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FEATURES OF ECONOMIC DEVELOPMENT OF THE TRANSPORT SYSTEM THE CITY OF ALMATY

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Passenger transport is an important part of urban infrastructure, and economic efficiency is crucial for the functioning of cities. The study uses the methods of multiple linear regression, correlation analysis and dispersion analysis. The aspects of increasing the investment attractiveness of the transport sector are investigated.

The results of the analysis show that the number of subway cars, passenger transportation revenues, CPI and fixed capital investments have a significant impact on passenger transportation revenues in Almaty. The multiple regression model showed a high degree of explanation of data fluctuations. In particular, the following factors were assessed here: the number of passenger buses, trolleybuses, subway cars, transportation tariffs and the amount of investment, etc. Correlation analysis showed that there is an important relationship between the number of passenger vehicles and transportation revenues, the rate of consumer price index, transportation tariffs and the volume of investment in fixed capital.

The purpose of the study is to analyze the economic factors affecting passenger transportation revenues and the level of GRP in Almaty. The regional development program ”Almaty - 2025” is aimed at modernizing the transport infrastructure, improving the quality of services and increasing investment in the transport sector. The data obtained indicate the importance of organizing the transport infrastructure and the level of development of economic factors in generating income. The paper provides recommendations for improving the development of the transport system of the city of Almaty.

Keywords: transport infrastructure, econometric model, passenger transportation, the city of Almaty

ОСОБЕННОСТИ ЭКОНОМИЧЕСКОГО РАЗВИТИЯ ТРАНСПОРТНОЙ СИСТЕМЫ ГОРОДА АЛМАТЫ

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Пассажирский транспорт является важной частью городской инфраструктуры, и экономическая эффективность имеет решающее значение для функционирования городов. В исследовании используются методы множественной линейной регрессии, корреляционного анализа и дисперсионного анализа. Исследуются аспекты повышения инвестиционной привлекательности транспортного сектора.

Результаты анализа показывают, что количество вагонов метрополитена, доходы от пассажирских перевозок, ИПЦ и основные капитальные вложения оказывают значительное влияние на доходы от пассажирских перевозок в Алматы. Модель множественной регрессии показала высокую степень объяснения колебаний данных. В частности, здесь были оценены такие факторы: количество пассажирских автобусов, троллейбусов, вагонов метро, тарифов на перевозки и количество инвестиций и др. Корреляционный анализ показал, что существует важная связь между количеством пассажирских транспортных средств и доходами от перевозок, темпами индекса потребительских цен, тарифами на перевозки и объемом инвестиций в основной капитал.

Целью исследования является анализ экономических факторов, влияющих на доходы от пассажирских перевозок и уровень ВРП в городе Алматы. Региональная программа развития ”Алматы - 2025” направлена на модернизацию транспортной инфраструктуры, повышение качества услуг и увеличение инвестиций в транспортный сектор. Полученные данные свидетельствуют о важности организации транспортной инфраструктуры и уровня развития экономических факторов в получении дохода. В работе приведены рекомендации по совершенствованию развития транспортной системы города Алматы.

Ключевые слова: транспортная инфраструктура, эконометрическая модель, пассажирские перевозки, город Алматы

АЛМАТЫ ҚАЛАСЫНЫҢ КӨЛІК ЖҮЙЕСІНІҢ ЭКОНОМИКАЛЫҚ ДАМУ ЕРЕКШЕЛІКТЕРІ

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Жолаушылар көлігі қалалық инфрақұрылымның маңызды бөлігі болып табылады, ал экономикалық тиімділік қалалардың жұмыс істеуі үшін өте маңызды. Зерттеуде көп сызықтық регрессия, корреляциялық талдау және дисперсияны талдау әдістері қолданылады. Көлік секторының инвестициялық тартымдылығын арттыру аспектілері зерттеледі.

Талдау нәтижелері Алматы қаласындағы жолаушылар кірісіне метро вагондарының саны, жолаушылар кірісі, ТБИ және негізгі капитал салымдары айтарлықтай әсер ететінін көрсетті. Көптік регрессия моделі деректердегі ауытқуларды түсіндірудің жоғары дәрежесін көрсетті. Атап айтқанда, мұнда келесі факторлар бағаланды: жолаушылар автобустарының, троллейбустардың, метро вагондарының саны, тасымалдау тарифтері мен инвестиция көлемі және т.б. Корреляциялық талдау жолаушылар көлігінің саны мен тасымалдаудан түскен кіріс, тұтыну бағаларының индексінің нормасы, тасымалдау тарифтері және негізгі капиталға инвестиция көлемі арасында маңызды байланыс бар екенін көрсетті.

