

Article

The Impact of Transport Infrastructure on Sustainable Economic Development of Russian Regions

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Abstract: This paper examines the impact of transport infrastructure on the economic development of regions, with an emphasis on sustainable development. Econometric models were used for the analysis, including generalized models and models with fixed and random effects. An assessment of factors such as the number of cars and the inflow of foreign direct investment showed their significant positive impact on the GRP per capita. At the same time, the consumer price index and the number of buses showed a negative impact. The best results in considering the specifics of the regions were obtained when using models with fixed effects. The results of the study highlight the key role of transport infrastructure for economic growth and highlight the importance of integrating sustainable development principles into the planning and development of transport systems. Sustainable development requires increasing economic activity and minimizing negative environmental impacts and ensuring social justice. Embedding sustainability principles in transport planning is expected to contribute to the creation of balanced and environmentally friendly infrastructure solutions that will ensure long-term prosperity. The models developed in the study can become the basis for the development of recommendations for improving transport systems aimed at maintaining sustainable economic growth and environmental stability.

Keywords: economic development; regional development; sustainable development; transport infrastructure



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1. Introduction

The sustainable development of the regions of each country is a priority of the country's state policy, which is aimed at achieving long-term economic growth and improving the quality of life of the population [1,2]. However, significant disparities in economic development between regions remain an unresolved issue. While some regions demonstrate stable growth and high living standards, others lag behind due to structural economic weaknesses, insufficient infrastructure, and limited investment opportunities. These disparities hinder overall national economic progress and contribute to increasing socio-economic inequality. Gross regional product (GRP) per capita is an important indicator of economic activity, well-being, and living standards in each region [3]. Despite the widespread use of GRP in economic analysis, the factors that determine its growth in different regions remain a subject of debate. While previous studies have examined the national determinants of economic growth, there is still a gap in understanding how specific regional characteristics—particularly infrastructure and transport development—shape economic performance [4]. Given the significant territorial differences and eco-

economic heterogeneity of the country under study, the study of factors affecting GRP is of particular relevance [5].

One of the key factors determining GRP is the state of the transport infrastructure and the presence of vehicles [6,7]. A well-developed transport network improves access to markets, reduces transport costs, increases labor mobility, and stimulates trade and investment. A large number of private cars indicates a high level of prosperity. The presence of a well-developed public transportation network indicates a high level of social development in the region [8], and the presence of trucks indicates a developed industrial sector [9]. Statistical databases show that regions with more developed transport infrastructure, such as capitals and large industrial cities, have GRP per capita that is higher on average than regions with less developed infrastructure [10]. Conversely, underdeveloped transport infrastructure can hinder economic growth and exacerbate socio-economic disparities between regions [11]. A recent study shows that improving the condition of roads can increase GRP per capita by an average of 2–3% [12].

Econometric models are used for detailed analysis and assessment of the impact of various factors on GRP per capita [13,14]. They quantify the contribution of each factor to the economic development of the region and take into account the complex relationships between the variables. Econometric methods make it possible to work with panel data, which is especially important when studying a large number of regions with different economic characteristics.

The purpose of this study is to construct and analyze various econometric models, such as generalized regression, binary variables, fixed effects, space–time fixed effects, and random effects models. Each of these models has different functions and benefits depending on the data structure and the objectives of the study. It is important to determine which model most effectively explains the variability of GRP per capita, considering the state of the transport infrastructure and the number of vehicles.

The use of econometric models in the study allows not only identification of the key factors affecting economic growth, but also the formation of reasonable recommendations for regional policy aimed at sustainable development and reducing socio-economic imbalances [15].

In order to achieve the research objective, a literature review will be conducted to identify the main factors for modeling; data will be collected and preprocessed; research methods suitable for the research objective will be determined; a comparative analysis of the constructed models will be conducted, and the best quality model will be selected; the selected model will be analyzed; and recommendations for regional development based on the application of the models will be given.

The search for the combination of the keywords “sustainable development” AND “transport infrastructure” in the Dimensions database revealed that the number of articles aimed at researching sustainability from the perspective of transport infrastructure development has been steadily increasing since 2015 (Figure 1). At the same time, the number of articles in 2015 decreased by almost 25,000 compared to 2014. The maximum number of written articles was reached in 2023—212,214 publications.

As the purpose of this study is to model the economic component of sustainable development in the context of the transport industry, the search for the combination of the keywords “sustainable development” AND “transport infrastructure” AND “econometric modelling” was conducted (Figure 2). There are noticeably fewer publications, but there is a growing trend which indicates the growing interest of researchers in the use of econometric modeling methods. In 2014 and 2018, there were bursts of activity, while the maximum number of articles was reached in 2023—17,379 articles.

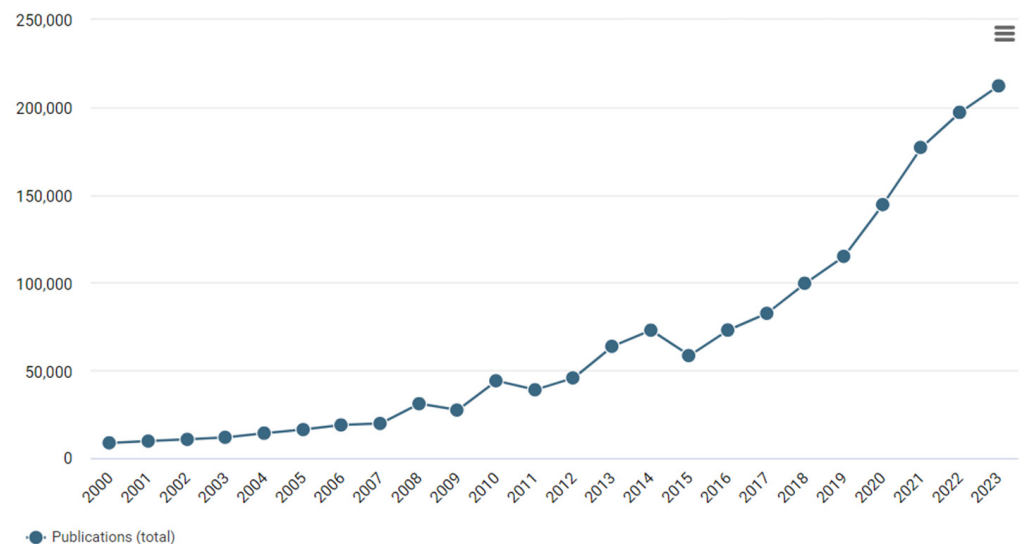


Figure 1. Analysis of the Dimensions database results for ‘sustainable development, transportation infrastructure’, 2000–2023 (Dimensions, 2024).

