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ANALYSIS OF PASSENGER FLOWS OF YEREVAN METRO AND OTHER MEANS OF TRANSPORT IN THE CONTEXT OF THE NEWLY CONSTRUCTED AJAPNYAK STATION

Yerevan, being the largest city in Armenia, as well as having a highly concentrated population, faces a number of problems related to transport infrastructure, the systemic solutions to which are fatal. The number of cars, as well as new buildings are increasing day by day, and the lack of appropriate infrastructures is deepening the crisis of the capital's transport system and emphasizing the need for the development of the metro, including a new metro station.

Within the framework of this study, a comprehensive analysis was conducted on public transport operating in Yerevan, in particular, the passenger flow in the metro. According to data provided by the Yerevan Metro, the number of citizens using the metro has been increasing year by year, exceeding 23 million in 2022. Based on 2022 monthly data of Yerevan Metro, the four busiest stations are Barekamutyun, Yeritasardakan, Garegin Nzhdeh Square, and Republic Square, whose average monthly passenger flows in 2022 were respectively equal to 352.685, 285.406, 273.381 and 259.938 thousand passengers.

By studying monthly and annual time series of passenger flows at all 10 stations of the Yerevan Metro, autoregressive econometric models were evaluated to estimate and

forecast passenger flows in some of the stations. To predict the passenger flow in the new Ajapnyak station based on the analog method, we used the passenger flow characteristics of the existing stations: Barekamutyun, Gortsaranay, and Republic Square stations.

Keywords: *passenger flow, metro, Ajapnyak station, transport infrastructure*

JEL:R41, R 42, R 53

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INTRODUCTION. Yerevan, the capital of the Republic of Armenia, being the economic and financial center, is the area with the highest population density in the Republic of Armenia. The high density, in turn, causes traffic and movement problems in the capital, which certainly lead to a series of negative chain effects.

The Yerevan Metro is not only a means of transportation, but it also has strategic importance. To ease the burden on the traffic network, the development of public transport, especially the metro, is considered a primary and sustainable strategy to balance population density and high-intensity traffic demand. The metro, as a sustainable mode of urban transportation, has been expanding dramatically in recent decades and is accepted as the first type of public transportation for most of the major cities, such as Beijing, Shanghai, Tokyo, and several other cities (Wang, 2012).

In 1962-1964, according to the new plan developed in Yerevan, serving the population with the metro was considered the most effective and corresponded to the perspective of the capital's development. On March 7, 1981, the opening ceremony of the Yerevan Metro took place, during which 5 stations were put into operation: Barekamutyun, Marshal Baghramyan, Yeritasardakan, Republic Square, Sasuntsi Davit stations. Later, in 1983, Garegin Nzhdeh station was also put into operation, in 1989 Zoravar Andranik, and in 1997 Charbakh stations. Yerevan Metro currently has 10 stations, more than 12 km of lines in operation, and the number of wagons in operation is 45. According to official data, 18 million 573 thousand 710 passengers used the Yerevan metro in 2021, and 23 million 317 thousand 633 passengers in 2022.

The current metro runs on a 13.4 kilometers line and serves 10 active stations at present. Trains run every five minutes from 6:30 a.m. until 11 p.m. local time.

In Yerevan, the area with the highest population density of the RA, the number of cars, as well as new buildings are increasing day by day, and the lack of appropriate infrastructures is deepening the crisis of the capital's transport system and emphasizing the need for the development of the metro, including a new metro station. The intersection of the Barekamutyun metro is overloaded, there are always traffic jams, especially in the morning, during the break, and between 6:00 and 8:00 p.m., and the Kiyevyan bridge does not solve the problem either.

Observations were made in April and May 2023 to determine which part of the traffic from Barekamutyun goes up to Komitas and which part goes to

Ajapnyak. About 60 percent of the traffic goes to Ajapnyak. If the new station is opened, most of the passengers choose the metro, and the issue of unloading from ground transport will be solved. Also, the addition of the new station will make the metro work more efficiently.

The Ajapnyak new metro station will connect the given administrative district with the Barekamutyun station and, in case of operation, will significantly ease the traffic in the city. The opening of the station will ensure a reliable transport connection for the population of the Ajapnyak administrative district between the city center and other administrative districts. It is also important from the point of view of easing the load on the 2 major bridges of the city, Davtashen and Kievyan.

The development of the metro and addition of new stations are especially important, along with the development of the capital, as the volume of traffic flows and congestion increases. Also, at the station, it will be possible to organize a transport exchange hub for private transport users and public transport passengers coming from areas adjacent to the Ajapnyak administrative district (from the regions of Aragatsotn and Armarvir marzes, close to the city of Yerevan).

This study aims to examine changes in passenger flows in both the Yerevan Metro and other public transport modes in the context of the newly constructed Ajapnyak metro station.

LITERATURE REVIEW. Studying the international experience, we can confidently assert that the metro is considered one of the most popular and convenient means of public transport today, which is continuously developing, covering more and more territories. In developed countries, a transport system without the presence of the metro is almost impossible to imagine, especially if we are talking about megacities or large cities.

One of the studies is dedicated to analyzing the impact of the opening of a new metro line in Shenzhen on passenger traffic. This paper not only analyzes the short and long-term impact of new lines opening on passenger flow from passenger volume but also proposes a new method to identify the growth period of the transfer flow in new lines. According to the results in the short term, adding new lines boosts the number of passengers boarding, alighting, and transferring in a short period of time, and the evening peak attracts more passengers than the morning peak. And when we talk about its long-term impact, then the opening of new lines changes the ratio of passenger flow in Shenzhen (Zihao Li et al., 2024).

Another study is dedicated to determining the impact of newly built metros on the transportation system of second-tier cities. According to calculations, the second-tier city's newly constructed metro network lowers travel costs and improves convenience, but it also makes the entire network more vulnerable and reconstructs the distribution of important nodes in the road network (Zhao et al., 2021).