Зерттеудің мақсаты – Алматы қаласындағы жолаушылар тасымалының кірісіне және ЖӨӨ деңгейіне әсер ететін экономикалық факторларды талдау. «Алматы – 2025» өңірлік даму бағдарламасы көлік инфрақұрылымын жаңғыртуға, қызмет көрсету сапасын арттыруға және көлік саласына инвестиция көлемін арттыруға бағытталған. Алынған мәліметтер көлік инфрақұрылымын ұйымдастырудың маңыздылығын және табыс алудағы экономикалық факторлардың даму деңгейін көрсетеді. Жұмыста Алматы қаласының көлік жүйесін дамытуды жақсарту бойынша ұсыныстар берілген.

Түйін сөздер: көлік инфрақұрылымы, эконометрикалық модель, жолаушылар тасымалы, Алматы қаласы

Introduction. The transport system is an integral part of the urban infrastructure, which plays a significant role in ensuring economic and social mobility. This is especially true for megacities such as Almaty, where the efficiency of transport is directly related to the quality of life of the population and the dynamics of socio-economic development. Analysis of the state and development of the transport system is becoming an urgent task due to the rapid growth of the urban population, urbanization and growing demand for transport services.

In addition, according to the ”Concept of Investment Policy of Kazakhstan until 2029” (Resolution of the Government of the Republic of Kazakhstan dated October 18, 2024, No. 868), the transport sector includes important measures to increase investment in: construction of new roads, renewal of freight transport and improvement of the

infrastructure of the transport hub.

Investments in fixed assets and modernization of vehicles are key factors in increasing the economic efficiency of passenger transportation systems. An integral part of this process are public and private investments aimed at developing infrastructure and improving the quality of transport services. The main objective of the study is to determine the factors that have the greatest impact on the revenues received from passenger transportation in Almaty. The study of factors affecting passenger transportation revenues not only identifies the main factors of economic activity in the region, but also provides recommendations for optimizing the city' s transport system. The study is conducted within the framework of the «Strategic Plan of the Almaty Development Program – 2025», which is aimed at modernizing and developing transport infrastructure, improving the quality of services and the efficiency of urban transport systems. The inclusion of initiatives such as updating vehicles, expanding and improving transport routes is part of a long-term plan aimed at improving the quality of life in the city.

In recent years, the transport system of large cities has been actively studied by researchers, since efficient transport infrastructure plays an important role in economic development and quality of life of the population. Many studies are aimed at studying the impact of transport factors on the economic development of cities.

Thus, energy policy in European countries stimulates economical and rational energy consumption, as well as increased energy productivity through the use of innovative and digital technologies. In particular, the work of Gruetzmacher, Vaz, Ferreira (2025) is devoted to the sustainability of transport activities in the EU. Here, scientists have implemented an economic analysis of the transport industry within the framework of applying alternative "Benefit-of-the-Doubt" models [1]. The authors concluded that in order to reduce the negative impacts on harmful emissions from transport, it is necessary to develop a strategy for improving green technologies and implement energy efficiency methods.

At the same time, today the organization and development of underground transport infrastructure "CCS" (Peng et al. 2024) is of significant importance for reducing harmful CO2 emissions. We believe that the use of the "CCS" system will provide an opportunity and incentives for the promotion of environmental monitoring projects and transport infrastructure sensing technology [2]. In addition, such systems will lead to increased transport safety in cities.

An analysis of existing studies on the impact of transport systems on the economic development of cities has shown that this issue is still relevant and multifaceted.

In general, transport infrastructure plays an important role in increasing population mobility, accessibility to markets and quality of life. However, the degree of its impact on the economic development of the city remains uneven. Almaty, as the largest economic center of Kazakhstan, faces a number of problems related to the modernization of the transport system, increasing tariffs and the impact of inflation. These factors not only affect production, but also create general conditions for the socio-economic well-being of the city.

Thus, this article describes the main relationship between the economic indicators of Almaty and revenues from passenger transportation. It is expected that the development of transport infrastructure and increased investment in the transport sector will have a significant impact on the growth of revenues from passenger transportation. To better understand these relationships, multiple correlation analysis was conducted to identify the most important factors affecting the efficiency of the transport sector. Addressing these issues is essential to developing an effective passenger transport management strategy and increasing the economic sustainability of urban transport systems.

