УДК 656.132:656.025
UDC 656.132:656.025

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PECULIARITIES OF PUBLIC ELECTRIC TRANSPORT DEVELOPMENT IN SOME UKRAINIAN CITIES

Analysis of the development of trolleybus transport in Ukrainian regional centers (Zhytomyr, Rivne, Ternopil, Chernihiv, the largest city in terms of population of Kyiv region - Bila Tserkva) was conducted. A comparison of these cities in terms of their area, population, population density in cities, the number of bus and trolleybus routes, the length of the catenary and the number of trolleybuses was carried out. The characteristic features of trolleybus routes of cities are analyzed and noted and the strategy of their further improvement and renewal of rolling stock is revealed. The peculiarity of the route network in Zhytomyr is noted, which consists in the presence of a ring route, which allows to connect the areas far from the city center.

It is shown that the peculiarity of the contact network of Rivne is its exit from the geographical boundaries of the city, which is justified by the large flow of passengers on working days of the week, who move to the Rivne plant of high-voltage equipment. It is noted that the AKSM 43303A double-decker bus and 12 Dnipro T203 trolleybuses with autonomous running were put into operation.

From the analysis of schemes, features of trolleybus routes, the existing fleet of trolleybuses and their service life in these cities, it is concluded that in the cities of Ukraine with these characteristics are dominated by trolleybus networks of radial location with the ability to combine suburbs. The best solution for choosing a trolleybus contact network in such cities is to choose radial routes from the center to the peripheral areas of the city in combination with circular routes connecting the main streets. The fleet of trolleybuses is outdated, they have been in operation for 20-40 years, so it needs more active renewal. The best in terms of age composition of trolleybus parks of the cities analyzed, as of 01.01.2020, is the park of Chernihiv, the worst - the city of Rivne.

Key words: urban passenger transportation, electric transport, trolleybus, route network, contact network, environment

INTRODUCTION

There are many cities in Ukraine that have very similar characteristics in population, area, geographic parameters, etc. There are many factors that influence the environmental conditions, especially in the settlements. It is known that one of the main negative impact factors on the environment is transport. The greatest amount of toxic substances in the air, in the ground, in wastewater and water can be observed in cities with a high concentration of transport.

One of the best ways to solve the problem of transport pollution in Ukrainian cities and other countries of the world is to eliminate transport with internal combustion engines (especially diesel engines) and the transition to electric transport. This also requires the development of alternative environmental-friendly transport.

ANALYSIS OF LITERATURE DATA AND FORMULATION OF THE PROBLEM

The authors [1] argue that to date there is no universal approach to assessing the efficiency of urban public transport, including electric transport. To assess the costs of public transport operation and the quality of passenger service, they propose a target function that makes it possible to estimate the costs of the carrier and passengers and find a balance between the interests of these parties in the transportation process. This function enables to improve methods of public transport organization in cities and to raise the quality of transport services for city population. The new approach is developed on the basis of the analysis of economic and social factors that affect the efficiency of urban public transport.

In [2], the authors considered the transport network of Odessa. Odessa. Specific geographical location of the city made it possible to form criteria for estimation of planning schemes of the street and road network. Investigations and comparisons with the normative values of the street and road network density and Odessa non-straightness coefficient were made. In connection with the increase of the density of the traffic flows the problems of the urban passenger transport movement arise, which should be immediately solved, which testifies to the urgency of the given works.

Passenger transportation has a significant influence on the social, ecological and production spheres of the City functioning which determines the conditions of competition for the carriers of various forms of ownership. Among the list of problems of development and functioning of cities, it is especially important to develop a system to ensure an appropriate level of safety and quality of passenger transportation [3].

Taking into account all the interests of urban passenger transportation market participants is impossible without solving the following tasks: achieving a balance of interests of participants in the

transportation process (accessibility, environmental safety and comfort, the carrier profit, creating conditions for attracting investment to improve the economic efficiency of the passenger transportation process) [4].

Electric transport significantly reduces environmental risks in the process of urban passenger transportation. But its development in different cities of Ukraine requires analysis and search for areas of improvement.

