



# Model of Transport System Optimization in Kyiv (Ukraine)

Viktoriia Ivannikova<sup>(✉)</sup>  and Oleksii Nesterov 

National Aviation University, Kyiv 03058, Ukraine

**Abstract.** Kyiv is a capital city of Ukraine having a developed transport infrastructure, which consists of the airports, railways, highways, waterways and bridges. In addition, Kyiv has a developed system of urban and suburban passenger transport. Subway, trams, buses, trolleybuses and other modes of transport carry thousands of passengers every day, mostly to the places of work or study from large sleeping areas on the outskirts of the city to the industrial downtown. However, unfortunately, the transport system of the city of Kyiv cannot be called ideal. Poor road conditions on most highways, underdeveloped subways and low capacity of many important roads lead to considerable congestion during rush hour. That's why, new project for the development of transport system of Kyiv, namely the subway, highway connection to other cities of Ukraine and helping to reduce traffic by constructing the detour road for transit transport, has been proposed in the article. The main aim of the project on transport system of Kyiv optimization is to overcome the problem of overcrowded vehicles during rush hour.

**Keywords:** Cargo transportation · Development project · Passenger transportation · Transport system · Urban transport

## 1 Introduction

Kyiv is the capital and the biggest city of Ukraine. The geographical location and political status of Kyiv led to the fact that for centuries the transport system of this city has been continuously improving to create the biggest and the most developed transport hub in modern Ukraine.

A city of Kyiv is located in a favorable position on the intersection of the main routes connecting western part of Europe with the eastern part and with Asia. Due to its convenient geographical location, from time immemorial Kyiv has been developing as an important transport hub.

The transport system of Kyiv consists of three airports, two of which are accommodated for handling passenger flights, railways with a hub at Kyiv-Pasazhyrskyi station [1], highways with bridges, among which seven bridges across the Dnipro River play a special role in transport communication, the subway in intra-city passenger traffic, and waterways, which now pay more historical than the practical role [2].

Urban transport system in Kyiv is represented by such transport modes, as subway, bus, trolleybus, tram, funicular, non-public minibuses and ring urban rail.

The Kyiv subway is not only one of the main transport arteries of the city. Currently, this network consists of three operating lines (see Fig. 1) with a total length of 70 km and 52 operating stations, the platforms of which are designed for five-car trains. The downtown lines have three transfer stations [3].



Fig. 1. Map of Kyiv subway with the urban rail and rapid trams lines [4].

The highest developed ground public transport in Kyiv is bus with 85 existing routes, one of which is working only at nights [5]. There are 22 routes of trams in Kyiv, 5 of which are called Kyiv Express Trams because they go by isolated rails and have specially accommodated stations that function like subway stations, having ticket desks and turnstiles. They also have more modern vehicles than the regular tram. Other tram routes function on free access rails and go slower than the rapid tram. Trolleybuses in Kyiv serve passengers on 51 routes – 47 of them function at days and other 4 routes are night ones [6]. The funicular in Kyiv is represented by only one route with two stations, which connects the Poshtova Square, located at the bottom near the Dnipro embankment, with Mykhailivska Square, which is located at the top. Minibus is a privately owned route taxi that uses short buses. Due to the special appearance and mostly bright yellow color, minibuses are always visible on the roads of Kyiv, which makes them the

most popular transport in the city, even though the vehicles are often in poor condition and it is almost impossible to feel comfortable inside the cabin.

However, unfortunately, the transport system of the city of Kyiv cannot be called ideal. Poor road conditions on most highways, underdeveloped subways and low capacity of many important roads lead to considerable congestion during rush hour, which is complicated by the low driving culture of local drivers and the inability of law enforcement to monitor all traffic violations. There are many promising projects to improve this transport system, which due to lack of financial resources have not yet been implemented. The development of transport in the city of Kyiv has been standing still for several years now, which is why there are more and more problems with communication between different districts of the city.