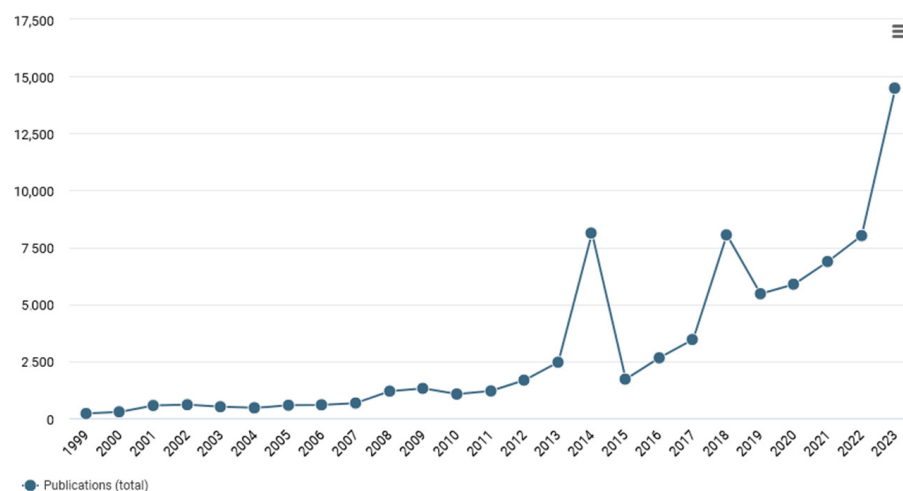


Figure 2. Analysis of the Dimensions database results for ‘sustainable development, transportation infrastructure, econometric modelling’, 1999–2023 (Dimensions, 2024).

2. Literature Review

The analysis of the relevant publications showed that most researchers adhere to the use of classical econometric models for panel data [16]. In this case, the spatial and temporal aspects of the data, as well as the causal relationships between different variables, are taken into account to obtain a more complete picture of the relationships between these factors and the economic growth of the country [17,18]. The set of variables in the models depends on the country of study.

China

Studies that use China as an example focus on investment in transport infrastructure [19,20] and its impact on the country’s total gross domestic product (GDP), as well as the role of the logistics infrastructure in supporting economic development [20,21] and international trade. The mutual influence of transport infrastructure and air pollution is also often considered [22–24]. Deteriorating air quality entails additional costs for environmental protection, which also affects the economic development of regions [25,26].

Southern Africa

On the other hand, studies conducted in southern African countries focus on the importance of air transport and its impact on the economic development of the region [27,28]. These studies highlight the relationship between air travel demand and economic development and consider various factors that influence this relationship, including per capita income, the availability of low-cost carriers, and the geographical characteristics of the region [29].

Europe

In addition to road and air transport, European studies use variables covering different aspects of rail infrastructure to analyze the impact of transport infrastructure on regional growth and economic development [30–32]. In this context, variables such as the length of roads and the railway network, the level of investment in rail transport [13,33], and energy consumption [34], as well as the level of urbanization and the degree of financial development, are the main factors to be analyzed.

The Role of Urbanization in Transport Infrastructure Development

In addition to the above-mentioned factors, urbanization should also be taken into account. The movement of people from rural to urban areas creates new centers of consumption and demand for goods and services, which stimulates economic growth and creates new investment opportunities [35]. Moreover, an increase in the area of urban land (which entails the development of transport infrastructure) and a decrease in the area of agricultural land change the structure of GDP formation and may affect its dynamics [36,37].

Russia as a Unique Case for Study

Many studies on this topic consider European countries, China, and African countries as the subjects of research, but there are few such studies in Russia [38,39]. Transport infrastructure, as well as motorization of the population and cargo road transport, is the most important element in the development of Russia's regions [40,41]. The length of public roads in Russia is about 1.5 million km, and about 50% of them need to be repaired or modernized. In addition, the density of the railway network of 5.1 km per 1000 km² plays a key role in economic development, especially in the regions of Siberia and the Far East. The vast territory of Russia makes it a unique subject of study as a country with the largest area of territory but not the longest length of roads. This is due to the geographical features of the country, which lies in all climatic zones, as well as to the strong differentiation of regions.

While numerous studies analyze the impact of transport infrastructure on economic growth in different regions of the world, existing work lacks a well-organized approach to understanding these relationships in Russia. Given the country's territorial and climatic diversity, research should explore how regional infrastructure differences affect economic performance and should identify key bottlenecks and strategic opportunities for sustainable economic development.

Table 1 shows hypotheses about the effect of independent variables on dependent variables based on the literature review (a table with the results of the literature review is presented in Appendix A).

The following factors (or groups of factors that include a number of similar indicators) were identified as independent variables:

Export is the export volume between regions/countries.

Cargo is the volume of exports between regions/countries.

Population is the population as a whole/individual groups of the population.

Num_transport is the number of vehicles of different types.

Roads is the length of roads/railways.

Invest is the investments in transport infrastructure.

Econ includes indicators of the economic development of the countries of the region.

Table 1. Hypotheses about the direction of the influence of independent variables on dependent variables.

Research (Appendix A)	Y	X						
		Export	Cargo	Population	Num_Transport	Roads	Invest	Econ
[3,5,8,11,13,16,30,33,37]	economic growth	+	+	+	+ / −	+ / −	+	+ / −
[3,18,21,22,26,32,42,43]	GDP	+	+	+	−	−	+	+
[1,15,17,23,36,44]	environmental pollution	−	none	+ / −	+	+	−	−
[6,9,25,34]	trade flows	none	+	+	+	+	none	+
[5,7,11,14,20,24]	transport development	+	+	+	none	+	+	−

+ / − shows the direction of the influence of independent variables on dependent variables.

The factors found in the articles form the basis for the selection of factors to build the models in this study.

3. Materials and Methods

To build the model, data on transport infrastructure and economic indicators for 81 regions of Russia were used. The source of the data is Rosstat and the Unified Interdepartmental Information and Statistical System [44].

Before building the model, preliminary data processing was carried out. This included cleaning up outliers, filling in missing values where appropriate, and converting the data into a format suitable for analysis.