It should also be noted that the study of this issue should be carried out in cities with similar infrastructure, geographical location of the population, similar rolling stock of electric transport, etc.

PURPOSE AND OBJECTIVES OF THE STUDY

The purpose of this study is to analyse the specifics of the trolleybus urban transport development process in some regional centers of Ukraine (Zhytomyr, Rivne, Ternopil, Chernihiv, Bila Tserkva) to identify areas for further improvement.

RESULTS OF THE STUDY

The regional centers (Zhytomyr, Rivne, Ternopil, Chernihiv) and the city of Bila Tserkva were chosen to analyze and compare the development processes and current state of trolleybus transport in Ukrainian cities. The city of Bila Tserkva has the largest population number in the Kyiv region. The authors consider abovementioned cities to be the most typical for Ukraine due to the following characteristics: radial location of the streets, with area of 60 to 80 sq. km, population from 209 to 287 thousand people, trolleybus transport availability (Table 1). In connection with this we can expect the same approach to the development of public electric transport in them, as well as the advantages and disadvantages in the further development of electric transport in analogous cities of Ukraine.

Table 1. Basic characteristics of the cities that are being portrayed as of 01.01.2020 [5-13]

City	Area, km^2	Population, num. of inhabitants	Population density, inhabitants /km^2	Number of bus routes	Number of trolleybus routes	Length, km	Number of trolleybuses
Zhytomyr	61	264 318	4 333	30	14	100,2	122
Rivne	64	246 003	3 844	26	9	60,8	88
Ternopil	72	223 462	3 104	33	10	86,3	61
Chernihiv	79	286 899	3 632	31	11	110,5	103
Bila Tserkva	67,84	209 238	3 084	18	7	44	25

The main streets of Zhytomyr are located radially in six directions, and in the center of the city they are in most cases perpendicular to one another (Fig.1). The location of the city is compact, which makes it possible to create both pendulum routes and loop routes. The trolleybus network has been developing here since the early 1960s. During those years, a lot of changes took place, routes were changed and lines were installed/dismantled.Contact network was located radially through the main streets of the city: Velyka Berdychivska St., Lekha Kachynskoho St., Chudnivska St., Peremohy St., Pokrovska St., Kyivska St., Vitruka St., Korolova St., Serhiia Paradzhanova St., Vokzalna St., Seletska St., Ivana Honty St., Kosmonavtiv St., Shevchenka St., Dmytra Dontsova St., Feshchenka-Chopivskoho St., Mikhaila Hrushevskoho St., Mala Berdychivska St., Skhidna St., Nezalezhnosti Avenue. This location allows one to connect the outskirts of the city with the center. The routes are designed in such a way so that it is easy to reach the most distant areas of the city, which creates convenience for the use of this type of transport. For transportation of passengers from the stations to the Smolianka district and the city center until 30.08.21 there were ring routes №1A " Vokzal - Center - Smolianka - Vokzal " and №1B " Vokzal - Smolianka - Center - Vokzal ". Ring routes with opposite directions reduced travel time from one area of the city to another, as it was possible to travel only the necessary short part of the route. These routes connected the central busy parts of the city, places of arrival (departure) of passengers: bus station, railway station, shopping malls, food and clothing markets, etc. From 30.08.21 both routes were combined into one №1 " Vokzal - Center - Kosmonavtiv St ". Instead, they created circular routes with branching to the Korbutivka area to the hydropark similar to routes №2 and №3: №15 “Hydropark - Smolianka - Vokzal” and №15a “Hydropark – Vokzal - Smolianka ”

Recently the trolleybus fleet in Zhytomyr has been actively renewed, 50 new trolleybuses, AKSM-321, manufactured in Belarus, were purchased and put into operation with the support of the European Bank for Reconstruction and Development. As of 02.09.21, there are plans to build a trolleybus contact line on Heroiv Pozhezhnykh St. and respective quotation documents for the construction of trolleybus line on the Kiivske Highway to the industrial park and international airport are being prepared. This will allow a better connection between the remote district of “Malovanka” and the adjacent villages Hlybochytsia using environmentally friendly transport within the infrastructure of the city.