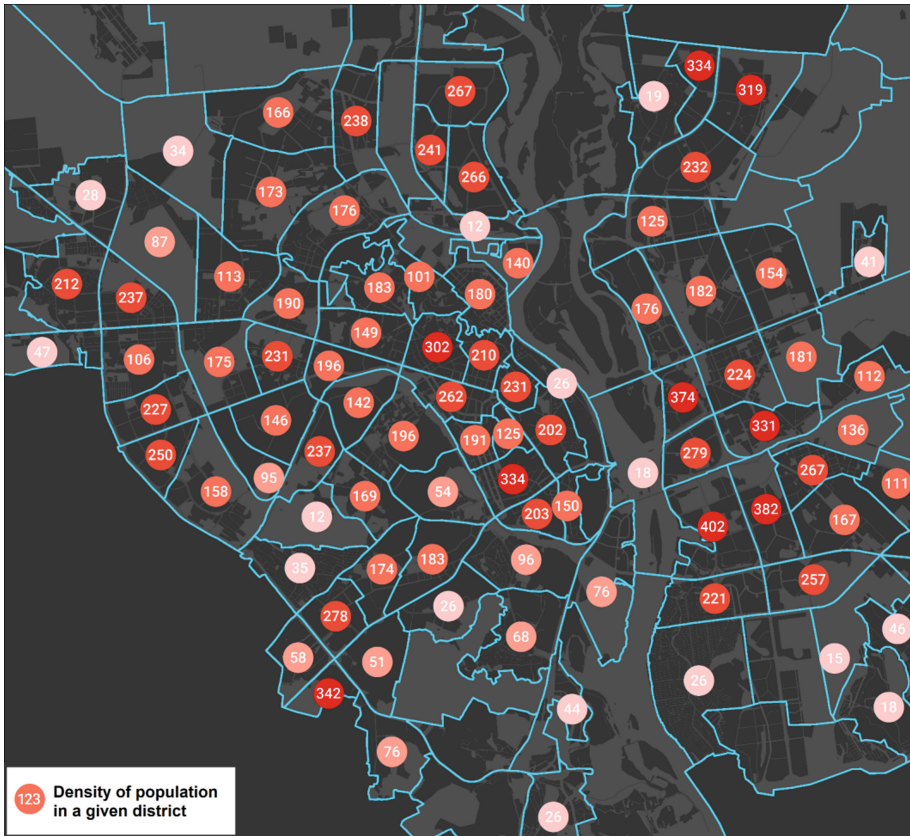
This study is aimed to present the new ideas of the authors for the development of transport system of Kyiv, namely the subway, highway connection to other cities of Ukraine and helping to reduce traffic by constructing the detour road for transit transport. If at least part of the existing projects to improve the transport system of the city and its environs are implemented, there will be a significant change in the quality and efficiency of this network [7]. If all the ideas, including those proposed in this study, are implemented, the city of Kyiv will receive a modern and very convenient European-style transport system.

## 2 Background

The current transport system of the city of Kyiv faces many problems every day, one of which is traffic jams. This is due to the fact that the majority of the city's population lives in remote outskirts and has to travel to work located mostly in downtown by its own or public transport every morning (see Fig. 2).

One of the most populated areas of Kyiv is Troyeshchyna with a population of over 250,000 inhabitants, located in the northwestern part of the city. Every day at its exits, the biggest traffic jams occur because this district does not have the subway transport [8]. In addition, not every city resident has their own car, which leads to the fact that during rush hour public transport is also overcrowded and unable to carry all interested passengers.

Buses, trolleybuses and minibuses run quite often, but they cannot serve all the passengers who need them, and they often get stuck in traffic jams, often even becoming their cause. Trams do not get stuck in traffic jams [9], but they are often slower than road transport, and there is a considerable risk of a complete stop of the entire line, which makes it risky to use this transport during rush hour [10]. The subway in Kyiv is underdeveloped: there are only three lines that do not even connect the most populated areas with the downtown, so locals have to use land transport to get to the nearest station, and it takes money and time.



**Fig. 2.** Scheme of population of Kyiv by neighborhoods.

In addition, the road surface on many of Kyiv's main highways is of poor quality, forcing drivers to slow down and go around particularly dangerous potholes, leading to accidents. Sometimes even a newly repaired road due to the unprofessionalism of workers and drivers is in good condition for a short time.