Materials and methods. There are many approaches and models that explore the relationship between transport infrastructure and economic performance. However, the question of how the transport system affects the long-term economic

development of the city remains an active topic of discussion in the scientific community.

In a European study, the authors Mamcarz et al. (2023) conducted economic and mathematical modeling on determining the role of public transport in Europe for consumers of these services [3]. Using a survey, the researchers proved that there are both positive and negative results of satisfaction with transport services among 642 respondents. For example, it was found that waiting time and free travel on public transport seem to be a positive factor in the consumption of services.

There are works that reveal the level of influence of different types of transport on travel in cities (Mouratidis et al. 2023). For example, here, using the methodology of quantitative and qualitative assessment of statistical data, it was checked how passengers are satisfied with public transport services in Greek cities. Based on the results obtained, it was found that it is necessary to develop urban transport infrastructure, modernize the pedestrian and road system [4].

Castagna, Lobo, Coppola, Couto (2024) carried out a comparative assessment of the performance of 23 European metro systems using econometric regression based on the Cobb-Douglas production function. The findings demonstrated high efficiency of metro service companies in the short term [5]. This characterizes the achievement of maximum profitability and profit from the operation of subways in the first years. In subsequent years, operating costs for the maintenance of subways increase significantly.

Therefore, given the social significance of the metro, local and state support for this type of transport should be provided. At the beginning of the 21-st century, bus rapid transit (BRT) appears to be the most innovative type of transportation for urban passengers.

However, as Alnsour (2023) notes, the introduction of a new type of ”BRT” presents certain organizational, technical and economic risks [6]. In this regard, the analysis of the questionnaire by A. Alnsour using the SPSS software showed that it is necessary to assess the above risks. For this, already at the initial stage it is necessary to carefully consider the planning process, then at the stage of technical operation and practical implementation of BRT. The results of the modeling revealed the following risks of the transport system: volatility of fuel prices, underdeveloped infrastructure, traffic violations, corruption, etc. Accordingly, for the normal course of BRT activities, it was recommended to consider the noted risk factors.

First of all, we are talking about a constant influx of investments in the development of transport infrastructure and optimization of local management of city routes and bus schedules. The purpose of this study is to analyze the influence of various factors, including types of transport on the level of GRP using the example of Almaty. To study these relationships, correlation analysis and the multiple linear regression method are used, allowing us to assess how various independent variables affect the dependent variable. Statistical tests (t-statistics) were conducted, including regression coefficient analysis to assess the importance of the impact of each independent variable on the poverty level. It is important to note that the significance level of 0.05 is adopted for statistical significance, meaning that if the p-value of a variable is below this threshold, it is considered statistically significant for the model. After analysis using the multiple linear regression method, a model will be created to measure the impact of each factor on the level of GRP.

The regression coefficient reflects the intensity and direction of the relationship between the independent and dependent variables. High coefficients indicate a significant impact on the level of GRP, while *p*-values demonstrate the statistical significance of these relationships. Large standard errors or high p-values may indicate instability or lack of significance of the estimate, which requires careful interpretation of the results. The overall significance of the model and individual predictors is assessed using these statistical tests. The following hypotheses were tested in the study:

Null Hypothesis (H_0): Economic indicators such as fares, consumer price index, and fixed capital investment, as well as the number of passenger buses, trolleybuses, and subway, do not

have a statistically significant effect on passenger transportation revenues in Almaty.

Alternative Hypothesis 1 (*H1*): The number of passenger buses, trolleybuses, and subway has a statistically significant effect on passenger transportation revenues in Almaty.

Alternative Hypothesis 2 (*H2*): Changes in the fare index and CPI significantly affect passenger transportation revenues in Almaty.

Alternative Hypothesis 3 (*H3*): Fixed capital investment plays an important role in increasing passenger transportation revenues in Almaty.

The study examines the following main questions.

1) The role of transport infrastructure in generating revenues. How do the number and type of transport (buses, trolleybuses, metro cars) affect the efficiency of transportation? This clearly shows to what extent the number of transports is a decisive factor in the economic efficiency of transportation.

2) Economic factors affecting revenues. How do the fare index and the consumer price index (CPI) affect revenues from passenger transportation? This issue analyzes how changes in tariff policy and inflation processes affect revenues from transportation.

3) Investments in infrastructure and their impact on the transport economy. How do capital investments, including the modernization of vehicles and the development of infrastructure, affect revenues from passenger transportation? The problem is to assess the effectiveness of public and private investments in the development of the city' s transport sector.