One study, using data from smart cards, examined passenger mobility patterns and evaluated the performance of the subway network in Nanjing, China. This article offers a thorough examination of smartcard data from the metro system to illustrate the impacts of rail transit growth in urban regions. The effects of the new metro line (specifically, Line 4 of the Nanjing metro) on the overall metro network and various kinds of commuters are examined through the analysis of passenger flow distributions, travel times, and travel time reliability. The findings indicate that the new metro line affects passenger flow, journey duration, and travel time reliability within the metro network, exerting varying impacts on distinct kinds of commuters (Fu et al., 2018).

A similar study was also conducted for the new metro station planned for Oslo. This study examines the impact of a proposed metro line in the Oslo region on workforce accessibility for the population. In particular, the article discusses the latter's impact on the city's socio-economic environment. According to the results obtained, it becomes clear from a social perspective that the new metro line contributes to a relatively modest increase in accessibility for all income groups, and that the increase is greatest among the richest households. This means that although investments are aimed at increasing access for all social groups, as in many other areas, social inequality persists (Lunke et al., 2024).

RESEARCH METHODOLOGY. The methodological basis is the set of comparative statistical data grouping, systematic, dynamic analysis, generalization, and graphical methods, which were used and combined in the research, and implies analyzing the structure of passenger flows at all stations in different periods and problem revelation. Within the framework of the research, econometric-mathematical analysis methods, based on available statistical data, were used.

To analyze the passenger flow in the Yerevan Metro stations, we have used annual, monthly, and daily passenger flow data received from the Yerevan Metro named after Karen Demirchyan.

By studying monthly and annual time series of passenger flows at all 10 stations of the Yerevan Metro, the Holt-Winters additive method was evaluated to forecast passenger flows at some of the stations. The Holt-Winters method, also referred to as triple exponential smoothing, is a widely used and uncomplicated technique for time series forecasting. The model demonstrates optimal performance in situations where the size of seasonal variations remains relatively stable across the observed period.

The Holt–Winters additive model divides the time series into three main components:

- Level: l_t
- Trend: b_t
- Seasonal component: s_t

Where m represents the seasonality period (e.g., $m=12$ for monthly data) and t is the time index.

The additive method's component takes the following form (Hyndman R., Athanasopoulos, G.,2018).

$$l_t = \alpha(y_t - s_{t-m}) + (1 - \alpha)(l_{t-1} + b_{t-1})$$

$$b_t = \beta^*(l_t - l_{t-1}) + (1 - \beta^*)b_{t-1}$$

$$s_t = \gamma(y_t - l_{t-1} - b_{t-1}) + (1 - \gamma)s_{t-m}$$

Where:

- y_t is the value of the observed time series
- α level smoothing parameter, $0 < \alpha < 1$
- β trend smoothing parameter, $0 < \beta < 1$
- γ seasonal smoothing parameter, $0 < \gamma < 1$

The prediction equation is:

$$\hat{y}_{t+h|t} = l_t + hb_t + s_{t+h-m(k+1)}$$

Where k is the integer part of $(h-1)/m$, which ensures that the estimates of the seasonal indices used for forecasting come from the final year of the sample.

The article uses the Analog Method to understand the dynamics of passenger flow demand at the newly constructed Ajapnyak metro station, based on the dynamics of the other stations considered, which were given weights according to their importance.

The prediction equation is:

$$\hat{y}_{Ajapnyak,t} = v_1 \hat{y}_{Barekamutyun,t} + v_2 \hat{y}_{Gortsaranayin,t} + v_3 \hat{y}_{Republic Square,t}$$

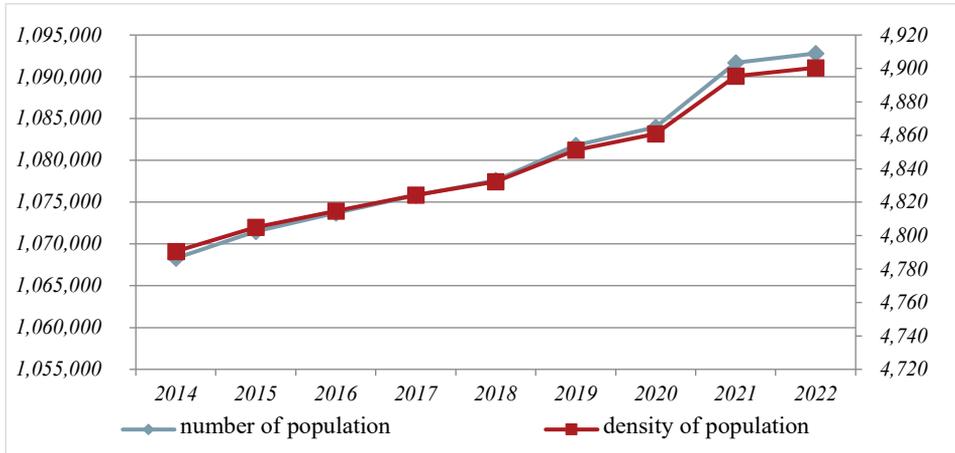
Where:

$\hat{y}_{Ajapnyak,t}$ - is the predicted passenger flow at Ajapnyak station

$\hat{y}_{i,t}$ - is the forecasted passenger flow at Barekamutyun, Gortsaranain, and Republic Square stations.

v_i - analogy weights, $v_1 + v_2 + v_3 = 1$

ANALYSIS AND RESULTS. As it becomes clear from Figure 1, during the considered period, the population in Yerevan continuously showed an increasing trend, which in turn led to an increase in the population density in the capital. According to the data of 2022, 37% of the entire population of the RA, about 1 million 92 thousand people, is concentrated in Yerevan, and the population density is about 4900 people per square kilometer.