Kyiv has two ring roads (see Fig. 3): the Small, which is the border for the downtown, and the Big, which currently runs only along the right bank of the Dnipro and is the immediate border for the cityline. Big Ring Road now exists only partly and runs along the western border of the city, mostly outside the city. It unites the Dnipro, Odessa, Zhytomyr and Hostomel directions. Small Ring Road is such only in fact, because it does not stand out as a separate street in Kyiv.

However, the map of Kyiv clearly shows the streets and bridges that merge in the downtown into a ring road with a total length of 38.9 km, which is on 4.5 km longer than the section of the Big Ring Road that exists today.

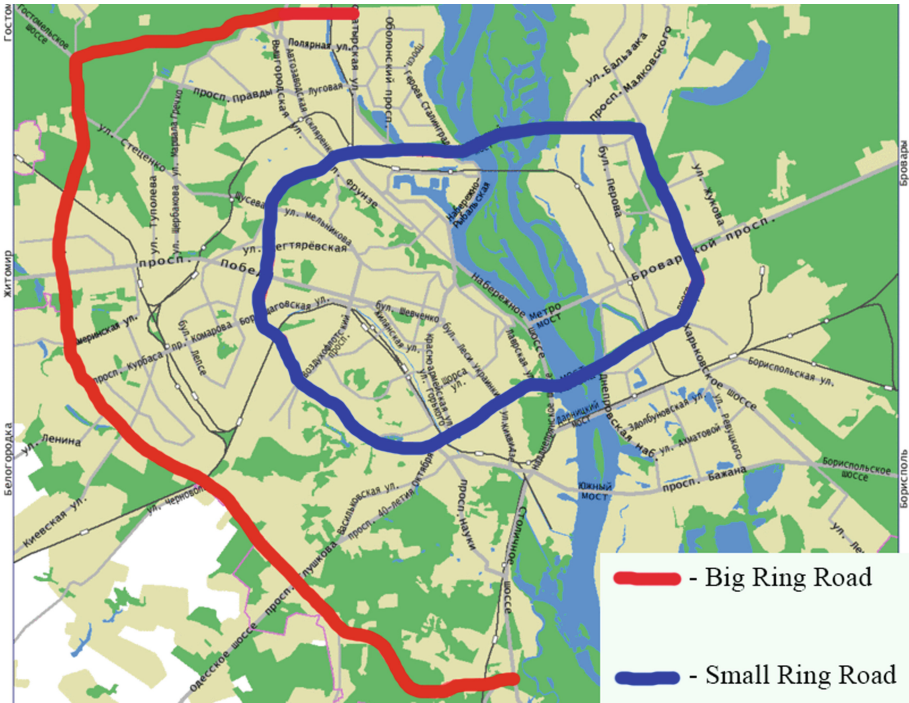


Fig. 3. Map of ring roads of Kyiv.

### 3 Project

Analyzing the identified opportunities of the transport system of Kyiv, the authors set the main directions of its development and create new projects for its optimization, which differ from the existing ones.

The project has been divided into two types. The first one is aimed to ensure the safe road passage of transit vehicles through the city without additional travel through Kyiv. The second project consists in improving Kyiv’s urban and suburban transport system to make it primarily convenient for passengers: residents of the city’s most populated areas and tourists.

#### 3.1 Road Detour

Unfortunately, now it is impossible to avoid the arrival of transit transport, which can significantly exceed the permissible limits within the city limits, within the cityline of Kyiv. This is due to several important factors:

- The city stands on the banks of the Dnipro, which must be crossed by land transport; the bridges are built only within Kyiv, so to travel between the river banks it is needed to drive through the city.

- The Big Ring Road is not built on the left bank of Kyiv, so it is impossible for transit trucks to go around the residential areas located there.
- Most of the highways of interregional and international importance are a continuation of the large avenues of Kyiv, on which the vehicles of local residents move daily. For example, the Kyiv-Chop highway is a continuation of Peremoha Avenue, Brovarskyi Avenue serves as a continuation of the St. Petersburg-Sumy-Kyiv highway, and the highway to Boryspil Airport and Kharkiv within Kyiv is Mykola Bazhan Avenue.
- Unlike many other cities in Ukraine and Europe, Kyiv's ring roads serve to travel between neighboring areas of the city rather than for transit traffic through it.