Initially, it was assumed that the time series used would be for the period from 2012 to 2023. However, for some variables, relevant statistics for 2012 and 2023 were missing, which may be due to the fact that data collection was carried out in Q1 2024 and, therefore, not all the statistics for 2023 were published.

In order to improve the correctness and generalizability of the results of this study, Moscow, St. Petersburg, and Chukotka Autonomous Okrug were excluded from the sample. This decision was made on the basis of both statistical considerations and analysis of the specifics of these territories, which differ significantly from the majority of the subjects of the Russian Federation in a number of key characteristics.

Moscow and St. Petersburg, being the largest centers of economic activity, demonstrate significantly overestimated values of most macroeconomic and infrastructural indicators. For example, in 2022, gross regional product in Moscow amounted to about RUB 34.7 trillion, and in St. Petersburg—about RUB 6.5 trillion, while the median value for the other regions does not exceed RUB 1.2 trillion. The density of the railroad network and investment per capita in these cities is many times higher than in most of the subjects, which leads to significant statistical distortions when including them in the aggregate analysis. Such observations act as outliers that can shift the center of distribution and significantly increase dispersion, thus reducing the accuracy of model estimates and limiting their applicability to the analysis of typical regions.

As for the Chukotka Autonomous Okrug, its exclusion is due to the opposite reasons. The region is characterized by extremely low population density (less than 0.07 people/km²), minimal transport connectivity (less than 300 km of paved roads for the entire entity), and specific conditions of economic activity that have no analogues in other parts of the country. In addition, Chukotka is characterized by significant lacunas in official statistics and insufficient completeness of time series, which makes it difficult to conduct a reliable analysis.

The refusal to include these regions in the study is in line with the practice used in a number of other scientific works, where large agglomerations and atypical entities are also excluded in order to ensure homogeneity of data and increase the reliability

of conclusions [45,46]. Thus, we are not talking about arbitrary selection, but about a methodologically balanced approach aimed at forming a stable and analytically manageable sample reflecting the characteristics of the bulk of Russian regions.

Thus, the dataset comprises panel data for the period from 2013 to 2021, including 702 observations.

To assess the economic development of the regions of Russia, it is appropriate to use GRP per capita as a dependent variable, as the researchers did in articles [3,18,21,22,26,32,42,43] (Appendix A). Independent variables indicate the degree of development of transport infrastructure, as well as the level of demand for industrial and consumer goods. The choice of indicators is justified by a review of the literature. The list of variables is presented in Table 2. References in parentheses are to the studies in Appendix A, where the same factors were applied in the modeling.

Table 2. Model specification.

Name of the Factor	Factor Code	Units
Endogenous variable		
GRP per capita	grp	Rubles
Exogenous variable		
Cargo turnover by road transport [34]	cargo	thousand tonne-kilometres
Exports among regions [25]	export	million USD
Population [6]	population	people
Number of buses [26,28,42]	bus	units/1000 persons
Number of trucks [26,28,42]	lorry	units/1000 persons
Number of cars [26,28,42]	car	units/1000 persons
Length of roads [33]	roads	km
Investments in fixed capital [3,21,26]	dir_inv	million rub./capita
Consumer price index [26]	CPI	%
Control variables		
Provision of retail space	shop	unit/1000 people
Land area allocated for industrial enterprises	S_industry	m ² /1000 people
Land used for transportation, communication, and engineering communications	S_transport	m ² /1000 people

Statistical methods and data modeling were used to analyze the impact of transport infrastructure on GRP per capita.

At the first stage, descriptive statistics and a correlation matrix were used to analyze the primary data. Descriptive statistics provide an overview of the nature and distribution of data, while a correlation matrix reveals relationships between variables.

Next, GRP per capita was modeled. It is based on the use of panel data and conventional least squares (OLS) methods. In addition, regression models were applied, such as generalized OLS, dummy variables, and fixed and random effects models. Modeling was carried out in two iterations—based on initial and logarithmic data. The logarithm was used to reduce the impact of outliers and bring the data closer to a normal distribution.

Pooled OLS (generalized OLS) can be used to estimate the parametric of regression in a data pool of all observations. It treats all observations as one group with no differences between them. However, this assumption may be problematic if the economic development of regions is influenced by uncontrolled individual characteristics. In addition, estimates of the regression coefficients of the pooled OLS model may be biased in the presence of endogeneity arising from the correlation of explanatory variables with an error term due to omitted factors, simultaneity, or measurement errors.

The OLS finds coefficient values that minimize the sum of squares of the differences between the observed values of the dependent variable and the predicted values calculated using the model.

Each coefficient in the pooled OLS model is interpreted as the change in the average value of the dependent variable when the corresponding independent variable changes by one unit, thereby assuming that the other variables remain constant. The regression equation is presented in Formula (1), given below.

$$\begin{aligned} \ln grp_i = & \beta_0 + \beta_1 * \ln cargo_i + \beta_2 * \ln export_i + \beta_3 * \ln population_i + \beta_4 * \ln bus_i \\ & + \beta_5 * \ln lorry_i + \beta_6 * \ln car_i + \beta_7 * \ln roads_i + \beta_8 * \ln dir_{inv_i} \\ & + \beta_9 * \ln shop_i + \beta_{10} * \ln CPI_i + \beta_{11} * \ln S_{industry_i} + \beta_{12} * \ln S_{transport-I} + \varepsilon_i. \end{aligned} \quad (1)$$

The pooled OLS model with dummy variables implies the inclusion of binary variables in the generalized MNC model. Binary variables characterize unobserved fixed effects (Formula (2)).

$$\begin{aligned} \ln grp_i = & \beta_0 + \beta_1 * \ln cargo_i + \beta_2 * \ln export_i + \beta_3 * \ln population_i + \\ & \beta_4 * \ln bus_i + \\ & \beta_5 * \ln lorry_i + \beta_6 * \ln car_i + \beta_7 * \ln roads_i + \beta_8 * \ln dir_{inv_i} \\ & + \beta_9 * \ln shop_i + \beta_{10} * \ln CPI_i + \beta_{11} * \ln S_{industry_i} + \beta_{12} * \ln S_{transport_i} \\ & + \alpha_1 * D_1 + \alpha_2 * D_2 + \dots + \alpha_k * D_k + \varepsilon_i. \end{aligned} \quad (2)$$

