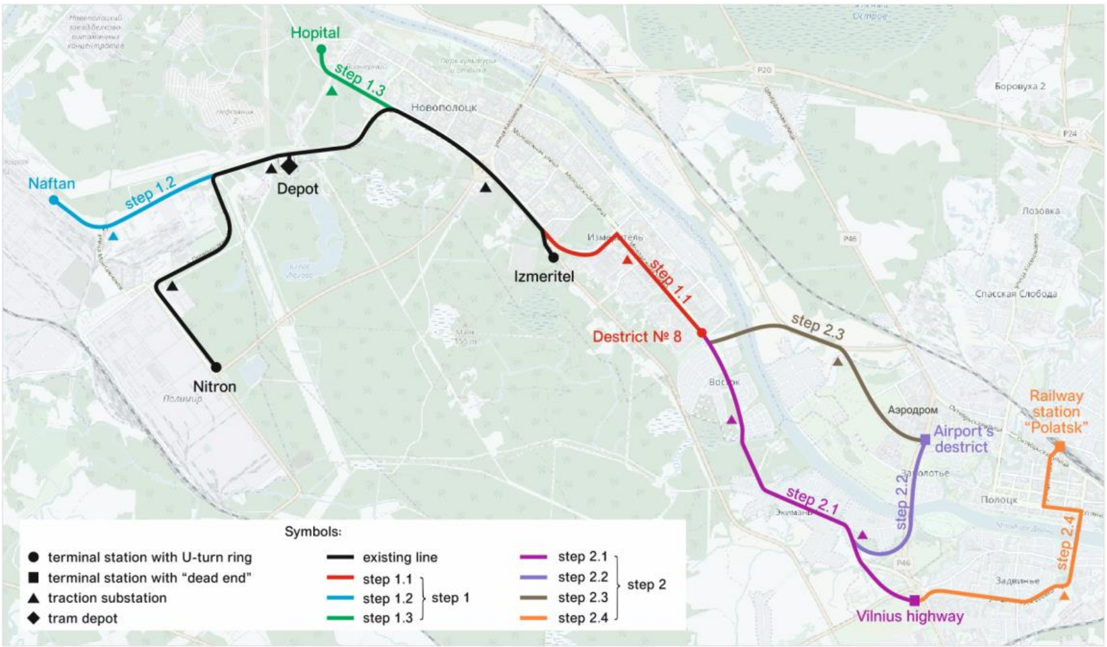

Figure 5: **Tram development scheme in the agglomeration of Polotsk-Novopolotsk**

Table 4: Analysis of application possibilities of non-rail electric transport

Name, Value	Electrobus OC, ONC	Trolleybus IMC	Trolleybus IMF
Experience of operating in the cities	–	–	–
Place of storage of vehicles	+/– (can be placed in the bus depot)		
Operational base (maintenance, repair)	– (need to build)		
Degree of binding to the infrastructure	Binding to charging stations	Partial binding to the contact wires	Full binding to the contact wires
Needing for driver training	Drivers license for Cat. "D" is necessary	Drivers license for Cat. "I" is necessary	Drivers license for Cat. "I" is necessary

Name, Value	Electrobus OC, ONC	Trolleybus IMC	Trolleybus IMF
Ability to change the route	From charging stations within the range of the autonomous range	From any point of site with a contact wires within radius of autonomous range	Without construction of a contact wires it is impossible to change route
Needing for a one-time purchase of vehicles for open new routes	Necessary	Necessary	Necessary
Equivalent value of the vehicle (for 1 people of passenger capacity)	4,26–4,66	2,20–2,75	2,20–2,75
Period of operation of the vehicles base (extended)	10	10 (15)	10 (15)
Presented (to 1 person of passenger capacity and a basic 10-year service life) the cost of the vehicle	4,26–4,66	2,20–2,75	2,20–2,75
Specific electricity costs for transportation of 100 passengers per 1 km in summer, USD / 100 pass.·km	0,18	0,18	0,18
Specific fuel consumption for transportation of 100 passengers per 1 km in winter, USD / 100 pass.·km	0,42	0,29	0,29
Ecological issue	+/– – – (emissions of harmful substances during the operation of diesel heating, tires, rubber dust in the interaction of wheels with the road surface)	+/– (disposal of traction batteries, tires, rubber dust by interaction of wheels and road surface)	+/– (recycling of tires, rubber dust by interaction of wheels and road surface)

The route technology of passenger service provides for the operation of the route passenger transport (RPT) vehicle along the laid routes from terminal station A (hereinafter referred to as Station A) to terminal station B (hereinafter referred to as Station B) and back according to the timetable. For a detailed study of the work of the RPT vehicle on the route, a model (4) was developed, characterized by the division of their parking time into stations A and B for mandatory and additional. The possibility of using the sectoral method for organizing the work of the vehicle on the RPT routes is to allocate and combine the routes with common segments on the basis of the rules of "switching" and combining routes within the sector, while maintaining the mandatory sequential alternation of work on them, rational distribution of driving and technical resources of the sector. The implementation of the sectoral method for organizing the work of the vehicle on the RPT routes is considered using the model presented in dependencies (4) and is carried out by allocating joint segments on the routes AB, AC (a section of the route AS), while route configurations are possible when AC is significantly larger than AB, when the route AC is part of the route AB and is intended to strengthen it, and in fact the common segment AS is the route AC, and also when AC = AB (figure 6).