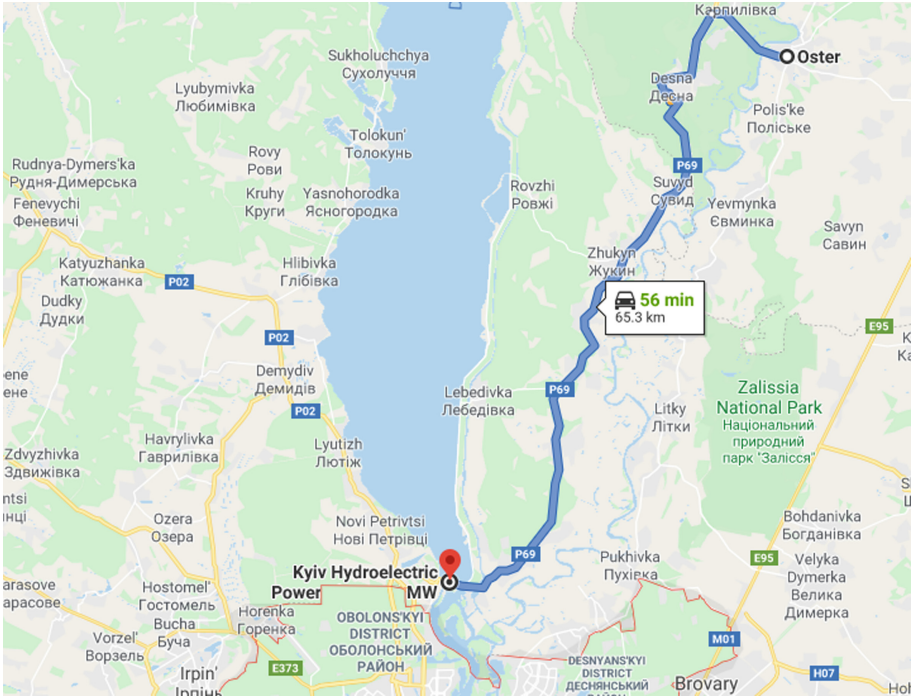
The authors' projects to optimize the road network of the city of Kyiv include solving all the above problems. Continuation of the Big Ring Road on the left bank of the Dnipro is a very expensive idea, because it requires the construction of additional bridges in the northern and southern parts of Kyiv, as well as pave a wide highway where there are now villages or cottages, thermal power plant and natural obstacles such as forests and lakes.

In order to ensure the safe transit of large trucks through Kyiv, the only existing bridge across the Dnipro outside the city can be used. This bridge is a road built on top of the dam of the Kyiv Reservoir near the suburbs of Kyiv called Vyshgorod. The length of the entire dam is 40 km, and the bridge across the Dnipro – a little more than one kilometer. At the moment, the road surface of the dam consists of only two lanes, so the structure serves the value of part of the Kyiv hydroelectric power plant rather than the transport road. However, in the future, this bridge, like the dam itself, can be expanded to have more capacity for transit vehicles and better protect the city from heavy water flows from the Kyiv Reservoir.

At the same time, the problem due to which this bridge is still rarely used is that it is located on the opposite bank of the Desna River, which is a tributary of the Dnipro and flows into it in the northern part of Kyiv. The nearest existing bridge to Kyiv across the Desna is located near the town of Oster in the Chernihiv Region, namely 65.3 km from the taken dam bridge (see Fig. 4). As the distance from Kyiv borders to Oster is approximately the same, so the total length of performed detour is equal to more than 130 km.

That is why, given the above conditions, it is possible to build a new bridge across the Desna, which can become part of the future bypass road for transit freight or passenger transport. The northern border road of Kyiv on the left bank is Myloslavska Street. At its end, there is an abandoned building and a swamp that surrounds the place, where the Desna flows into the Dnipro. In the case of the final dismantling of this building and the construction of the overpass and the bridge over the Desna, a road can be built that can connect the dam bridge with Kyiv. Then there will be a single highway that will allow transit traffic to bypass Kyiv downtown, located on the right bank, from the north. In addition, this road will allow residents of the left bank of Kyiv to get faster to the northern outskirts of the city on the right bank without having to go through other districts where there is a risk of getting stuck in traffic jams. Thus, the highway, which will consist of an overpass over swampy soils and a bridge over the Desna River, will connect the existing Myloslavska Street and the dam of the Kyiv Hydroelectric Power Station, crossing it near the village of Oseshchyna.