Source: *The regions of the Republic of Armenia and the city of Yerevan in numbers.*

Figure 1. Population and population density in the city of Yerevan, 2014-2022

Observing the number and density of the population according to administrative districts, it becomes clear that the indicators differ by administrative district. Some administrative districts also have a fairly high level of density, which leads to some difficulties and problems in the movement of citizens. In particular, Qanaqer-Zeytun, Nor-Nork, Kentron administrative districts stand out with the highest population density, respectively 9702, 9525, and 9431 people.

Table 1

Population and population density by administrative districts of the city of Yerevan, 2022

	Population	Population density
<i>Achapnyak</i>	110,400	4,276
<i>Avan</i>	53,300	6,564
<i>Arabkir</i>	115,000	8,679
<i>Davtashen</i>	43,300	6,641
<i>Erebuni</i>	130,100	2,682
<i>Kentron</i>	125,900	9,431
<i>Malatia-Sebastia</i>	141,000	5,604
<i>Nor Nork</i>	134,400	9,525
<i>Norq-Marash</i>	11,900	2,500
<i>Nubarashen</i>	10,400	603
<i>Shengavit</i>	142,100	3,500
<i>Qanaqer-Zeytun</i>	75,000	9,702

Source: *The regions of the Republic of Armenia and the city of Yerevan in numbers, 2022.*

Yerevan is becoming more densely populated day by day; there are more cars, as well as new residential buildings and constructions, and the lack of appropriate infrastructure complicates the work of the capital's transport system and further emphasizes the need for the development of the metro, as well as the launch of a new metro station.

INITIAL SITUATION

THE MAIN CHARACTERISTICS OF THE CURRENT STATE OF THE YEREVAN METRO AND AJAPNYAK DISTRICT

The Ajapnyak administrative district covers an area of 2582 hectares. It is located on the western right side of the Hrazdan River. By area, Ajapnyak is the 4th largest administrative district of Yerevan, occupying 11.21% of the total area of the city. According to 2022 official data, the population of this region was 110,400 people, occupying the 7th place in the population of Yerevan's administrative regions (Yerevan Municipality, 2025).

Ajapnyak administrative district borders on Arabkir, Davtashen, Kentron, and Malatia-Sebastia administrative districts, as well as Armavir, Aragatsotn, and Kotayk regions /marzes/. The connection with the Kentron administrative district is provided by the Kievyan bridge.

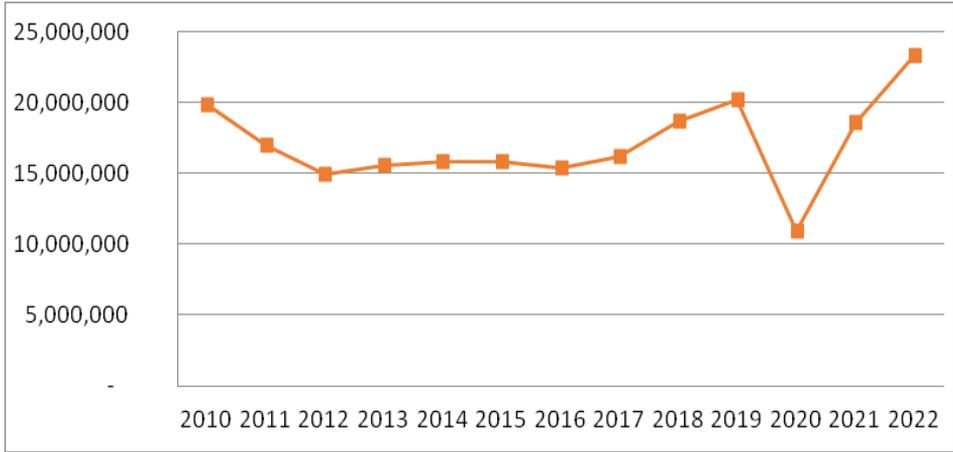
According to the 2022 data, there were 444 apartment buildings, 6100 residential houses in the territory of Ajapnyak. There were many large industrial companies, such as "Biokat" milk products, "Aparan" mineral waters, "Elit Shant" ice cream, "Profmet" metal pipe factories, "Amelia" mining, "Martin Star" companies, etc.

There are 16 kindergartens, 20 public schools, 4 private schools, as well as children's, art, music, mixed martial arts, and chess schools. There are also many higher educational institutions in the Ajapnyak administrative district, such as Yerevan "Haybusak" University, Agricultural University, the Yerevan branch of the Moscow State University of Informatics, Economics and Statistics, the research center of the Yerevan Institute of Physics, and the Tumo creative technology center, which was opened in Ajapnyak in 2011. Yerevan Republican Hospital, the largest hospital in Yerevan, is also located in Ajapnyak.

Currently, the Yerevan city transport service is carried out by buses, trolleybuses, minibuses, and the metro. There are 699 buses in 45 directions, and 430 minibuses with 41 trolleybuses in 34 directions. According to the data of 2022, about 74.1 million passengers were transported by buses, which is about 3.6 million passengers more than the previous year. The volume of transportation by trolleybuses was about 4307.5 thousand passengers, which is 388.5 thousand passengers more than in the previous year. The passenger traffic by minibuses was 44.2 million passengers, which is about 15.5 million less than in 2021.