This analysis is based on the longitudinal construction of time series of the study, since it covers changes in indicators over a long period of time (14 years).

Sample. Sample type: secondary data. Number of observations: 140 observations (from 2010 to 2023) for each variable (one for each year).

The econometric model is presented as follows:

$$Y = \beta 0 + X1 * \beta 1 + X2 * \beta 2 + X3 * \beta 3 + X4e * \beta 4 + X5 * \beta 5 + X6 * \beta 6 + X7 * \beta 7 + \epsilon$$

where:

1. *Y*— Gross regional product, million tenge, dependent variable.

2. Independent variables:

X1 — Number of passenger buses, units

X2 — Number of passenger trolleybuses, units

X3 — Number of passenger subway cars

X4 — Revenue from passenger transportation, million tenge

X5 — Indices of transportation tariffs (in %)

X6 — Rates of CPI %

X7 — Investments in fixed capital, in %

3. $\beta 0$ is a constant (intercept).

$\beta 1, \beta 2, \beta 3, \beta 4, \beta 5, \beta 6, \beta 7$ — coefficients for each independent variable, showing the magnitude and direction of their influence on GRP.

4. ϵ — error coefficient.

Expected results: Assessment of the influence of factors: determination of the degree and nature of the influence of independent variables on GRP.

Statistical significance: Identification of statistically significant influencing factors to confirm or refute hypotheses.

Thus, the research methodology offers a comprehensive approach to the analysis of GRP, aimed at identifying the main factors and assessing their impact on the development of effective socio-economic strategies in the Almaty transport system.

Results and discussions. Currently, the world is undergoing an active process of urbanization (Larriva et al. 2023). The growth of the territory and population of cities requires the same pace of construction and new introduction of public transport routes [7]. Larriva et al. (2023) used econometric methodology to determine the level of influence of urban public transport projects on the well-being of different socio-economic groups. Thus, the researchers analyzed the influence of the first metro line on the adoption of rational decisions on planning investments in the development and mobility of transport infrastructure.

The transport system plays a very important role in the economic development of the city. It

directly or indirectly affects various aspects of life, including production, employment, consumption and distribution of goods and services.

Today, there is significant urban sprawl in the world (Giduturi, 2015). For the efficient operation of urban space, the availability of passenger transportation and services is necessary [8]. It is noted that the efficiency of urban planning should be observed in order to ensure the sustainability of urban transport infrastructure.

In the modern world, transport is an important element of infrastructure that contributes not only to the efficient movement of people and goods, but also to economic growth. Almaty, as the largest economic and cultural center of Kazakhstan, has a developed transport system, which includes buses, trolleybuses, metro and other types of transport. In recent years, the load on the transport infrastructure has increased due to the growth of the urban population and increased economic activity. Thus, the efficient operation of the city' s transport system directly affects the economy.

Table 1 - Initial data

Years	Y	X1	X2	X3	X4	X5	X6	X7
	Gross regional product, million tenge	Number of passenger buses, units	Number of passenger trolleybuses, units	Number of passenger subway cars	Revenue from passenger transportation, million tenge	Indices of transportation tariffs (in %)	Rates of CPI %	Investments in fixed capital, in %
2 010,00	3 923 412,6	1 564,00	191,00	0,00	80 000,00	100,20	107,80	100,40
2 011,00	4 860 213,9	1 780,00	113,00	7,00	90 000,00	100,10	107,40	100,60
2 012,00	5 715 879,2	1 580,00	136,00	7,00	110 000,00	128,30	106,00	106,30
2 013,00	7 127 916,4	1 709,00	239,00	7,00	130 000,00	102,50	104,80	102,50
2 014,00	8 143 570,2	1 855,00	212,00	7,00	140 000,00	113,50	107,40	94,80
2 015,00	9 100 006,0	9 327,00	135,00	7,00	160 000,00	153,80	113,60	102,40
2 016,00	10 601 347,8	9 058,00	139,00	7,00	180 000,00	107,80	108,50	104,00
2 017,00	11 893 225,9	8 433,00	160,00	7,00	219 661,50	100,60	107,10	104,80
2 018,00	12 132 649,7	8 315,00	172,00	8,00	257 365,20	110,10	105,30	110,90
2 019,00	13 546 958,4	8 758,00	180,00	9,00	295 068,80	103,00	105,40	108,30
2 020,00	13 459 802,6	2 245,00	196,00	10,00	144 197,10	104,80	107,50	117,90
2 021,00	15 000 060,4	2 058,00	196,00	10,00	306 140,40	113,30	108,40	115,10
2 022,00	19 154 536,7	2 137,00	246,00	11,00	304 877,80	106,60	120,30	112,50
2 023,00	24 895 989,6	2 154,00	296,00	15,00	375 046,20	101,20	120,30	125,20
Note - compiled by the authors based on sources [https://taldau.stat.gov.kz; https://stat.gov.kz]								