**Fig. 4.** Map of the existing road detour of Kyiv.

As for the continuation of this highway after the dam on the Right Bank, it is worth mentioning the existence of such an important transport hub in that part of the Kyiv agglomeration as Hostomel Antonov Airport. The option of building a highway from Vyshgorod to Hostomel is possible, and it could become a road directly to Antonov Airport. Route P69, which is a continuation of the dam on the right bank of the Dnipro north of Vyshgorod, rests on a dead end at the intersection with highway P02, while being approximately at the same latitude as Hostomel Airport. The space between these objects consists of forests and swamps without settlements, so it was proposed to build a highway there (see Fig. 5). It will be an access road to the airport from the east, where the railway station is located.

Thus, together with the existing P69 route and the previously proposed route from the Kyiv district of Troyeshchyna to the dam bridge across the Dnipro, there will be a highway that will connect the left bank of Kyiv with Antonov Airport. Its total length from intersection with Myloslavska Street to the border of Hostomel village will be equal to 30 km, 7.5 km of which exist now. The highway will solve the following problems:

- The highway can become a bypass road for Kyiv from the north for transit transport, so the need to build the Big Ring Road on the left bank with the construction of two additional bridges will be partially eliminated.

- This route will allow residents of the left-bank part of Kyiv to get to the north-western outskirts of the city faster without passing through the center.
- As part of the highway will be a new bridge across the Desna, it will allow Kyiv residents to reach the northern part of Ukraine faster.
- The dam bridge will be used more and will unload those bridges across the Dnipro, which are located further south within Kyiv, first of all the Pivnichnyi Bridge, which faces the problem of congestion on a daily basis.
- In case of opening passenger flights through Antonov Airport, it will be possible to get to it quickly and conveniently by road.

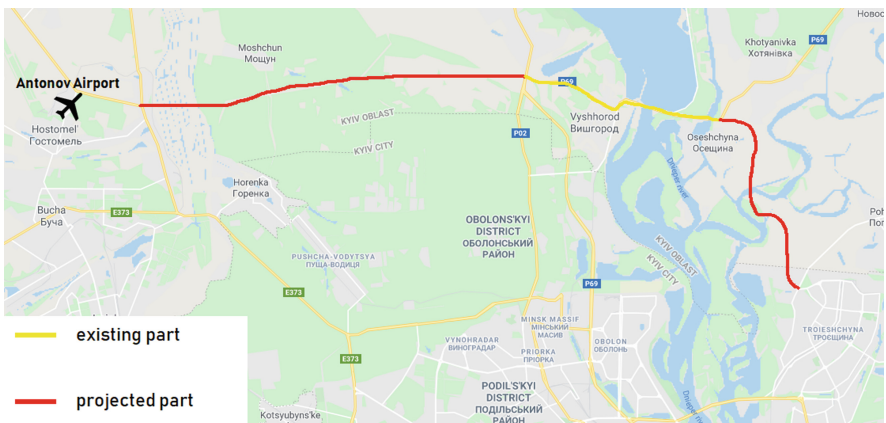


Fig. 5. Complete project of the highway from northern Kyiv to Hostomel.

### 3.2 Urban Transport

The main aim of the project on optimization of urban passenger transport is to overcome the problem of overcrowded vehicles during rush hour. However, land transport should not be called poorly developed, given the variety of vehicles in Kyiv and the sufficient number of their routes. That’s why, the project is aimed at improving the subway itself, which is lacking in several prominent residential areas of Kyiv. There have been projects for decades to build a fourth subway line to Troyeshchyna district, but so far they have not been implemented due to the unfinished construction of the Podilsko-Voskresenskyi Bridge, which is to become a connecting subway bridge for this line.