Before the active introduction and development of trolleybus transport in the city sufficient attention was given to the city streetcar. There were 5 lines in the city: Berdychivka, Kyivska, Chudnivska, Vilska and Moskovska. As of today, there is only one line "Tsenter-Lonokombinat" left. Such changes are explained by the more active development of trolleybus transport in the city, which gradually overtook the streetcar transport.

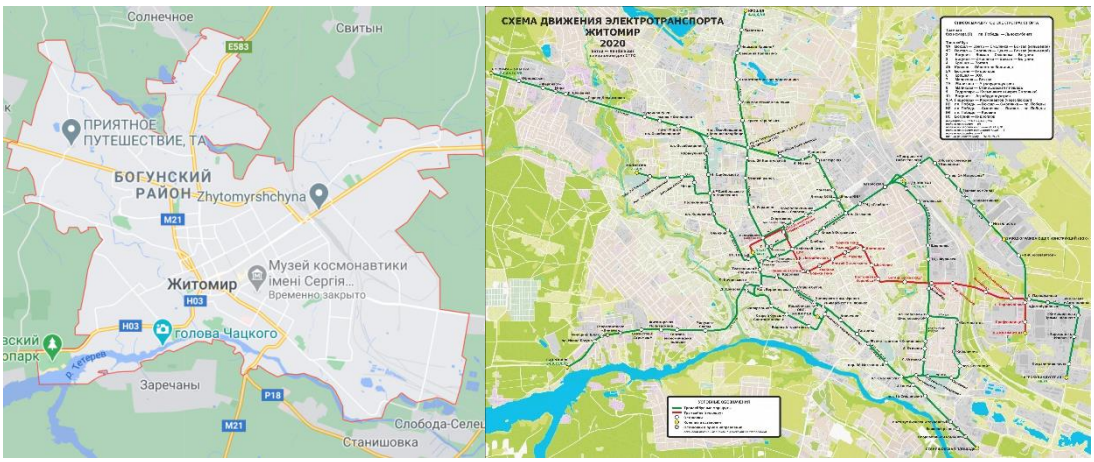

Fig.1. Map of the city Zhytomyr and the scheme of its trolleybus routes [14, 15]

In the city of Rivne since 1974 there has been a steady development of trolleybuses. Since 1974 there has been a constant growth of trolleybus transportation, the number of lines and trolleybus rolling stock is perpetually increasing. The city has also adopted a radial layout of trolleybus routes on the streets, trolleybuses run in seven directions. But analysis of the city map and scheme of trolleybus routes shows that the main streets are not occupied: Viacheslava Chornovola St., Rivnenska St., Kyivska St. (to the zoo), Kniazia Volodymyra St., Dubenska St. (to the airport), Romana Shukhevycha St. (Fig.2.). Contact network is located on the central streets Soborna, Kyivska and extended on the streets Danyla Halytskoho St., Videnska St., Akademika Hrushevskoho St., Lonokombinativska St., Henerala Bezruchka St., Haharina St., Kniahyni Olhy St., Stepana Bandery St., Nebesnoi Sotni St., Dubenska St., Kotsiubynskoho St., Ostrozkoho St., Makarova St. A special feature of the contact network of Rivne is that it goes beyond the geographical boundaries of the city. On the national motor road of state importance H22 it connects the city to the Rivne plant high-voltage equipment.