Figure 2 shows the passenger flow of all stations from 2010 to 2022. According to 2010 data, the passenger flow was almost 20 million passengers. Then, in the following 2 years, the passenger flow gradually decreased, and in 2012 it reached its lowest value of the considered period, amounting to almost 15 million. From 2012 to 2019, passenger flow almost always increased year-by-year, surpassing 20 million in 2019. In 2020, conditioned by the epidemic situation, the passenger flow decreased by almost 50 percent compared to 2019, amounting to 10 million 957 thousand passengers. According to the statistics of

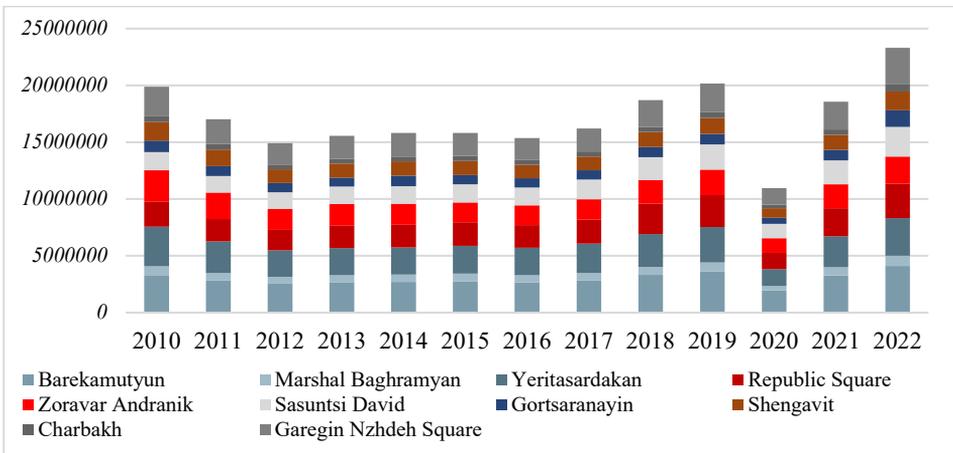
2022, the passenger flow was 23 million 317 thousand people, which is the highest value of the considered period.



Source: Yerevan Metro after Karen Demirchyan CJSC

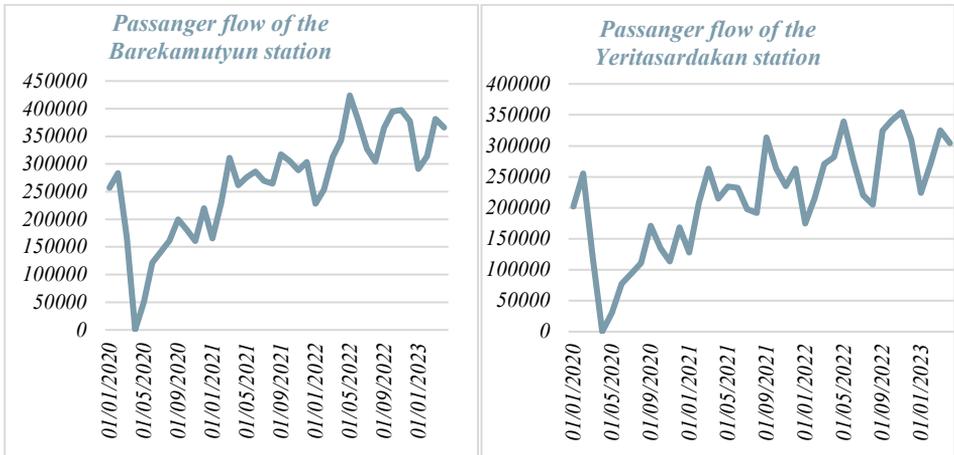
Figure 2. The passenger flow of the Yerevan metro from 2010 to 2022

Examining the passenger flow of 10 metro stations by year and month, during 2010-2020, it is noticeable that the dynamics of passenger flow show an irregular behavior. In particular, as it becomes clear from Table 2, which calculates the growth rate of the passenger flow of each individual station compared to the previous year, we can state that Gortsaranayin station is the leader with 7 percent of the average indicator of the observed period. Then, it is followed by Sasuntsi Davit with 6.7 percent, Republic Square with 6.2 percent, and Berekamutyun and Garegin Nzhdeh stations with 5.1 percent and 5 percent, respectively. The Zoravar Andranik and Charbakh stations had the most modest growth rate with 1.7 and 2.4 percentage points, respectively.



Source: Yerevan Metro after Karen Demirchyan CJSC

Figure 3. Passenger flow from 2010 to 2022 according to stations



Source: Yerevan Metro after Karen Demirchyan CJSC

Figure 4. Passenger flow of the Yeritasardakan and Barekamutyun stations, monthly, 2020-2023

Table 2

Growth rates of passenger flows by stations from 2011 to 2022, and the average annual indicator

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Barekamutyun	-13.3%	-7.5%	3.3%	0.8%	2.4%	-4.1%	6.8%	17.1%	8.6%	-46.1%	68.6%	25.3%
Marshal Baghramyan	-19.5%	-16.4%	5.7%	6.2%	3.7%	-2.8%	4.1%	7.7%	13.8%	-50.2%	75.2%	28.5%
Yeritasardakan	-19.4%	-17.4%	3.9%	0.1%	1.4%	-0.7%	6.7%	11.0%	8.4%	-52.4%	85.5%	20.7%
Republic Square	-10.6%	-7.6%	8.1%	1.1%	5.8%	-5.1%	5.7%	27.4%	4.6%	-48.5%	71.2%	22.4%
Zoravar Andranik	-16.5%	-19.9%	2.2%	-1.9%	-6.7%	0.4%	2.9%	16.0%	8.5%	-44.1%	66.2%	13.0%
Sasuntsi David	-9.6%	-2.0%	7.6%	0.4%	2.3%	-0.5%	10.0%	16.9%	9.1%	-42.2%	63.7%	24.6%
Gortsaranayin	-11.5%	-4.8%	-4.2%	16.7%	-9.6%	-5.8%	4.5%	7.3%	5.2%	-41.9%	73.6%	55.0%
Shengavit	-12.9%	-15.8%	2.1%	0.0%	-2.0%	-2.9%	1.5%	10.3%	6.5%	-40.2%	56.8%	25.8%
Charbakh	-8.0%	-19.0%	2.5%	5.1%	-0.1%	-5.5%	2.8%	1.9%	9.6%	-36.6%	52.7%	44.4%
Garegin Nzhdeh Square	-14.6%	-12.7%	7.4%	1.9%	-1.5%	-4.8%	4.5%	16.5%	7.8%	-42.9%	68.5%	30.1%