But even the existing subway projects do not solve another issue for Kyiv’s infrastructure: the connection with Kyiv’s largest airport, Boryspil. That is why, it was decided to propose new subway development project in Kyiv, taking into account not only existing ideas, but also other factors, such as the population of different parts of the city and their importance for the city’s economy. It includes the extension of two of the three existing lines and the construction of four new ones. Thus, Kyiv will have a developed subway system of seven lines, the scheme of which is shown in Fig. 6.



The priority projects that are being implemented now are the extension of the green subway line to the Vynohradar district and the construction of a yellow line from the Troyeshchyna district to Zhuliany airport. After modification of these projects to get a more convenient and clear subway scheme in the end, it is propose to extend the green line not to the northwest, but to the north of Kyiv with the final station on Taras Shevchenko Square. The yellow line after the Igor Sikorsky Airport can be extended to the Big Ring Road to implement the future project. In addition, the route of this line on the left bank has been changed: instead of heading east to Bratislavska Street, it was proposed to turn the line directly to Troyeshchyna district and lay the subway on or under Vladimir Mayakovski Avenue, which is the most important transport artery in this area.

The next step is to extend the green line east to Boryspil airport from Chervonyi Khutir station with the construction of extra stations in the villages of Shchaslyve and Chubynske along this route. Thus, it will be convenient and cheap for passengers to get from the airport to the downtown, and residents of those villages that mainly work and study in Kyiv will be able to use this fast and relatively inexpensive transport.

The cyan left-bank line will allow direct connections from Troyeshchyna to the southern residential areas of Darnytskyi district. However, the construction of this line has not been considered as a priority due to the development of a developed tram system in this part of Kyiv, but this line has been kept in the scheme, because of its existence in the official projects of Kyiv subway development.

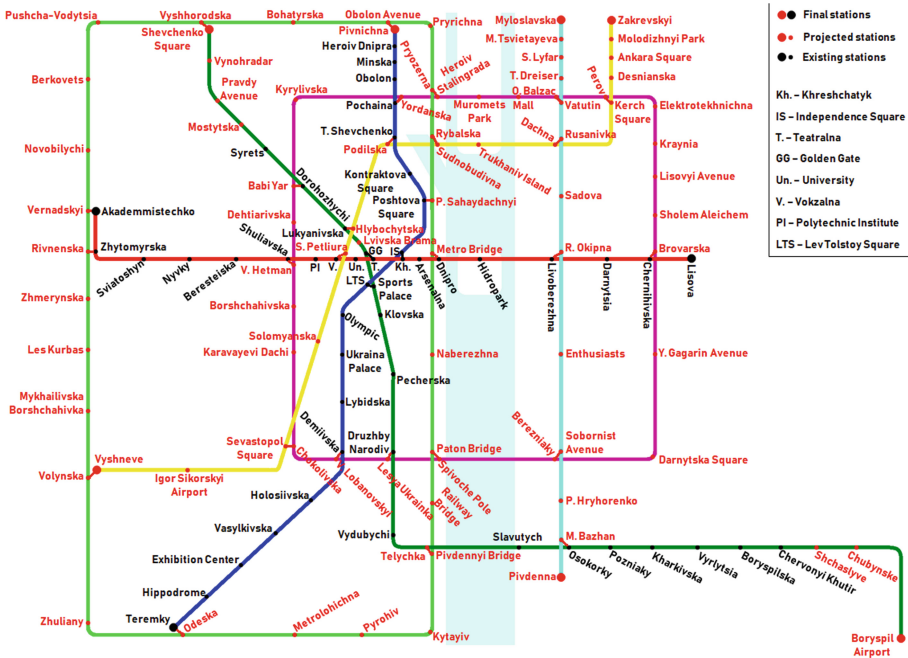


Fig. 6. Prospective project of subway development in Kyiv.

The two new, not represented in existing subway development projects lines, which have been added to the proposed scheme will run under two ring roads in Kyiv: the purple one will follow the Small Ring Road, and the lime line will follow the Big Ring Road. Since the Big Ring Road is built only on the right bank of the city, it was decided to connect its north and south ends in a lime line along the Dnipro embankment and Stalingrad Heroes Avenue, so that this line came out completely on the right bank. In order to connect all the terminals of the subway lines on the right bank with the lime line, it is proposed to extend the blue line one station north to the Pivnichna station, which is the same name as the street under which it will be located.