Space fixed effects models and space and time fixed effects models take into account the fixed characteristics of regions and/or periods that may affect the dependent variable.

$$\begin{aligned} \ln gr_{it} = & \beta_0 + \beta_1 * \ln cargo_{it} + \beta_2 * \ln export_{it} + \beta_3 * \ln population_{it} + \\ & + \beta_4 * \ln bus_{it} + \beta_5 * \ln lorry_{it} + \beta_6 * \ln car_{it} + \beta_7 * \ln roads_{it} + \beta_8 * \ln dir_{inv_{it}} + \\ & + \beta_9 * \ln shop_{it} + \beta_{10} * \ln CPI_{it} + \beta_{11} * \ln S_{industry_{iT}} \\ & + \beta_{12} * \ln S_{transport_{iT}} + \alpha_i + \varepsilon_{it}. \end{aligned} \quad (3)$$

When unobserved effects are not correlated with the regressor, the model takes the form of a random effects model (pooled OLS with random effects). This method accounts for random variation in the dependent variable, which may be specific to each region.

$$\begin{aligned} \ln gr_{it} = & \beta_0 + \beta_1 * \ln cargo_{it} + \beta_2 * \ln export_{it} + \beta_3 * \ln population_{it} + \\ & + \beta_4 * \ln bus_{it} + \beta_5 * \ln lorry_{it} + \beta_6 * \ln car_{it} + \beta_7 * \ln roads_{it} + \beta_8 * \ln dir_{inv_{it}} + \\ & + \beta_9 * \ln shop_{it} + \beta_{10} * \ln CPI_{it} + \beta_{11} * \ln S_{industry_{iT}} \\ & + \beta_{12} * \ln S_{transport_{iT}} + \alpha_i + \varepsilon_{it}. \end{aligned} \quad (4)$$

Furthermore, a partial residual plot (CCPR plot) is used to estimate the effect of each predictor on the dependent variable when the other predictors are fixed. It enables the estimation of how much of the variability in the dependent variable can be explained by each of the independent variables and helps to identify how linear the relationships among the variables are.

In addition, a scatter plot of residuals and predicted values is constructed to assess the homoscedasticity of the model and estimate outliers, and a scatter plot of predicted and raw Y values is constructed to assess the quality of the predictions.

In order to improve the reliability and validity of the econometric estimates, a number of tests were carried out to identify potential problems in the constructed models. In particular, the variance inflation factor (VIF) was calculated to check for multicollinearity between explanatory variables. In cases when its values turned out to be excessively high, this signaled a possible correlation between independent variables, which required additional analysis and possible changes in the model structure, including transformation or exclusion of some variables.

The Goldfeld–Quandt test was used to assess the homogeneity of the variance of the residuals, and the Durbin–Watson test was used to analyze autocorrelation. In addition, the normality of the distribution of the residuals was checked using the Jarque–Bera test, which is particularly important when using methods that are sensitive to the deviation of distributions from normal.

Despite the desire to maximize the correctness of the estimates, it should be noted that the problem of endogeneity is not completely eliminated in this analysis. There is a risk of bias associated with possible omitted variable bias and interdependence between explanatory and explanatory variables. In particular, transportation infrastructure can be both a factor influencing sustainable development and a result of the already existing level of development of the region, which creates a threat of two-way causality. Although potential sources of endogeneity are recognized in the limitations section, the main analytical framework does not implement an instrumental variable or other methodological strategy to correct for this distortion.

The application of the instrumental approach to eliminate the endogeneity problem, although theoretically justified, faces a number of significant methodological and empirical difficulties in the context of this study. First, the choice of reliable and valid instruments at the level of Russian regions is extremely difficult: potential variables that meet the conditions of correlation with the endogenous variable (transport infrastructure) and uncorrelatedness with the regression error are either not available in open sources or are characterized by unstable dynamics and insufficient variability. Second, institutional and spatial differences between regions significantly complicate the search for a universal tool suitable for the entire set of RF subjects. Third, the use of tools related to historical heritage or geographical features, as it is practiced in a number of international studies, in the Russian context faces limitations related to the weak specification of models and a high level of multicollinearity [47].

This circumstance should be taken into account when interpreting the results obtained: they describe predominantly associative rather than strictly causal relationships between variables.

Comprehensive verification and subsequent adjustment of the models allowed us to significantly improve the quality of econometric analysis. The performed diagnostics guarantees that the obtained dependencies between the transport infrastructure and economic development of Russian regions are statistically valid. This approach reduces the risk of biased or unstable estimates caused by internal model problems, including multicollinearity, heteroscedasticity, and endogeneity, and thus strengthens the reliability of the obtained conclusions.

4. Results

A correlation matrix was constructed as part of the statistical analysis.

It was constructed from the logarithmic data (Table 3).

There is a correlation of 0.88 between the regressors ‘Land area allocated for industrial enterprises’ and ‘Land of transportation, communication, engineering communications’. Both these indicators cannot be used. The indicator ‘Area of land allocated for industrial enterprises’ (‘S_industry’) was retained for further analysis. This indicator will enable the industrial development of the region to be taken into account.

Table 3. The correlation matrix.

	Export	Cargo	Grp	Bus	Lorry	Car	Roads	Dir_Inv	Shop	CPI	S_Industry	S_Transport
export	1.00											
cargo	0.49	1.00										
grp	0.40	0.37	1.00									
bus	−0.19	−0.19	0.09	1.00								
lorry	−0.04	−0.01	0.36	0.59	1.00							
car	0.18	0.29	0.53	0.30	0.58	1.00						
roads	0.35	0.57	−0.06	−0.22	−0.18	−0.05	1.00					
dir_inv	0.30	0.25	0.86	0.15	0.32	0.36	−0.12	1.00				
shop	0.28	0.45	0.29	−0.18	0.02	0.35	0.29	0.11	1.00			
CPI	0.06	−0.04	−0.18	−0.13	−0.12	−0.18	−0.00	−0.13	−0.10	1.00		
S_industry	0.54	0.62	0.37	−0.20	−0.13	0.26	0.59	0.27	0.26	−0.00	1.00	
S_transport	0.55	0.61	0.36	−0.15	−0.07	0.22	0.54	0.26	0.26	0.01	0.88	1.00

The results of the simulation are presented in Table 4—generalized regression (column 1); the model with binary variables (column 2); the model with fixed effects (column 3); the model with space and time fixed effects (column 4); and the model with random effects (column 5).