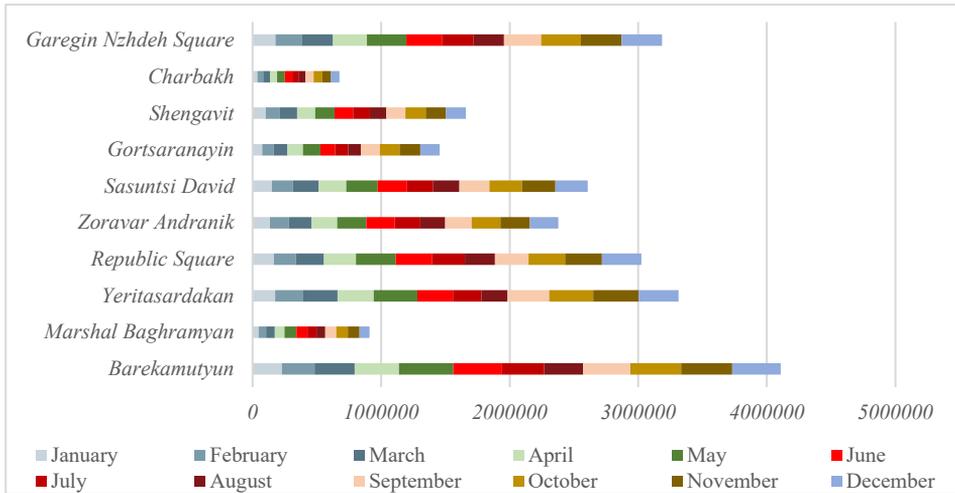
Source: Calculated by the authors

In April 2020, due to COVID-19 pandemic restrictions, a sharp decrease in passenger flow was recorded at all stations. The sharpest decline was in the city's central stations: Yeritasardakan -52,4%, Marshal Baghramyan -50.2%, and Republic Square -48.5%. After 2020, there is an increase in the passenger flow of all metro stations, which is mainly due to the problems of traffic that are getting worse every year.

Figure 4 represents Yeritasardakan and Barekamutyun stations' monthly passenger flow from January 2020 to April 2023. The output is also quite similar at the other stations.

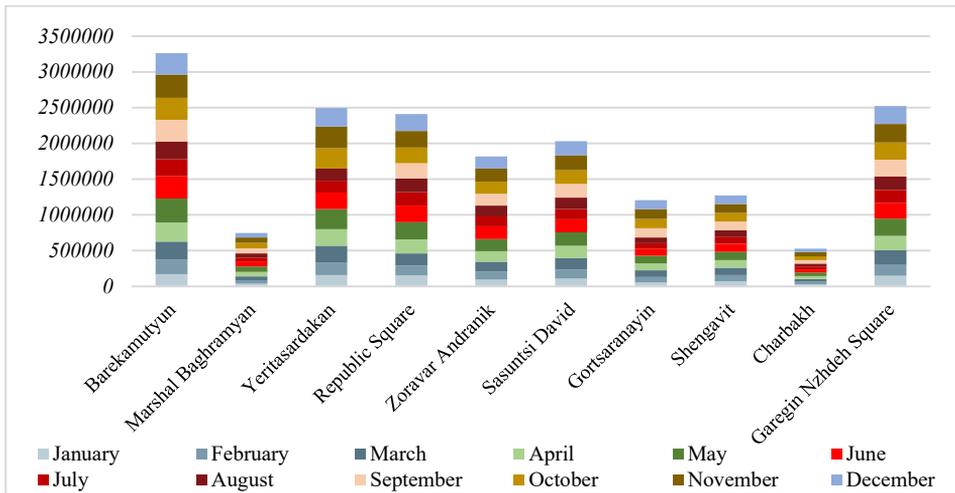
Based on 2022 monthly data of the Yerevan Metro, the four busiest stations are Barekamutyun, Yeritasardakan, Garegin Nzhdeh Square, and Republic Square, whose average monthly passenger flows in 2022 were respectively equal to 352.685, 285.406, 273.381 and 259.938 thousand passengers. These four

stations are almost overloaded on working days. Moreover, passenger flows are almost the same for stations in different months.



Source: Yerevan Metro after Karen Demirchyan CJSC

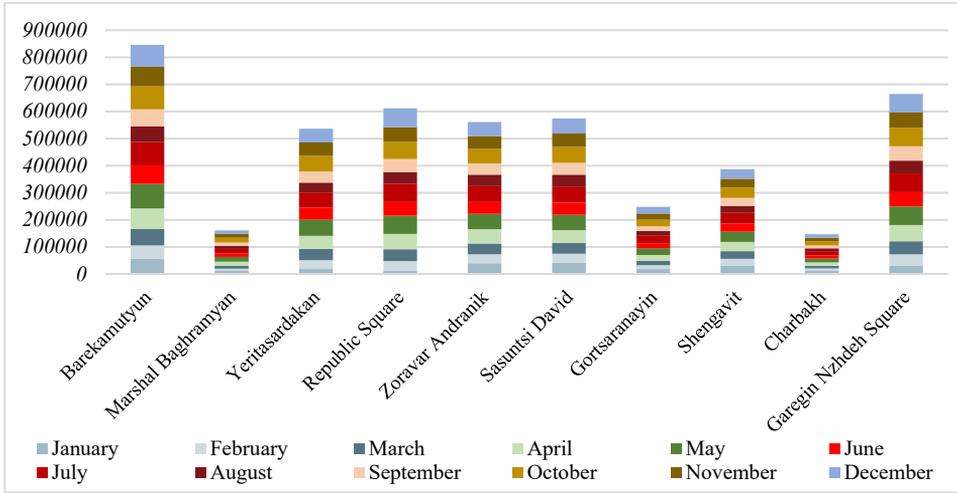
Figure 5. Monthly passenger flow in 2022 by all stations