This analysis is devoted to identifying and assessing the factors affecting the gross regional product. The study was conducted using multiple regression, using various transport and economic variables to assess the impact of various factors on passenger revenues. Among the included variables are the number of passenger buses, trolleybuses, metro cars, the tariff index for transportation, the consumer price index (CPI) and investment in fixed assets. The main objective of the study is to determine the statistical significance of each factor and their impact on passenger transportation revenues (Table 1).

Analysis of the correlation between various economic and transport indicators will allow us to determine the relationship between them and assess the impact of one indicator on another. In this case, we consider several variables: gross regional product (GRP), the number of passenger

buses, trolleybuses, the number of cars, income from passenger transportation, transportation tariff indices, consumer price index and investment in fixed capital.

Table 2 - Correlation model

Indicators	GRP million tenge	Number of passenger buses	Number of passenger trolleybuses	Number of passenger carriages, meter	Income from transportation of passengers	Indices of tariffs for transportation	Rates CPI %
Number of passenger buses,	0,049						
Number of passenger trolleybuses	0,674	-0,433					
Number of passenger carriages, meter	0,875	-0,051	0,521				
Revenues from passenger transportation	0,918	0,214	0,552	0,774			
Transportation tariff indices	-0,190	0,279	-0,375	-0,066	-0,161		
CPI rates, %	0,711	-0,141	0,538	0,566	0,545	0,113	
Investments in fixed capital	0,847	-0,109	0,530	0,788	0,730	-0,188	0,499
Note - Compiled by the authors							

1. Correlation between GRP and other variables.

GRP shows a strong positive correlation with passenger transportation revenues (R=0.918). This shows that the growth of economic activity in Almaty is closely related to the increase in revenues in the transport sector. GDP has a significant impact on the development of transport infrastructure, especially passenger transportation.

GRP also shows a strong positive correlation with the number of metro passenger cars (R=0.875) and investment in fixed assets (R=0.847). This confirms that economic growth affects the development of infrastructure and the modernization of the transport sector, which contributes to an increase in the number of transport units, especially the metro.

In particular, Yang, Lin (2024) identified the criteria and favorable conditions for the construction of metro stations in cities using the example of the northern regions of China [9]. In order to improve the quality of metro construction, a system of engineering prefabricated and waterproofing structures is proposed. Such innovative engineering technologies of prefabricated metro construction contribute to the growth of quality, productivity and safety for the construction of public metro stations in cities.

2. Correlation between the number of passenger buses, trolleybuses and metro cars.

The number of passenger buses has a weak positive correlation with the number of passenger trolleybuses (R = 0.674), which may indicate that an increase in one mode of transport is associated with an increase in another mode of transport. However, this correlation is not strong enough, indicating differences in the demand and use of these modes of transport.

The number of passenger buses and trolleybuses is negatively correlated with the number of passenger metro cars (R = -0.051 and R = -0.433). This may mean that the increase in the number of buses and trolleybuses is not always related to the increase in the number of metro cars, and may also be related to different passenger needs depending on the type of transport network. Giagnorio, Börjesson, D' Alfonso (2024) examine the degree of electrification of city buses using Stockholm as an example. They found that optimization of fares and pricing policy of the bus fleet has a positive effect on improving the well-being of city residents [10].

3. Fare Index and CPI.

The fare index shows a weak negative correlation with passenger revenue (R = -0.161) and the number of passenger buses (R = -0.190). This suggests that the growth of transport costs may have some negative impact on total passenger revenue and

demand for buses. However, the correlation with the number of buses and trolleybuses remains small (R = -0.141 and R = -0.141), indicating that there is no direct relationship between inflation and the dynamics of the number of vehicles.

4. Fixed Capital Investments.

Fixed capital investments have a strong positive correlation with passenger revenues (R = 0.788) and GRP (R = 0.847), confirming the importance of investment in transport infrastructure for income growth in this sector and contributing to economic development.