Table 4. Summary of modeling results.

Variables and Model Parameters	Model	Pooled Regression	LSDV Models	FE Model (Panel)	FE Model (Panel + Year)	RE Model
Export		0.0254 ***	0.0131 ***	0.0131 ***	0.0071 ***	0.0254 ***
		(0.0050)	(0.0045)	(0.0045)	(0.0023)	(0.0050)
Cargo		0.0103 **	0.0307 ***	0.0307 ***	0.0084 **	0.0103 **
		(0.0052)	(0.0077)	(0.0077)	(0.0039)	(0.0052)
Bus		−0.1081 ***	−0.4821 ***	−0.4821 ***	0.0501	−0.1081 ***
		(0.0290)	(0.0578)	(0.0578)	(0.0321)	(0.0290)
Lorry		0.1449 ***	0.1699 ***	0.1699 ***	0.0147	0.1449 ***
		(0.0373)	(0.0616)	(0.0616)	(0.0312)	(0.0373)
Car		0.2691 ***	0.6858 ***	0.6858 ***	−0.0746 *	0.2691 ***
		(0.0479)	(0.0794)	(0.0794)	(0.0442)	(0.0479)
Dir_inv		0.6291 ***	0.3383 ***	0.3383 ***	0.1156 ***	0.6291 ***
		(0.0174)	(0.0265)	(0.0265)	(0.0151)	(0.0174)
Roads		−0.0857 ***	0.2626 ***	0.2626 ***	−0.0492 *	−0.0857 ***
		(0.0157)	(0.0515)	(0.0515)	(0.0281)	(0.0157)
Shops		0.0796 ***	0.2185 ***	0.2185 ***	−0.0181	0.0796 ***
		(0.0134)	(0.0197)	(0.0197)	(0.0114)	(0.0134)
S_industry		0.0580 ***	0.0742	0.0742	0.0159	0.0580 ***
		(0.0131)	(0.0833)	(0.0833)	(0.0420)	(0.0131)
CPI		−0.8892 ***	−0.5887 ***	−0.5887 ***	−0.6160**	−0.8892 ***
		(0.2364)	(0.1556)	(0.1556)	(0.2815)	(0.2364)

Table 4. Cont.

Variables and Model Parameters	Model	Pooled Regression	LSDV Models	FE Model (Panel)	FE Model (Panel + Year)	RE Model
Model parameters						
R-squared		0.8397	0.9435	0.7249	0.1787	0.8397
R-Squared (Within)		0.5516	0.7249	0.7249	0.1073	0.5516
R-Squared (Between)		0.9142	1.0000	−0.0379	0.2772	0.9142
R-Squared (Overall)		0.8397	0.9435	0.1188	0.2423	0.8397
F-statistic		361.90	117.80	161.78	13.187	361.90
p-value (F-stat)		0.0000	0.0000	0.0000	0.0000	0.0000

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

It is evident that not all the variables defined at the beginning of the study are included in the models. After the first iteration of model building, it was realized that a few variables had low significance (very high p -value); therefore, their use in the model is inappropriate—they explain a rather small part of the variance (or do not explain it at all) but make the model more cumbersome.

The remaining independent variables have a high level of significance—most are significant at the 1% level. The overall p -value for all the models is less than 0.05. This suggests that there is a statistically significant relationship among the remaining variables, which implies that the independent variables make a significant contribution to the explanation of the variability of the dependent variable. From the perspective of theory, a small p -value indicates that the null hypothesis that the coefficients of the independent variables are equal to zero is rejected.

The difference in the values of the coefficient of determination in the presented models is explained by their different specifications and the approaches to accounting for the heterogeneity of the data. Pooled regression shows a high level of explained variance of the dependent variable with $R^2 = 0.8364$, which at first glance indicates a high predictive ability of the model. However, such a model does not take into account the individual features of the regions, assuming that all observations obey a single pattern. This leads to an overestimation of the coefficient of determination, since the model uses one general dependence for the whole sample without dividing it into groups.

The addition of dummy variables in the LSDV (least squares dummy variable) model reduces R^2 to 0.7249, as the inclusion of binary variables redistributes some of the explained variance. Nevertheless, this specification allows us to account for individual differences between regions, which makes the model results more interpretable and statistically sound.

The fixed effects model (FE model) shows a value of $R^2 = 0.77249$, which is slightly lower than in the pooled regression but higher than in the LSDV. This decrease is explained by the fact that fixed effects remove the influence of unmeasured characteristics of regions by excluding them from the total variance. As a result, the model becomes more accurate in terms of accounting for individual differences, but the formal value of R^2 is reduced because some of the variation is now interpreted as fixed differences between regions rather than explained by the included independent variables.

The inclusion of time effects (FE model with space and time fixed effects) leads to a significant decrease in the coefficient of determination to 0.1073. This is due to the fact that time effects can absorb a significant part of the variation in the dependent variable, leaving a smaller share explained by classical factors. If temporal fluctuations have a weak influence, taking them into account may formally worsen the R^2 indicator, although the model itself becomes more reasonable from the point of view of dynamic processes.

The random effects model (RE model) demonstrates an average level of explanatory power with $R^2 = 0.5516$. Unlike the fixed effects model, it does not eliminate the possible correlation of individual characteristics with independent variables, which leads to less accurate coefficient estimates. As a result, much of the variance remains unexplained, which reduces the R^2 .

Thus, the difference in the values of the coefficient of determination is explained by the peculiarities of each model: pooled regression overestimates the coefficient by ignoring regional differences; fixed effects models reduce it but make the estimates more accurate, and the inclusion of time effects further reduces R^2 if time variation is weakly related to the dependent variable. Therefore, when selecting a model, the coefficient of determination should not be considered as the only quality criterion: it is important to consider the economic sense of the obtained estimates and their interpretability in the context of the processes under study.

In the course of the analysis, panel regression models were used, including those with fixed effects and time indicators, which made it possible to partially account for differences between regions and to trace the dynamics of changes over time. Nevertheless, these models are based on the assumption that the impact of transport infrastructure on the sustainable economic development of all the subjects is uniform, which may limit the accuracy of the interpretation of the results. Given the high degree of differentiation of Russian regions by a number of socio-economic and spatial characteristics, in the future it seems advisable to use methods that allow the heterogeneity of influence to be taken into account, such as models with varying coefficients or approaches that involve the preliminary division of regions into clusters with subsequent assessment of the influence within these groups.