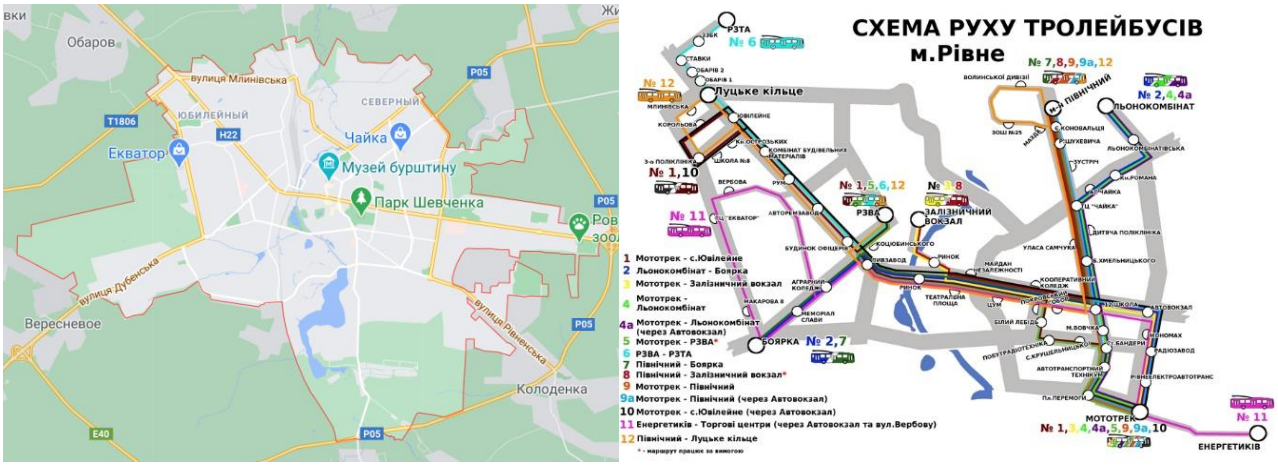

Fig.2. Map of the city Rivne and the scheme of its trolleybus routes [14, 16]

This is justified by the high volume of passengers on weekdays. There is no streetcar service in the city, but other types of electric transport are developing: in 2016, the AKSM 43303A duobus was purchased. It has autonomous drive, which is ensured by a diesel generator and an asynchronous alternating current motor. Also during the 2017-2018 years trolleybuses Dnipro T203 in number of 12 units (at 01.01.20.) were launched. In the future, there are plans to buy 3-4 new trolleybuses every year to continually renew the fleet. This year, they did not allocate funds for new trolleybuses because they want to analyze their transport network.

Ternopil trolleybus service was launched in 1975. The city has its own geographical pecularities. A pond on the Seret River forms the districts of “Kutkivtsi” and “Proniatyn” (on the western side of the city) which are not served by trolleybuses today (Fig.3). A separate district “Klenovyi hai” is located on the east of the city on Mykulynetska St., which is served by trolleybuses. The trolleybus network of the city was located on the main streets: Mykulynetska St., Berezhanska St., Hetmana Mazepy St., Ruska St., Stepana Bandery Avenue, Zamkova St., Krushelnytska St., Protasevycha St., 15-ho kvitnia St., Brodivska St., Kniazia Ostrozkoho St., Anatoliia Zhyvova St., Luchakivskoho St., Maksyma Kryvonosa St., Lesi Ukrainky St., Slivenska St., Bohdana Khmelnytskoho St., Oleksandra Dovzhenka St., Romana Kupchynskoho St., Kyivska St., Henerala Myrona Tarnavskoho St., Vasylia Symonenka St., Volodymyra Velykoho St., Lesia Kurbasa St., Tekstylna St., Zbarazka St., Zluky Avenue.

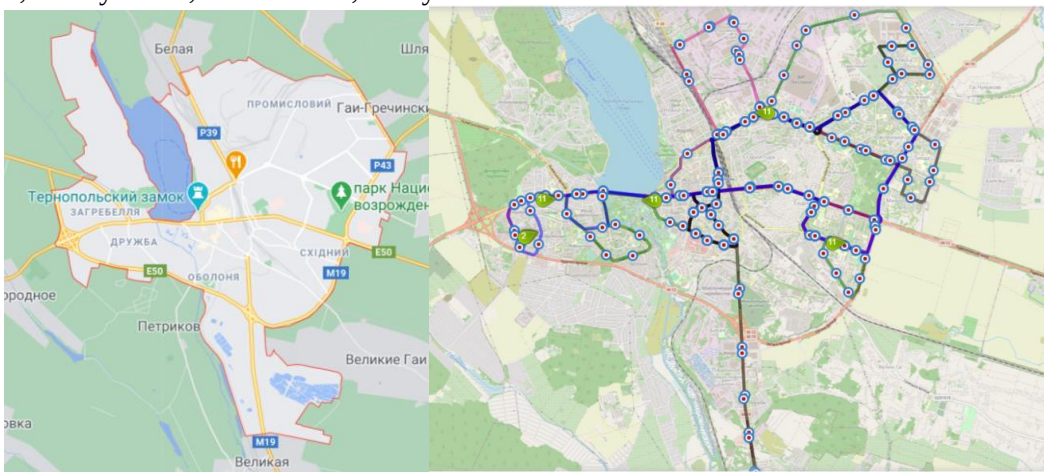

Fig.3. Map of the city Ternopil and the scheme of its trolleybus routes [14, 17, 18]