Table 3 - Model of coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	-44201719	9183958	-4,81	0,003	
Number of passenger buses,	274	123	2,22	0,068	2,37
Number of passenger trolleybuses	19515	9460	2,06	0,085	3,00
Number of passenger carriages, meter	447799	164063	2,73	0,034	3,78
Revenues from passenger transportation	16,79	6,80	2,47	0,048	5,35
Transportation tariff indices	-36972	23086	-1,60	0,160	1,51
CPI rates, %	272964	76534	3,57	0,012	2,04
Investments in fixed capital	168181	60758	2,77	0,033	3,18
Note - Compiled by the authors					

Thus, the correlation analysis showed that factors such as economic activity (GRP), transport infrastructure (number of passenger cars in the metro) and investment in fixed capital have the greatest impact on passenger transportation revenues in Almaty. These results highlight the importance of an integrated approach to the development of the transport sector, including the modernization of existing facilities and increased investment. On the other hand, tariff policy, although it affects transportation, does not have such a pronounced relationship with passenger transportation revenues, which is confirmed by a negative correlation with a number of variables. The data obtained in the correlation analysis can be used to improve the transport system and optimize tariff policy in Almaty, develop effective strategies to increase profitability and improve the quality of passenger transportation. For example, Hluško, Stanek, Ďurček, Kusendová (2024) determined the location and activity of public transport in Bratislava at different times of the day [11]. Thus, the authors modeled how convenient and accessible it is for certain categories of city residents based on the ”UPTS” transport route. The peculiarity here is that the ”UPTS” route has a high level of occupancy in the morning and evening. This is of particular concern to women, pensioners and children. Next, we will conduct a regression analysis. The regression equation looks like this:

$$Y = -44201719 + 274 \cdot X_1 + 19515 \cdot X_2 + 447799 \cdot X_3 + 16.79 \cdot X_4 - 36972 \cdot X_5 + 272964 \cdot X_6 + 168181 \cdot X_7$$

The results of the regression analysis are presented in Table 3.

Evaluation of the significance of factors.

1) The number of passenger buses (thousand units). The coefficient of the number of buses is 274, which indicates that an increase in the number of buses by 1 thousand units is associated with an increase in passenger transportation revenue by

274 thousand tenge, all other things being equal. Everything else is the same. However, the *p-value* (0.068) is greater than 0.05, so this factor is not statistically significant at the 5% level. The *t-value* (2.22) indicates low statistical significance, which can be significant at the 10% level.

2) The coefficient of the number of trolleybuses is 19.515, which indicates an increase in passenger transportation revenue by 19.515 thousand tenge and an increase in the number of trolleybuses by 1 unit. However, the *p-value* (0.085) is greater than the threshold of 0.05, which indicates that 5% is statistically insignificant. *t-value* (2.06) shows moderate significance of this parameter.

3) The coefficient of the number of metro cars is 447,799, which means that an increase in the number of vehicles by one unit is associated with an increase in passenger transportation revenue by 447,799 thousand tenge. *P-value* (0.034) indicates the statistical significance of this parameter at the 5% level, therefore, it is an important factor affecting transportation revenue.

4) Passenger transportation revenue. The coefficient of passenger transportation revenue is 16.79, which means an increase in revenue by 1 thousand tenge is associated with an increase in transportation revenue by 16.79 thousand tenge. *P-value* (0.048) confirms the statistical significance of this parameter at the 5% level. This indicates that it is important to consider current revenues in the process of forecasting future revenues.

5) Transportation tariff indices. The coefficient for the indices of transportation tariffs is -36.972, which indicates that as tariffs increase, transportation revenues decrease. However, the *blood value* (0.160) significantly exceeds the threshold of 0.05, so this parameter is statistically insignificant at the 5% level.

6) CPI (%). It is a coefficient of 272,964, which indicates that if the CPI increases by 1%, passenger transportation revenues will increase to 272,964 thousand tenge. The *t-value* (3.57) and *p-value* (0.012) confirm the statistical significance of this parameter at the 5% level.

7) Investment in fixed capital. The coefficient of investment in fixed capital is 168,181, which means that transportation revenues increase by 168,181 thousand tenge with an increase in investment by 1 thousand tenge. *T-value* (2.77) and *p-value* (0.033) indicate statistical significance of this parameter is at the level of 5%.

Multicollinearity problem. The *VIF* indicator for most variables is within the acceptable limit (*VIF* <5), indicating a low level of multicollinearity. The exception is the variable ”passenger revenue”. This variable is specified on December 5.35, which may indicate a correlation between these variables.