When creating this subway project, it was taken into account, that all proposed routes passed through existing roads and bridges: thus, the construction of a purple line involves laying rails for subway trains on the Pivnichnyi and Paton bridges. If the project is implemented, it will solve the following problems [11, 12]:

- Providing convenient, fast and cheap travel to two airports in Kyiv – Zhuliany and Boryspil. Given the current price of the Kyiv subway and ground transport to Boryspil airport, a trip there by subway will cost 10 times cheaper than by bus or train.
- Providing communication with the most populated areas of Kyiv: Troyeshchyna, Vynohradar and Borshchahivka.
- Creation of two ring lines that will provide fast communication between other lines and will run on two ring roads in Kyiv.

In total, the project consists of 4 new subway lines and 86 new stations, as well as 28 new transfer points between lines, which looks colossal compared to the current three. The detailed description of the proposed Kyiv subway development project is as follows:

1. The red line (Lisova-Akademmistechko) remains unchanged, except for the completion of new transfer points to new stations.
2. The blue line (now Teremky-Heroiv Dnipra) should be extended to the end of Obolonskyi Avenue to connect it with the Big Ring Road and the future lime line.
3. The green line (now Syrets-Chervonyi Khutir) should be extended to Taras Shevchenko Square after Syrets and by Boryspil Highway to Boryspil Airport after Chervonyi Khutir, as well as to receive the completed stations Lvivska Brama and Telychka, which will serve as a transfer station in the future.
4. The yellow line (Zakrevskiyi Street-Vyshneve) will run from Myloslavska Street along Vladimir Mayakovski Avenue, the new Podilskiyi Bridge, through the Podil district and the Central Railway Station to Povitroflotskiy Avenue to Sevastopol Square, Zhuliany Airport and Big Ring Road near the route to Vyshneve village. Compared to the existing project [11], the unnecessary Zatoka Desenka station has been removed, which would be located in a non-residential and informal area, so it would not be popular and could become unprofitable. In addition, the route on the left bank has been changed so that it turned into the Troyeshchyna district.
5. The cyan line (Myloslavska-Pivdena) will run along Honore de Balzac Street, residential areas Rusanivka, Berezhniaky and Osokorky to Kolektorna Street.

6. The purple line (small ring) will run along the Small Ring Road, namely Roman Shukhevych Avenue, Bratyslavska Street, Yuri Gagarin Avenue, Sobornist Avenue, Paton Bridge, Druzhby Narodiv Boulevard, Valeriy Lobanovskiy Avenue, Chokolivskiy Boulevard, Vadym Hetman Street, Oleksandr Dovzhenko Street, Olena Teliga Street, Stepan Bandera Avenue and Pivnichnyi Bridge.
7. The lime line (big ring) will run along the Big Ring Road, Poliarna Street, Pivnichna Street, Stalingrad Heroes Avenue and the embankment along the Dnipro.

In addition to the above advantages of the proposed subway project, a few other important locations in Kyiv that will be served by this mode of transport in case of implementation of all these ideas are described below:

- Both passenger airports in Kyiv will be connected to the subway network.
- The Electrotekhnichna and Sholem Aleichem stations of the purple line will be located near two important markets on the left bank of Kyiv – Troyeshchyna and Lisovyi, respectively.
- Yordanska Station will serve as a transfer station for the Pochaina subway station, which will help to unload the poorly organized stop of many land transport routes located there.
- Stations Babi Yar, Naberezhna, Spivoche Pole and Pyrohiv will be located near the famous sights of Kyiv and will help tourists to reach them easier.
- Stations Karavayevi Dachi, Vyshneve and Volynska will be located near important for suburban transport railway stations.
- Vadym Hetman and Borshchahivska stations will be located near major universities in Kyiv, so students and teachers will get there much faster.
- Rusanivka, Sadova, Dachna and Pivdenna stations will be located in cottage villages within Kyiv, where urban transport is currently poorly developed.
- Subway lines will run under all major highways in Kyiv, so this will help solve the problem of congestion.

## 4 Conclusions

The novelty of the presented research is the introduction of a new bypass for transit transport passing through Kyiv, as well as additional metro lines in the city of Kyiv, which were not implemented in previous projects for the development of urban transport.