Ternopil trolleybus routes are well developed, and the trolleybus network connects to all districts of the city. At the beginning of the 2000s there were 16 trolleybus routes in the city, but as of January 01, 2020 their number decreased to 10. At the same time, the trolleybus network expanded in a radial direction focusing on neighborhoods located on the outskirts of the city. For the renewal of the rolling stock the documentation for the procurement of 30 new trolleybuses is being prepared. Also in 2020, school trolleybuses were launched on certain routes of the city.

The city of Chernihiv has nine main trolleybus routes (Fig.4). The city started trolleybus traffic in 1963 and for a long time trolleybuses have been the main type of transport.

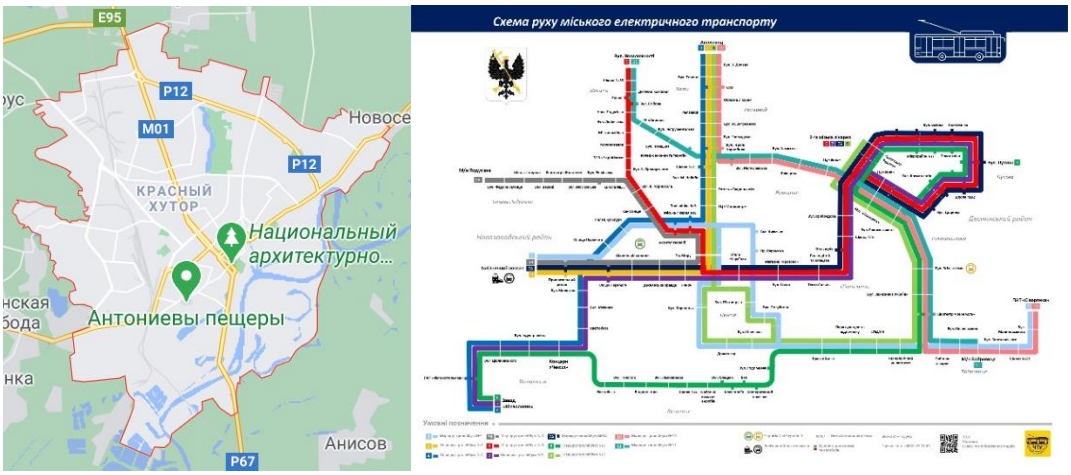

Fig.4. Map of the city Chernihiv and the scheme of its trolleybus routes [14, 19]

Despite financially insecure times, today the trolleybus network is expanding radially from the center of the city within these main streets: Ivana Mazepy St., Shevchenka St., Hetmana Polubotka St., 77-yi Hvardiiskoi Dyvizii St., Rokossovskoho St., Malynovskoho St., Tolstoho St., Liubetska St., Haharina St., Heroiv Chornobylia St., 1-ho Travnia St., Oleksandra Molodchoho St., Peremohy Avenue, Myru Avenue, etc. The municipality covers most of the city, but not the main street on the east side – Myru Avenue (from the junction with Peremohy Avenue to the Desna River on the west).

The fleet is constantly updated. Last year 5 new trolleybuses manufactured in Chernihiv were purchased, this year 4 new trolleybuses "Etalon-T121" (Barvinok) were purchased. In August 2021, a draft of a new transport model of the city was proposed to the local council, which provided for the complete abandonment of small-capacity buses and an increase in the number of trolleybuses.