For further discussion and comparison of the results with the hypotheses and analogous studies of the authors, whose articles are reviewed in the 'Literature Review' Section, it is necessary to select the model that is most suitable for modeling GRP per capita as an indicator of the economic potential of the sustainable development of Russian regions in terms of the development of transport infrastructure. Furthermore, it is necessary to take into account both the context of the research—a large number of studied regions and their heterogeneity—and the resulting econometric estimates of the models.

Since the number of regions is large and they are characterized by heterogeneity, a random effects model should be the most preferred and appropriate model. When the number of clusters is large, a random effects model allows for the random nature of interregional differences and provides the opportunity to draw conclusions for the entire population of regions, not only those included in the sample.

However, if there is an assumption that the unique characteristics of each region (particularly geographic, economic, or infrastructure features) significantly affect the dependent variable and these effects need to be accounted for as fixed effects, then it would be better to use:

- A model with space and time fixed effects if both regional and time effects are important.
- A space fixed effects model if time effects are not so important.

The LSDV model is also used to account for individual effects in panel data. However, this model—unlike the fixed effects model—adds dummy variables for each region, which in the case under consideration (81 regions are studied in the paper) significantly loads the model.

As mentioned above, the model with fixed effects of space and time shows significantly lower results of model quality assessment. Given the wide geography of Russian regions, the space factor will be more important than the time factor. Thus, from among all the

constructed models with fixed effects, the model with fixed effects of space will be the most appropriate to select.

In this study, a Hausman test was conducted to choose between a fixed effects model (FE) and a random effects model (RE) when analyzing panel data. This test determines whether there is a correlation between individual effects and independent variables, which is a key factor in choosing an econometric model.

The fixed effects (FE) model is based on the assumption that individual effects (i.e., unmeasured characteristics of the observed objects) can be related to independent variables. In contrast, the random effects (RE) model assumes that individual effects are random and not correlated with explanatory variables. If this condition is met, the RE model is preferable because it provides more accurate and efficient estimates.

The Hausman test tests whether the coefficient estimates in the two models differ significantly by formulating the following hypotheses:

The null hypothesis (H_0): individual effects are independent of the independent variables and, therefore, the random effects model estimates are valid. In this case, the application of the RE model is justified.

Alternative hypothesis (H_1): individual effects are correlated with independent variables, making the random effects model invalid and the fixed effects model favored.

The Hausman test resulted in a statistical value of 909.1 with 11 degrees of freedom. A significance level of 0.05 is used for decision making. Since the p -value obtained was found to be small (significantly less than 0.05), the null hypothesis was rejected. This indicates that there is a statistically significant correlation between individual effects and independent variables, which makes the use of the random effects model incorrect.

Hence, based on the Hausman test, the fixed effects (FE) model should be favored. This confirms the need to take into account the individual characteristics of the observed objects, as their influence is not random and can distort the results in the case of using the random effects model. The choice of the fixed effects model allows us to obtain more reliable estimates and avoid bias, which is critical for subsequent econometric analyses.

5. Discussion

The study yielded an equation with re-regression coefficients. Since the model was built based on logarithmic data, the coefficients in front of the variables—considering the sign—can be interpreted as the percentage of the change in Y .

For the “Exports” variable, the coefficient is 0.0131, which indicates an increase in grp of 0.013%, with an increase in export volume of 1%. This result is significant at the level of 0.1% ($p < 0.001$), which confirms the existence of a close and positive relationship between foreign trade and the economic development of the region. An increase in export flows contributes to the growth of production activity and foreign economic relations, which, in turn, has a positive impact on the economy.

The coefficient for the “Cargo” variable is 0.0307, which means that an increase in the volume of cargo transported of 1% leads to an increase in grp of 0.031%. The result has a statistical significance of 0.1% ($p < 0.001$), which indicates a significant role of freight transportation in stimulating economic growth. This factor may be due to the growth in transport activity, an increase in trade turnover, and the improvement of infrastructure for freight transportation.

For the “Buses” variable, the coefficient is -0.4821 , which indicates a negative relationship: an increase in the number of buses of 1% is associated with a decrease in grp of 0.48%. The significance level is 0.1% ($p < 0.001$), which indicates a statistically significant negative impact of this variable on economic growth. Such an effect can be caused by the congestion of transport infrastructure, which leads to a decrease in the efficiency of economic activity.

The coefficient for the “Trucks” variable is 0.1699, which means an increase in grp of 0.17%, with an increase in the number of trucks of 1%. This result also has a significance level of 0.1% ($p < 0.001$), which confirms the positive impact of the increase in the number of trucks on economic activity. The growth in the number of trucks is associated with an increase in the production and delivery of goods, which contributes to the improvement of the conditions for economic growth.

For the Passenger Cars variable, the ratio is 0.6858, which indicates a 0.69% increase in grp with a 1% increase in the number of passenger cars. The result is significant at the level of 0.1% ($p < 0.001$), which demonstrates a strong impact of the growth of personal consumption and mobility of the population on the economic development of the region. An increase in the number of passenger cars contributes to improved transport accessibility and increased mobility and consumer activity.

The ratio for the Direct Investment variable is 0.3383, which means that a 1% increase in direct investment leads to a 0.34% increase in grp. This result has a statistical significance of 0.1% ($p < 0.001$), which emphasizes the importance of foreign direct and domestic investment as factors stimulating economic growth. Direct investment contributes to the modernization of productive potential and the creation of jobs.

For the “Road length” variable, the coefficient is 0.2626, which indicates that an increase in the length of roads of 1% leads to an increase in grp of 0.26%. This result has a significance level of 0.1% ($p < 0.001$), which emphasizes the role of infrastructure investments in the development of the transport system as an important factor in the growth of the region’s economy. The development of the road network contributes to improving connectivity between regions and optimizing transport processes.

The coefficient for the “Stores” variable is 0.2185, which means that a 1% increase in the number of stores leads to a 0.22% increase in grp. This result has a significance level of 0.1% ($p < 0.001$), which confirms the relationship between retail development and economic activity. An increase in the number of outlets stimulates consumer demand and contributes to the growth of economic indicators.

The Industrial Production indicator has a coefficient of 0.0742, which does not reach statistical significance, which indicates that there is no strong relationship between this factor and the growth of grp. This result confirms that within the framework of this analysis, industrial production does not have a significant impact on the dynamics of the gross regional product.