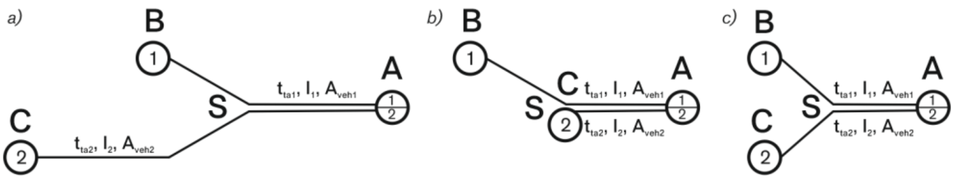

Figure 6: **Models of RPT routes, the work of which is organized by the sectoral method**

At the same time, the proposed scheme of sectoral service provides for the operation of the AB and AS routes in such a way that the AS segment on them is always serviced according to the principle of equality of the network interval I_1=I_2 with the guaranteed exception of the so-called Vernier effect, which entails not only an even distribution of the production load, but also reduces the economic losses of passengers, consisting in wasting their time on excessive waiting for the RPT vehicle at stopping points, while overloading the vehicle and complicating the work of drivers on routes is prevented. Such infrastructural combinations of routes (and even types of RPT) are also a solution to increase the throughput and productivity of the sector by minimizing t_{lstaA1}, t_{lstaB1} and t_{lstaC2} when the assigned conditions are met for the use of the sectoral method for organizing the work of the vehicle on RPT routes. The expected economic effect of servicing each two routes by the sectoral method, if the necessary conditions are met, is expressed for a bus for a 10-year period (the life cycle of one vehicle) at current prices of 665 kEUR, for a trolleybus for a 15-year period 968 kEUR, for a tram for a 30-year period 1895 kEUR.

Conclusions

Thus, a further increase in the share of electric transport in the cities of Belarus is also possible due to the organization of the movement of IMC trolleybuses on some busy routes with the construction of a contact wires for charging energy storage in IMC trolleybuses on certain sections of the route outside the central part of the city. This solution from the point of view of traffic organization, transportation and traffic safety is the most optimal and attractive. The advantages of this solution are: distributed load on the electric network throughout the day, operation of autonomous onboard energy sources in a gentle mode, electric heating and air conditioning, charging of autonomous onboard energy sources during the route without downtime of vehicles at end stations or depots. This combined solution makes it possible to significantly expand the geography of use of IMC trolleybuses due to the possibility of including sections of the road network that are not equipped with contact wires in their routes.

A methodology for assessing the efficiency of urban passenger transport has been developed, including taking into account the development of electric vehicles, which made it possible to determine the need to purchase appropriate vehicles for organizing the movement of non-rail electric vehicles; create a base for their repair and maintenance; construction of traction substations (new or additional); construction of cable networks; train staff. In addition, for the use of IMF trolleybuses, it is necessary to build a contact network along the entire length of the route, for IMC trolleybuses and duobuses - on some routes. To organize the movement of electric buses, it is necessary to build charging stations in parks (for OC electric buses - and at terminal stations).

It should be noted that the development of a network of tram lines will attract additional passengers and increase the annual volume of passenger traffic (according to preliminary expert estimates) by approximately 4.1 million passengers. during the implementation of all stages of stage 1 (in Novopolotsk) and 6.7 million passengers. during the implementation of all stages of stage 2 (in the agglomeration). The most efficient operation of the tram will become when it starts to be used for "agglomeration" transportation on the sections with the highest passenger traffic (for example, along the route of the existing bus route No. 5 and route taxis No. 5t). The "agglomeration" rail passenger system of Novopolotsk-Polotsk will be the only one in Belarus and may become one of the ways to develop the tourist potential of cities.

Also, an algorithm has been developed for the implementation of the least costly activities at the initial stage with limited funding. The studies performed allowed us to formulate a concept and propose specific comprehensive measures aimed at improving the quality and efficiency of the route passenger transport in Polotsk and Novopolotsk, including optimizing the existing route network of route passenger transport.

Studies of the effectiveness of measures aimed at reducing delays in route passenger transport have been carried out, criteria and places of their application in Polotsk and Novopolotsk have been determined, as well as an assessment of the technical and economic indicators of the proposed options using the international CBA methodology (Cost Benefit Analysis).

A business model has been developed for the implementation of standard measures aimed at improving the quality and efficiency of the route passenger transport, has been proposed a set of measures to increase the attractiveness and efficiency of urban passenger transport.

The proposed expanded classification system for route vehicles with electric drive will allow classifying and categorizing various solutions offered by manufacturers of route vehicles with electric drive, which will facilitate the work when making decisions by both operating organizations and design bureaus, since the designation of the scheme supplemented by the category number will make it easy to determine the scope and capabilities of this vehicle, the need for charging infrastructure.

The IMC-2 and IMC-3 trolleybuses are of the greatest interest for cities with trolleybus traffic, which allow expanding the route network of an environmentally friendly trolleybus and replacing a number of bus routes with trolleybuses.

Improving traffic safety by the development of route passenger transport will be achieved by deterring motorization. Statistics show that there are fewer road accidents per route vehicle than per vehicle for personal use. Drivers of fixed-route vehicles are professional drivers, they are well prepared and trained. A further increase in the share of route passenger transport will contribute to an increase in the number of trips using route vehicles. This will contribute to further unloading of the road network, improving traffic conditions on the streets of cities.

For a comprehensive assessment of the quality of decisions taken, a loss assessment methodology based on accounting for the economic costs arising from the use of each type of transport should be used. Costs differ from expenses in that costs take into account all costs (explicit and implicit, which cannot be accounted for transparently). All such costs, which are losses, can be classified into accidents, environmental, economic, operating and social. Total losses by definition represent the sum of all types of losses and are used for a comprehensive assessment of the quality of traffic.

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