Source: Yerevan Metro after Karen Demirchyan CJSC

Figure 6. Monthly passenger flow, Working Days in 2022

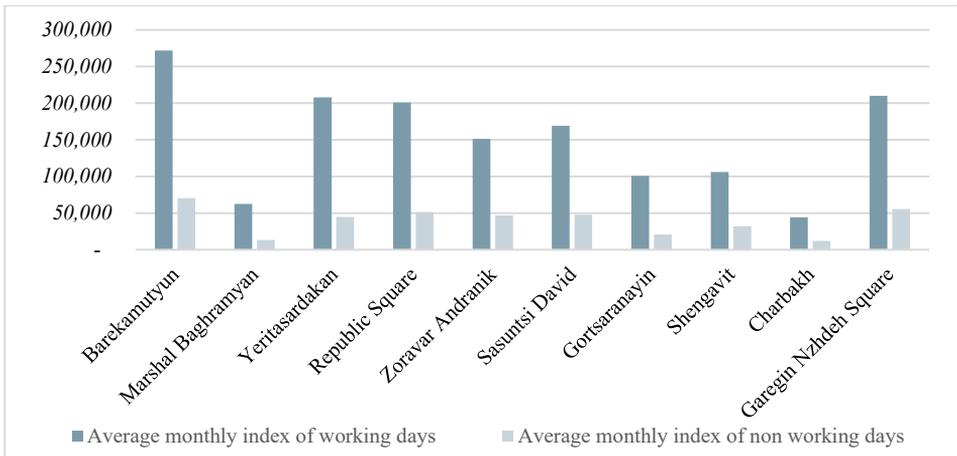
According to the monthly data of 2022 (Figure 6), Barekamutyun, Garegin Nzhdeh Square, Yeritasardakan, and Republic Square stations are overloaded stations on working days.



Source: Yerevan Metro after Karen Demirchyan CJSC

Figure 7. Monthly passenger flow, Non-Working Days in 2022

The graph shows the average monthly indicators of passenger flow on working and non-working days by stations.



Source: Yerevan Metro after Karen Demirchyan CJSC

Figure 8. Average monthly passenger flow on working and non-working days in 2022

From the graph, we can understand that the load of the stations is almost unchanged on both working and non-working days. In other words, in those stations where there is more congestion on working days, the congestion on non-working days is also high compared to others.

During April 17-21 (2023), observations were made at these two busiest stations.

As a result of observations made at Garegin Nzhdeh and Barekamutyun metro stations, the passenger flow data was recorded during the rush hours of 7:00–9:00 am and 6:00–8:00 pm.:

Table 3

Results of field statistics conducted at Garegin Nzhdeh and Barekamutyun stations

		<i>Morning rush hour</i>	<i>Evening rush hour</i>
Day 1	Garegin Nzhdeh Square	2961	2665
	Barekamutyun	3660	3294
Day 2	Garegin Nzhdeh Square	2717	2445
	Barekamutyun	3400	3362
Day 3	Garegin Nzhdeh Square	2514	2499
	Barekamutyun	3510	3502
Day 4	Garegin Nzhdeh Square	2710	2511
	Barekamutyun	3290	3260
Day 5	Garegin Nzhdeh Square	2771	2860
	Barekamutyun	3599	3650

Source: Calculated by the authors

Based on the monthly data of 2022, relatively busy months were May, June, September, October, November, and December, when the monthly passenger flow was 2.1 to 2.3 million, and the least active month was January with 1.3 million passengers.

Also, comparing the 2022 data with the 2023 data, we can see that the increase in passenger flow is evident in all the months observed at all stations. This once again proves that the number of metro users is increasing year by year, and the opening of new stations and the development of the metro should be one of the primary goals.

Table 4

Passenger flow in 2022 and 2023, from January to April

	<i>January</i>		<i>February</i>		<i>March</i>		<i>April</i>	
	<i>2022</i>	<i>2023</i>	<i>2022</i>	<i>2023</i>	<i>2022</i>	<i>2023</i>	<i>2022</i>	<i>2023</i>
Barekamutyun	228,206	290,767	253,541	313,837	312,554	381,318	343,136	366,003
Marshal Baghramyan	48,606	62,700	55,780	71,017	67,634	83,252	75,384	79,382
Yeritasardakan	174,830	223,960	215,405	271,444	270,721	324,756	281,550	304,639
Republic Square	164,747	229,238	173,001	227,558	217,147	283,169	250,154	270,255
Zoravar Andranik	135,289	162,225	146,350	172,983	176,906	213,854	199,866	205,432
Sasuntsi David	149,552	187,860	164,164	200,693	200,114	242,407	215,578	229,639
Gortsaranayin	74,892	103,595	88,974	126,678	108,291	157,115	119,634	149,329
Shengavit	102,938	125,754	111,483	131,565	131,863	153,683	141,910	152,427
Charbakh	38,571	53,055	43,983	55,449	51,632	67,262	55,623	65,489
Garegin Nzhdeh Square	178,069	233,967	202,576	253,634	245,327	311,146	263,967	296,206