Finally, for the Consumer Price Index variable, the coefficient is -0.5887 , which indicates that a 1% increase in the CPI leads to a 0.59% decrease in grp. This result is statistically significant at 0.1% ($p < 0.001$), which confirms the strong negative impact of inflation on the region’s economic activity. Rising prices lead to a decrease in the purchasing power of the population and, as a result, to a weakening of economic activity.

Table 5 compares the obtained results with similar results from other researchers.

Table 5. Comparison of study results.

X	Y = GDP	Y = Economic Growth	This Study
export	+	+	+
cargo	+	+	+
num_transport	—	+ / —	+ / —
roads	—	+ / —	+
invest	+	+	+
econ	+ / —	+ / —	—

+ / — shows the direction of the influence of independent variables on dependent variables.

Based on the table, we can conclude that most of the results are similar to those discussed in the literature review and are also consistent with the hypotheses posed.

With regard to the number of different types of transportation, as in this study, there is no unambiguously positive indicator of the coefficient in a number of works. This may be due to the fact that the impact of transportation on GRP per capita depends on various factors, such as infrastructure, the level of development of regional markets, and other economic and socio-cultural aspects [19,28,36].

The opposite results for the indicator ‘length of roads’ are interesting. In a number of studies, the length of roads has a negative impact on GRP per capita, while in this study the impact is positive [33,35]. This may be primarily due to differences in the context of the study. This study considers that investment in road infrastructure can contribute to economic growth. Thus, the positive impact of road length on per capita income can be explained by the fact that better road infrastructure makes access to markets more convenient and reduces the cost of transporting goods.

The studies reviewed in the Literature Review Section that evaluated the long-run impact of transportation infrastructure investments (and units of transportation infrastructure) obtained similar results—in the long run, the impact is positive [33,35]. However, when assessing the impact in the short term, the results may vary from region to region [19,20,30].

To increase the economic growth and efficiency of the region’s transport system, it is necessary to implement a set of measures aimed at stimulating key development factors.

First, support for export activities should be strengthened. For this purpose, it is important to create favorable conditions for exporters by providing them with tax benefits, subsidies, and access to government support programs. An essential role in this process is played by the development of transport and logistics infrastructure, which will reduce the cost of the transportation of goods and increase their competitiveness in international markets. The development of specialized export clusters and international trade routes will help increase foreign trade turnover.

An equally important task is to improve freight transportation, as its growth is directly related to the intensification of industrial production. It is necessary to invest in the modernization of transport highways and the creation of modern logistics centers and automated systems for managing cargo flows. It is also recommended to develop public–private partnerships, attracting businesses to finance transportation projects. The introduction of digital technologies in logistics will make it possible to increase the speed of cargo processing and optimize transportation routes.

The optimization of public transport also requires attention, as its overdevelopment may provoke congestion of the transport infrastructure, reducing its efficiency. It is important to implement integrated transportation strategies to improve accessibility and reduce congestion. At the same time, priority should be given to environmentally friendly modes of transportation, such as electric buses and new-generation streetcars, which can reduce costs and the negative impact on the economy.

In addition, the development of freight transportation should be supported, as its growth indicates an increase in production activity in the region. In this direction, it is advisable to develop multimodal logistics hubs that ensure efficient interaction between different modes of transportation. The introduction of tax preferences for transportation companies engaged in freight transportation may become an additional incentive for their expansion.

A key element of transportation policy should be the development of road infrastructure. Investments in the construction and modernization of roads will not only reduce transportation costs but also increase the territorial connectivity of regions. The introduc-

tion of intelligent transport systems that allow real-time monitoring of road traffic will help minimize congestion and improve road safety.

In addition, attracting direct investment is important. For this purpose, it is necessary to create a favorable investment climate by reducing administrative barriers and providing guarantees of capital protection. Increased investment in industry and infrastructure will lead to employment growth and increase the technological level of enterprises, which will have a positive impact on the economic development of the region.

The growth of the consumer sector also has a significant impact on the economy. The development of the retail trade and store networks contributes to the increase in consumer activity, which in turn leads to the growth of gross regional product. To support this area, it is necessary to improve the transport accessibility of shopping areas and introduce modern technologies in retail, including automated sales systems.

We should not forget about the factors that can slow down economic growth. In particular, rising inflation has a restraining effect on the purchasing power of the population and business activity. To minimize the negative effect, it is necessary to control the inflation rate by conducting a competent monetary policy. It is also advisable to introduce mechanisms of social support, including indexation of citizens' incomes and reduction in the tax burden on producers of key goods.

Thus, the implementation of the proposed measures will make it possible to form a balanced strategy of socio-economic development of the region, improve the efficiency of its transport system, and create conditions for sustainable economic growth.

6. Conclusions

In this study, we constructed and analyzed five different regression models to explain GRP per capita. The FE model (panel) was selected as the most preferable model for analysis, which is confirmed by econometric estimations of the model as well as by the Hausman test. This model most effectively considers the individual characteristics of each region, which is important in the context of the study of the transport infrastructure in Russia. The regression coefficients indicated a significant impact of variables such as the number of passenger cars and foreign direct investment on the GRP. Simultaneously, the consumer price index and the number of buses have a negative impact on the GRP. The remaining independent variables were found to have a high level of significance, which confirmed their contribution to the explanation of GRP variability. Thus, the analysis enabled us to identify the key factors affecting the economic growth of Russian regions and to determine their relative importance.

This study focuses on the economic aspect of sustainable development, which is viewed through the lens of transport development. Environmental and social factors were not included in the main analysis, which indeed limits the completeness of the picture. However, this approach was chosen consciously, as the aim of the work was to study in detail the economic mechanisms affecting the development of the transport system and its sustainability.

At the same time, it is important to consider that sustainable development is a multifaceted concept in which economic growth can be accompanied by negative consequences for society and the environment. The development of transport infrastructure often leads to increased emissions of harmful substances, increased noise levels, and a deterioration in the quality of life of the population. In addition, increased economic activity can lead to social inequalities, creating an imbalance in access to transport resources.

Recognizing these limitations, it is planned to further expand the analysis to include environmental and social factors. This approach will provide a more holistic understanding

of sustainable transport systems and the recommendations that take into account not only economic benefits, but also possible risks to the environment and society.