To assess the quality of the regression model, it is important to consider several basic statistical indicators: standard error (*S*), coefficient of determination (*R-sq*), adjusted coefficient of determination (*R-sq*(adj)) and predicted coefficient of determination (*R-sq*(pred)). These indicators not only assess the accuracy of the model, but also check the ability to generalize to new data (Table 4).

Table 4 - Model

S	R-sq	R-sq(adj)	R-sq(pred)
991709	98,63%	97,03%	89,38%
Note - Compiled by the authors			

Here are the obtained results of the model.

1) The standard error for this model is 991.709. This indicator shows the average deviation from the calculated value of the actual observation. The smaller the value of the standard error, the more accurate the model. In this case, the value is very low, which indicates good quality of the model in terms of forecasting.

2) Determination Ratio (*R-sq*): The decision ratio is 98.63%, which is a very high level of explanation of the variability in the dependent variable model. This means that the model accounts for almost 99% of the total variability in the data. Such high scores indicate good quality of the model. This indicates that the selected variable really affects the dependent variable.

3) The adjusted determination ratio (*R-sq*(adj)) is 97.03%, which is a very effective result. The adjusted decision factor considers the number of independent variables in the model and adjusts the square root of *R-sq* to avoid over-fitting the model. This indicator confirms that the model remains very stable even for possible additional variables.

4) Predicted coefficient of determination (*R-sq*(pred)) its value is 89.38%, which indicates that the model has a high generalization ability with unprecedented new data. This indicator evaluates the degree to which the model can predict the value of the tested sample and is an important indicator confirming the stability of the model in real conditions. A high value of this indicator confirms that the model can not only describe the current data well, but also predict the behavior of the dependent variables in future observations.

Based on the analysis of statistical indicators, it can be concluded that the proposed regression model is very effective for data analysis. High values of the measurement coefficients (*R-sq and R-sq*(adj)) and the predicted decision coefficients *R-sq*(pred) indicate the ability to describe the existing data well and adequately predict the results in new samples. The standard errors in the model also indicate high accuracy. Overall, this model can be considered reliable for use in other studies and practical applications.

Table 5 - Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	7	4,24726E+14	6,06752E+13	61,69	0,000
Number of passenger buses,	1	4,86174E+12	4,86174E+12	4,94	0,068
Number of passenger trolleybuses	1	4,18512E+12	4,18512E+12	4,26	0,085
Number of passenger carriages, meter	1	7,32675E+12	7,32675E+12	7,45	0,034
Revenues from passenger transportation	1	6,00035E+12	6,00035E+12	6,10	0,048
Transportation tariff indices	1	2,52234E+12	2,52234E+12	2,56	0,160
CPI rates, %	1	1,25105E+13	1,25105E+13	12,72	0,012
Investments in fixed capital	1	7,53559E+12	7,53559E+12	7,66	0,033
Error	6	5,90092E+12	9,83487E+11		
Total	13	4,30627E+14			
Note - Compiled by the authors					

To further assess the importance of the influence of various factors on passenger transportation revenues in Almaty, we used the analysis of variance. This method allows us to determine the importance of independent individual variables such as the number of passenger buses, trolleybuses, metro cars, passenger transportation revenues, the transportation tariff index, the consumer price index, and the amount of investment in fixed capital (Table 5).

1. Overall regression effect. The overall F-statistic value for the model is 61.69 and the *p-value* is 0.000, indicating that the overall model is statistically significant. This means that the set of

independent variables significantly affects Almaty' s passenger transportation revenue.

2. The number of passenger buses is one thousand. The F-value for the number of buses is 4.94 and the *p-value* is 0.068, which is slightly higher than the standard significant level of 0.05. This means that the coefficient of the number of buses is positive, but its effect on transportation revenue is statistically insignificant at 5%. However, given the *p-value* of 0.068, the effect of the number of buses can be significant at the 10% level.

3. The number of passenger trolleybuses. The *f-value* for the number of trolleybuses is 4.26 and the *p-value* is 0.08. Furthermore, it is not statistically significant at 5%, but it can be significant at 10%. Therefore, the impact of the number of trolleybuses on transportation revenues should also be the subject of further study.

4. Number of metro cars. The *f-statistic* is -7.45 for the number of metro cars, and the *p-value* is 0.034, which is statistically significant at the 5% level. This confirms that the number of metro cars has a significant impact on passenger transportation revenues in Almaty.

5. Passenger transportation revenues, million tenge. The F coefficient for passenger transportation revenues is 6.10, and the *p-value* is 0.048, which indicates statistical significance of this parameter at the 5% level. This confirms that passenger transportation revenues in the previous period had a significant impact on future revenues.