Source: Yerevan Metro after Karen Demirchyan CJSC

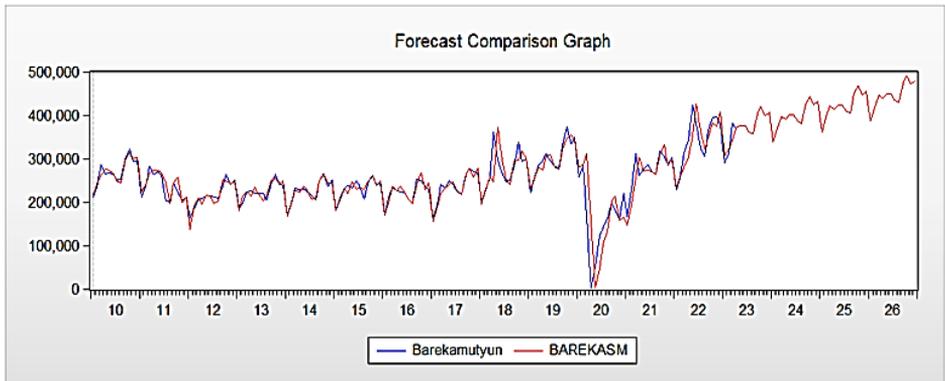
Several methods have been used for forecasting, including first-order autoregression, SARIMA, Seasonal Holt-Winters, and ETS forecasting models. Taking into account the values of a number of indicators that characterize the quality of the forecast, as well as the nature of the data, the Holt-Winters Additive

Seasonal model was selected for the forecast. Given the simple seasonality of subway ridership data, as well as the slow-changing trend, the Holt-Winters Additive Seasonal model effectively predicts future ridership dynamics without unnecessary complications and parameters. The Holt-Winters Additive Seasonal model demonstrates a good forecasting performance. The mean square and mean absolute deviation of the forecast from the actual values are 27.1 and 15.2, respectively, which means that the predicted values deviate quite a bit from the actual values. The evaluated model shows good forecasting performance, with a SMAPE of less than 8% and a Theil U1 value close to 0, indicating a close match with the observed passenger flows.

The passenger flow prediction graph of Barekamutyun station is shown in Figure 9.

Forecast Evaluation
 Date: 01/11/26 Time: 18:59
 Sample: 2010M01 2026M12
 Included observations: 204
 Evaluation sample: 2010M01 2026M12
 Number of forecasts: 1

Evaluation statistics						
Forecast	RMSE	MAE	MAPE	SMAPE	Theil U1	Theil U2
BAREKASM	27.19277	15.25114	2.329099	8.200887	0.053030	0.925783



Source: Calculated by the authors.

Figure 9. The passenger flow prediction graph of Barekamutyun station

Using the same approach, let us estimate the model for the passenger flow at the Gortsaranayin station and also the Republic Square station.

The passenger flow prediction graph of Gortsaranayin and the Republic Square stations will be:

Forecast Evaluation

Date: 01/11/26 Time: 19:54

Sample: 2010M01 2027M12

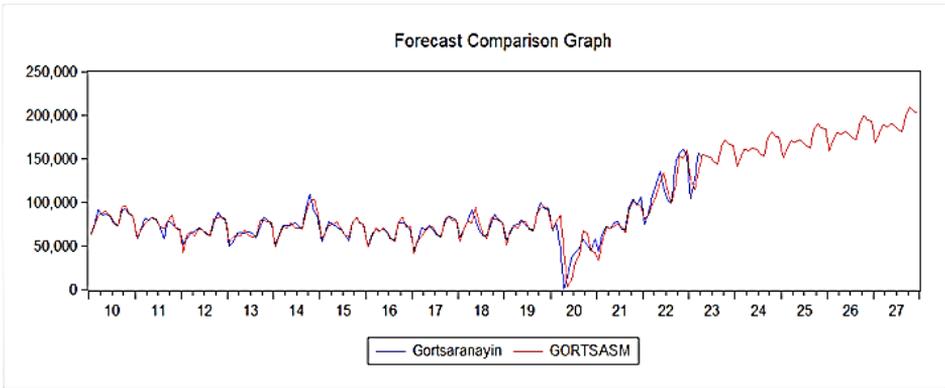
Included observations: 216

Evaluation sample: 2010M01 2027M12

Number of forecasts: 1

Evaluation statistics

Forecast	RMSE	MAE	MAPE	SMAPE	Theil U1	Theil U2
GORTSASM	81.39952	50.22793	1.711292	8.765750	0.051402	0.838861



Forecast Evaluation

Date: 01/11/26 Time: 20:05

Sample: 2010M01 2027M12

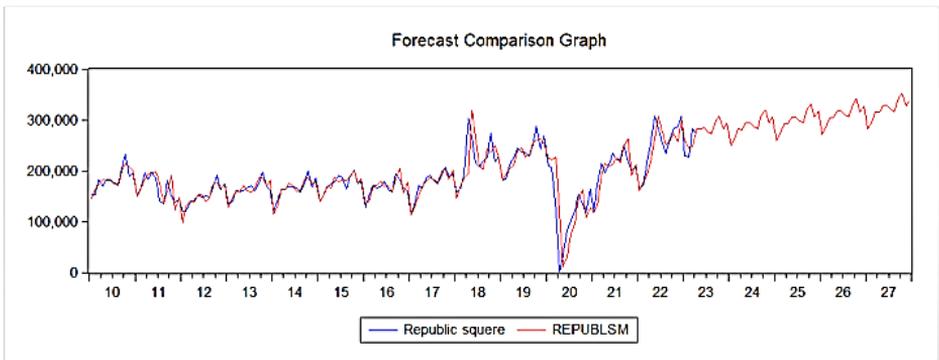
Included observations: 216

Evaluation sample: 2010M01 2027M12

Number of forecasts: 1

Evaluation statistics

Forecast	RMSE	MAE	MAPE	SMAPE	Theil U1	Theil U2
REPUBLSM	22.40422	13.71150	9.552327	9.089121	0.058876	0.692802