Development of trolleybus transport in Bila Tserkva began in 1978 with the construction of the first trolleybus lines and depot. The city is geographically distributed in the east-west and east-north directions, with the main streets extending to the ends of the city (Fig.5). Analyzing the network of trolleybus routes, it should be noted that it is poorly developed. It, unlike the previous ones, has one main line with several extensions that pass through the main streets: Levanevskoho St., Hryboiedova St., Zaiarska St., Tarashchanska St., Selianska St., Druzhby St., Kniazia Volodymyra Avenue, Oleksandriiskyi Boulevard. It should be noted that the existing trolleybus routes are entirely replaced with route taxis. There are also important shortcomings: the contact network does not allow the trolleybuses to run near the bus and train stations, the renewal of the trolleybus fleet is in progress. The trolleybus system was planned, but due to certain circumstances it is still under revision.

From the analysis of trolleybus schemes, peculiarities of trolleybus routes, available trolleybus fleet and their operating time in the mentioned cities (Tables 2,3) we can conclude that trolleybus networks with the characteristics above prevail in Ukrainian cities with the possibility to connect the outskirts of the cities. The best solution for selecting trolleybus contact lines in these cities is to choose radial routes from the center to the peripheral areas of the city in conjunction with loop routes linking the main streets together, leading to the peripheral districts with minimal traffic in the central part of the city.

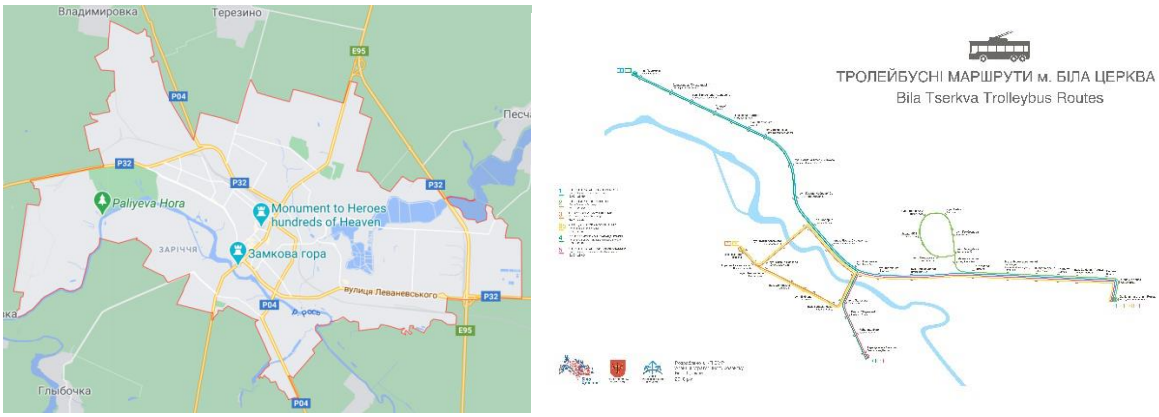

Fig.5. Map of the city Bila Tserkva and the scheme of its trolleybus routes [14,20]

The trolleybus fleet is outdated and has been in operation mainly for 20-40 years (Table 3), which requires more active renewal. The top trolleybus fleet in the cities surveyed as of 01.01.2020 was in the city of Chernihiv, while the highest number of trolleybuses was in the city of Rivne.

Table 2. Number of passenger trolleybuses by model (as of 01.01.20) [13]

№	Trolleybus brand, model	Zhytomyr	Rivne	Ternopil	Chernihiv	Bila Tserkva
1.	ЗиУ-9	74	-	-	44	9
2.	ПМЗ-Т1	5	-	1	-	-
3.	ПМЗ-Т2	5	2	-	25	3
4.	Škoda 9Tr	-	11	1	-	-
5.	ЛАЗ-52522	-	-	1	-	1
6.	Škoda 14Tr	24	49	24	-	-
7.	Škoda 15Tr	8	-	31	-	-
8.	МАЗЕТОН-103Т	-	-	-	-	6
9.	ЛАЗЕ-183Д1	6	1	3	2	-