6. Transportation tariff index. The F-statistic is 2.56, and the *p-value* is 0.160. This value is significantly higher than 0.05 and shows that the fare index is not statistically significant in this model.

7. Consumer Price Index %. The *f-value* for CPI is 12.72 and the *p-value* is 0.012, indicating that the statistical significance of this indicator was confirmed at the 5% level. This shows that changes in the consumer price index have a significant impact on passenger transportation revenues in Almaty.

8. Fixed Capital Investment. The *f-value* for fixed capital investment is 7.66 and the p-value is 0.033, indicating that this parameter is statistically significant at the 5% level. This confirms the importance of investment in transport infrastructure to increase passenger transportation revenues.

Conclusions. Khademi-Vidra, Nemecz, Bakos (2024) conducted a case study on public transport operations in Hungary, Budapest. The authors conducted a survey among passengers using public transport in electronic form [12]. The study found that the following factors influence the growth of the number of passengers: investments in the quality of public transport, cleanliness, innovation, safety, and schedule. These results can allow local authorities to improve the development of urban public transport in the world.

The results of our analysis of variance confirm that the number of metro passenger cars, passenger revenues, consumer price index, and investment in fixed capital have a statistically significant effect on Almaty' s passenger revenues. However, the effect of the number of passenger buses and trolleybuses is less significant, which may be due to their smaller role in the entire transport system of the city during the study. This model is generally important, and its results can be used to develop new political and economic strategies aimed at improving transport infrastructure and increasing passenger revenues.

The study allowed us to conclude that transport infrastructure and macroeconomic factors have a heterogeneous effect on the gross regional product in Almaty. Regression analysis conducted from 2010 to 2023 showed that factors such as the number of passenger buses, trolleybuses and metro cars, consumer price index (CPI), transportation tariffs and investment in fixed assets significantly affect the revenue generated from passenger transportation in Almaty. Transport means such as metro and economic indicators related to tariffs and inflation are the most important for generating transportation revenue, which is confirmed by the high value of regression coefficient and the importance of factors. Multiple linear regression and analysis of variance methods analysis showed that effective management of transport infrastructure and economic factors can significantly improve the profitability of passenger transportation. In particular, improving transport infrastructure and increasing investment in transport

development, i.e. modernizing cars and expanding transport routes, can be important strategies to increase revenue. In addition, existing Almaty city development programs such as the «Almaty Development Program – 2025» are aimed at modernizing transport infrastructure and improving the quality of urban transport. This coincides with the conclusion of the study.

Improving the efficiency of transport systems is directly related to increasing revenues from transportation. According to the city' s strategic documents, transport services should be further improved, and the investment attractiveness of the sector should steadily grow. Thus, in the context of city development and improving the transport system, it is necessary to continue investing in upgrading infrastructure and vehicles to ensure stable growth in passenger transportation revenues in Almaty, and also consider the economic situation, such as the consumer price index and electricity prices. transport fees.

The prospects for the development of the urban transport system in the global economy include the introduction of zero-emission buses (Avenali et al. 2024). For example, Avenali et al. (2024) analyzed the factors affecting the use of zero-emission buses (ZEB) in cities. During the quantitative assessment, negative factors were revealed that lead to the inhibition of the development of "ZEB" [13]. In particular, these include: technological, organizational, managerial and economic factors. And the promotion of institutional, social and environmental indicators - stimulated the introduction of buses (ZEB).

The results of the study emphasize the need for an integrated approach to the development of transport infrastructure and macroeconomic regulation in the city of Almaty. In order to improve the efficiency of the urban transport system, it is recommended to modernize the existing infrastructure, optimize the tariff policy and promote the growth of passenger transportation.

Some experts assess traffic jams in cities that interfere with the normal movement of public transport (Cantos-Sánchez et al. 2011) The authors' recommendations are aimed at the strategic development of road infrastructure and optimization of the schedule of transport modes in cities [14].

In addition, stabilizing inflation and increasing the profitability of the transport sector can further stimulate economic growth. Recently, significant emphasis has been placed on the development of "Green Economy" measures in the world. In this regard, the processes of introducing innovations that reduce emissions into the atmosphere in the organization of public transport are increasing (Stępniak et al. 2023). At the same time, maintaining environmental sustainability in the operation of passenger transport is also supported [15].

It should be noted that future research could focus on studying the nonlinear effects of transport and macroeconomic factors, analyzing the long-term impact of transport investments, and developing multifactor models to more accurately forecast GRP.

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