Source: Calculated by the authors

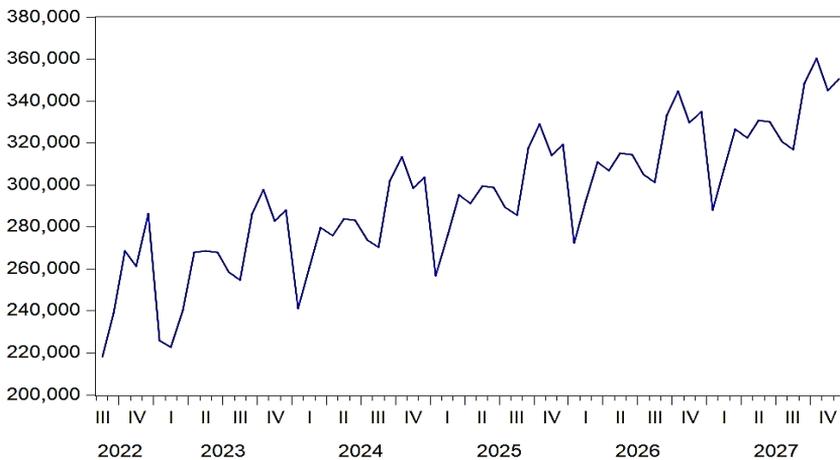
Figure 10. The passenger flow prediction graph for Gortsaranayin and Republic Square stations

From the evaluations of both the Factory Metro Station and the Republic Square Station, we can conclude that the quality of the model is quite high. The

MAPE values of 1.7% and 9.5% for the Republic Square metro station, respectively, indicate that the model has high forecasting accuracy. Their $U_2 < 1$ confirms that the applied model has an information advantage over simple regression methods. The mean square deviation is also small for both metro stations, which once again proves the suitability and advantage of the model compared to other models.

From the analysis of the graphs, we can understand that the forecasted series almost completely follows the actual series; in particular, the seasonal variations correspond to the actual data (monthly recurring pattern), and the trend direction also fully corresponds to the dynamics of the actual data.

Based on the Analog method, we used the passenger flow characteristics of the existing stations (Barekamutyun, Gortsaranayin, and Republic Square) to forecast the passenger flow of the new station (Ajapnyak). The selected stations are comparable to the new station in terms of area, population density, transport role, and demand structure. In particular, Barekamutyun and Gortsaranayin metro stations, as well as the newly constructed Ajapnyak metro station, in addition to being ordinary city stations, also perform the function of intercity inflow. The Republic Square station, being a central station, is also one of the stations providing transit passenger flow. All four stations are public transport hubs, which further justifies the choice of the above-mentioned stations.



Source: Calculated by the authors.

Figure 11. Ajapnyak station’s passenger flow short-term forecasting

Based on the analog method and giving appropriate weights to each of the predicted stations according to importance, you can see the graph of passenger flow dynamics at Ajapnyak metro station in the attached diagram. The graph clearly shows that the passenger flow at Ajapnyak station has a long-term trend of steady growth, reaching about 350–360 thousand passengers by the end of 2027. The predicted time series dynamics of Ajapnyak metro station are consistent with the passenger flow structure of comparable stations of the

Yerevan Metro, which confirms the applicability of the analog method. From the results obtained, we can conclude that Ajapnyak station will become a high-load entry node, playing a significant role in the urban transport system.

CONCLUSION. In addition to being a means of transportation, the metro also has strategic importance. The development of public transport, especially the metro, is considered a primary and sustainable strategy to balance population density and high-intensity traffic demand to ease the traffic network load.

The metro, as a suitable mode of urban transportation, has been expanding dramatically in recent decades and is accepted as the first form of public transportation for most major cities. According to the new plan of Yerevan developed in 1962-1964, the movement of the population by metro was considered the most effective and corresponded to the development perspective of the capital city.

As a result of the observations made in April and May 2023, we found out which part of the traffic from Barekamutyun goes up to Komitas, which part goes to Ajapnyak, and about 60 percent of the traffic goes to Ajapniak.

The new Ajapnyak metro station will connect the given administrative district with the Barekamutyun station and will significantly ease the traffic that is getting worse day by day. The opening of the station will ensure a reliable and jam-free transport connection between the city center, other administrative regions, and the Ajapnyak administrative region. It is also important from the point of view of easing the load on the Davtashen and Kievyan bridges.

By studying the monthly and annual time series of passenger flows of all 10 stations of the Yerevan Metro, we estimated Holt-Winters' additive models to forecast the passenger flow of Barekamutyun, Gortsaranayin, Republic Square, and Ajapnyak stations. Then the passenger flow characteristics of the existing stations (for example Barekamutyun, Gortsaranayin, and Republic Square) were used to forecast the passenger flow of the new station (Ajapnyak). From the results obtained, we can conclude that Ajapnyak station will become a high-load entry node, playing a significant role in the urban transport system.

Analyzing the monthly and annual time series of passenger flows of all 10 stations of the Yerevan Metro, we can conclude that from 2020 to April 2023, passenger flows showed fluctuating growth at all stations, and each period is correlated with its previous one (Coefficient of Correlation is 0,78 on average).

Based on the monthly data of 2022 relatively busy months were May, June, September, October, November and December, when the monthly passenger flow was 2.1 to 2.3 million and the most inactive month was January with 1.3 million passengers. There was more congestion on working days, the congestion on non-working days was also high particularly for Barekamutyun, Garegin Nzhdeh Square, Yeritasardakan and Republic Square stations.

In the last two years, we can see that the increase in passenger flow is evident in all the observed months at all stations of the Yerevan Metro, which is mainly

due to the problems of traffic that are getting worse every year. The number of metro users is increasing year by year, and the development of the metro and the opening of new stations should be one of the primary goals.

The expansion of the metro route is important due to a number of circumstances, in particular, as a result of it, the traffic of the administrative region will be relieved, and the capacity of the roads will increase due to the decrease in the number of alternative public transport options in the given sections. The problem is also relevant from an environmental point of view.

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