In case of implementation of the two proposed projects for the development of the transport system, Kyiv will receive a modern and convenient system for all transport users. The semi-ring road on the Left Bank will allow vehicles traveling from Eastern Ukraine and the Middle East to the west to bypass Kyiv from the north. Thus, transit transport will not get stuck in traffic jams or create them on the most important highways of the city, and it will be able to go through the capital of Ukraine faster without passing through its downtown. It should be noted that most of the future highway has already been built: only one Vyshgorod-Hostomel highway and an overpass from Troyeshchyna district to the Kyiv hydroelectric dam with a bridge across

the Desna near the village of Oseshchyna need to be completed to the existing roads on the left bank of Kyiv and on the outskirts of Vyshgorod.

Implementation of the project of this highway will open additional prospects for Hostomel Antonov Airport. In this way, it will be possible to finally open passenger terminals near this airfield, because then it will be much easier for people to get to it. Moreover, the existence of a freight railway station on the territory of the airfield together with the future highway will make Antonov Airport an important multimodal hub for air, rail and road transport.

As for the second project of subway development in Kyiv, it is primarily aimed at resolving an important issue that has been raised by Kyiv authorities for years: providing residential areas in Troyeshchyna, Vynohradar and Borshchahivka with this type of transport, which, importantly, does not get stuck in traffic jams. In addition, if this idea is implemented, both passenger airports in Kyiv will also have a connection with this relatively inexpensive mode of transport. After the final implementation of the project of the Kyiv subway development, which will consist of seven lines, the land transport network in the city will be significantly unloaded. This will be an improvement for the roads of Kyiv, because then the number of accidents and traffic violations will be reduced.

## References

1. Kyiv-Pasazhyrskiy Railway Station. [https://en.wikipedia.org/wiki/Kyiv-Pasazhyrskiy\\_Railway\\_Station](https://en.wikipedia.org/wiki/Kyiv-Pasazhyrskiy_Railway_Station). Accessed 17 Apr 2021
2. Transport in Kyiv. [https://en.wikipedia.org/wiki/Transport\\_in\\_Kyiv](https://en.wikipedia.org/wiki/Transport_in_Kyiv). Accessed 8 Apr 2021
3. About subway. <http://www.metro.Kyiv.ua/node/90>. Accessed 8 Apr 2021
4. Scheme of subway lines. <http://www.metro.kiev.ua/node/101>. Accessed 8 Apr 2021
5. Transport modes and advantages of bus. <http://svit-express.com.ua/perevozki-po-ukraine/>. Accessed 17 Apr 2021
6. Trolleybus as a mode of public transport. <https://ria.ru/20101122/299491309.html>. Accessed 12 Apr 2021
7. Savchenko, V., Laptiev, O., Kolos, O., Lisnevskiy, R., Ivannikova, V., Ablazov, I.: Hidden transmitter localization accuracy model based on multi-position range measurement. In: 2020 IEEE 2nd International Conference on Advanced Trends in Information Theory, IEEE ATIT 2020, Proceedings, pp. 246–249 (2020)
8. 11 Infrastructural Projects that can make Kyiv better. <https://www.epravda.com.ua/rus/publications/2019/12/11/654728/>. Accessed 8 Apr 2021
9. How the tram is better than the bus. <https://gre4ark.livejournal.com/678424.html>. Accessed 19 Apr 2021
10. Disadvantages of tram. <https://zen.yandex.ru/media/id/5d9e3e07bc251400b1190385/nedostatki-tramvaia-5dc6166172b73d07e87e14c0>. Accessed 11 Apr 2021
11. Sokolova, O., Soloviova, O., Borets, I., Vysotska, I.: Development of conceptual provisions to effectively manage the activities of a multimodal transport operator. *Eastern-Eur. J. Enterp. Technol.* **13**(109), 38–50 (2021)
12. Yudin, O., Ziubina, R., Buchyk, S., Matviichuk-Yudina, O., Suprun, O., Ivannikova, V.: Development of methods for identification of information-controlling signals of unmanned aircraft complex operator. *Eastern-Eur. J. Enterp. Technol.* **2/9**(104), 56–72 (2020)