10.	Дніпро Е-187	-	-	-	-	1
11.	АКСМ-321	-	-	-	3	-
12.	Дніпро Т203	-	12	-	-	-
13.	Дніпро Т103	-	3	-	-	1
14.	Еталон Т12110	-	-	-	29	-
15.	АКСМ 43303А	-	1	-	-	-
16.	Ikarus 280.94	-	-	-	-	4
17.	JELCZ (PR110E / PR110T / 120MT)	-	9	-	-	-
Total		122	88	61	103	25

Table 3. Number of trolleybuses put into service over the years in the cities analyzed [21]

City	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019
Zhytomyr	-	51	57	15	-
Rivne	2	39	28	4	16
Ternopil	-	21	35	5	-
Chernihiv	-	22	28	26	32
Bila Tserkva	-	7	10	2	7
Total	2	140	138	52	55

DISCUSSION OF THT RESULTS OF THE STUDY

As a result of the research it is easy to establish that some regional centers of Ukraine in terms of organization of passenger trolleybus transportation have a lot in common. The trolleybus electric contact network of such cities was mainly formed in the 80s of the last century and took into account at that time the demand of the population for transportation between the areas of population and labor application. This was formed objectively and historically influenced the formation of networks of this type of transport. But since then there have been radical changes regarding the location of industrial, commercial enterprises, and new residential neighborhoods have been built. Obviously, this fact should be taken into account in the future development of this type of transport, in terms of the fact that not all regional centers can be geographically, by population size, development of trolleybus networks, etc. united into a single group. Important criteria for the development of joint approaches to the further development of trolleybus networks for a group of cities should be considered: geographical location of transport areas, population size, city infrastructure, the level of development of trolleybus networks, etc.

CONCLUSION

Further development of the trolleybus network in the cities requires a comprehensive solution of their energy supply problems. In the future it is necessary not only to update the fleet of trolleybuses in all the cities analyzed, but also to improve the routes by increasing their capacity further from the center in order to connect the most distant adjacent areas or near-by settlements to the city. This can be solved through the introduction of the existing trolleybus fleets of self-propelled electric transport.

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Корнікова К., Ільченко А., Шумляківський В. **Особливості розвитку громадського електротранспорту в деяких містах України**

Проведено аналіз розвитку тролейбусного транспорту обласних центрів України (м. Житомир, м. Рівне, м. Тернопіль, м. Чернігів) та найбільшого міста за кількістю населення Київської області – м. Біла Церква. Зроблено порівняння вказаних міст щодо їх площі, кількості населення, щільності розташування населення в містах, кількості автобусних та тролейбусних маршрутів, довжини контактної мережі та кількості тролейбусів. Проаналізовано та відзначено характерні особливості тролейбусних маршрутів міст та розкрито стратегію їх подальшого удосконалення та оновлення рухомого складу. Відзначено особливість маршрутної мережі в м. Житомир, яка полягає в наявності кільцевого маршруту, що дозволяє зв’язати віддалені від центра міста райони між собою.

Показано, що особливістю контактної мережі м. Рівне є її вихід за географічні межі міста, що виправдано великим потоком пасажирів в робочі дні тижня, які рухаються до Рівненського заводу високовольтної апаратури. Зазначено, що в експлуатацію введено дуобус АКСМ 43303А та 12 тролейбусів Дніпро Т203 з автономним ходом.

З аналізу схем, особливостей тролейбусних маршрутів, наявного парку тролейбусів та їх термінів експлуатації у вказаних містах зроблено висновок, що в містах України з зазначеними характеристиками переважають тролейбусні мережі радіального розташування з можливістю об’єднання околиць міст. Кращим рішенням вибору тролейбусної контактної мережі в таких містах є

вибір радіальних маршрутів від центру до периферійних районів міста в поєднанні з кільцевими маршрутами з'єднання між собою головних вулиць. Парк тролейбусів застарілий, в основному вони експлуатуються вже 20-40 років, тому потребує більш активного оновлення. Найкращим за віковим складом парків тролейбусів міст, що проаналізовано, станом на 01.01.2020 року є парк м. Чернігів, найгіршим - м. Рівне.

Ключові слова: міські пасажироперевезення**,** електротранспорт, тролейбус, маршрутна мережа, контактна мережа, навколишнє середовище.

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DOI 10.36910/automash.v2i17.630