This study also has several limitations that may affect the accuracy and completeness of the findings. First, the data are limited to Russian regions only, which may reduce their applicability to other countries with different economic conditions and levels of infrastructure development. This limits the possibility of applying the results in international studies.

In addition, despite considering key factors, the study does not include other important variables such as political changes, education levels, or demographic characteristics. These elements may also have an impact on economic development, and their absence may be a limitation.

Another limitation is that the study does not cover long-term effects, such as the impact of accumulated investment in infrastructure or innovative changes that may significantly affect economic development in the future. This makes it difficult to assess sustainable changes that may occur over time.

Finally, the fixed effects model is the most appropriate model for this study, but it may not account for random changes and external factors affecting outcomes, which limits its ability to analyze all possible influences.

It is worth adding that the studies that used spatial econometrics as a methodology suggest that transport infrastructure has a strong positive spatial impact on regional growth [13,42,48]. Simultaneously, for Russia the issue of using spatial methods in research is particularly relevant due to the large size of the territory, wide geography, and strong differentiation of regions [42,43].

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Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three-letter acronym
LD	Linear dichroism

Appendix A. Literature Review

No	Authors	Year	Journal	Name	Purpose	Methodology	Factors	Outcomes
1	Abam, F. I., et al.	2021	<i>Energy Reports</i>	Environmental sustainability of the Nigeria transport sector through decomposition and decoupling analysis with future framework for sustainable transport pathways [27]	To assess the sustainability of Nigeria's transport sector and propose pathways for sustainable development	Decompositional and decoupling analysis	CO ₂ emissions, transport infrastructure	The need for transition to low-carbon technologies is shown
2	Alotaibi S. et al.	2022	<i>Research in Transportation Business & Management</i>	Transport investment, railway accessibility and their dynamic impacts on regional economic growth [30]	To study the impact of transport investment and railway accessibility on regional economic growth	Econometric analysis, panel data	Investment, accessibility, economic growth	The positive impact of investments on growth is shown
3	Alam K. M. et al.	2021	<i>Research in Transportation Economics</i>	Causality between transportation infrastructure and economic development in Pakistan: An ARDL analysis [33]	To study the cause-and-effect relationship between transport infrastructure and economic development in Pakistan	ARDL analysis	Infrastructure, GDP, transport	A two-way causal relationship is found
4	Bychkova, A. A.	2024	<i>Bulletin of the University</i>	The possibilities of using econometric methods in the study of interregional interactions of migration in transport [49]	To assess interregional migration interactions from a transport perspective	Econometric analysis	Migration, transport	Key interregional relations are identified
5	Cascetta E. et al.	2020	<i>Transportation Research Part A</i>	Economic growth, transport accessibility and regional equity impacts of high-speed railways in Italy: Ten years ex post evaluation and future perspectives [31]	To assess the impact of high-speed rail on economic growth and regional equity	Ex-post analysis	High-speed rail, equality	Improved accessibility and regional cohesion confirmed
6	Chacon-Hurtado D. et al.	2020	<i>Journal of Transport Geography</i>	The role of transportation accessibility in regional economic resilience [18]	To study the role of transport accessibility in the economic sustainability of regions	Spatial analysis	Availability, sustainability	Improved accessibility increases economic resilience
7	Elburz Z., Cubukcu K. M.	2021	<i>Spatial Information Research</i>	Spatial effects of transport infrastructure on regional growth: The case of Turkey [13]	Analysis of the spatial effects of transport infrastructure on regional growth	Spatial econometric analysis	Infrastructure, regional growth	Positive impact of infrastructure on growth found
8	Fong et al.	2020	<i>Sustainable Development</i>	Evidence of the environmental Kuznets curve for atmospheric pollutant emissions in Southeast Asia and implications for sustainable development: A spatial econometric approach [48]	Study of the Kuznets curve for emissions in Southeast Asia	Spatial econometrics	Emissions, factors of sustainable development	Confirmed Kuznets curve for emissions

No	Authors	Year	Journal	Name	Purpose	Methodology	Factors	Outcomes
9	Hakim et al.	2019	<i>Transport Policy</i>	Econometric evidence on the determinants of air transport in South Asian countries [26]	To identify the factors affecting air transport in South Asia	Econometric analysis	GDP, transport, infrastructure	Key determinants of air transport identified
10	Huang G. et al.	2020	<i>Energy Economics</i>	Impact of transportation infrastructure on industrial pollution in Chinese cities: A spatial econometric analysis [24]	Investigate the impact of transport infrastructure on industrial pollution	Spatial econometrics	Pollution, infrastructure	Infrastructure reduces pollution in major cities
11	Huang Y., Hong T., and Ma T.	2020	<i>Cities</i>	Urban network externalities, agglomeration economies and urban economic growth [34]	To study the effect of network external factors and agglomerations on economic growth	Econometric analysis	Network effects, agglomeration	A positive impact on economic growth is established
12	Hussain et al.	2023	<i>Innovation and Green Development</i>	Towards sustainable development: The impact of transport infrastructure expenditure on the ecological footprint in India [25]	To assess the impact of transport infrastructure spending on India's ecological footprint	Econometric analysis	Ecological footprint, infrastructure spending	Reduced environmental footprint with increased costs
13	Ke, X. et al.	2020	<i>Sustainability</i>	Transport infrastructure development and economic growth in China: recent evidence from dynamic panel system-GMM analysis [16]	To study the relationship between the development of transport infrastructure and economic growth in China	GMM system analysis	Infrastructure, economic growth	Significant link confirmed
14	Kikkas, K.N.	2015	<i>MIR (Modernization. Innovation. Development)</i>	Modeling the sustainable development of the Arctic region of Russia [15]	Modeling of sustainable development of the Arctic region of Russia	Econometric modeling	Sustainable development, Arctic	The importance of sustainable development was confirmed
15	Kwilinski, A et al.	2023	<i>Sustainability</i>	Environmental sustainability within attaining sustainable development goals: The role of digitalization and the transport sector [6]	To explore the role of digitalization and the transport sector in sustainable development	Econometric analysis	Sustainable development, digitalization	The impact of digitalization on sustainability is shown
16	Magazzino C., Mele M.	2021	<i>Research in Transportation Economics</i>	On the relationship between transportation infrastructure and economic development in China [19]	Analysis of the relationship between transport infrastructure and economic growth in China	Econometric analysis	Transport, economic growth	Significant correlation confirmed
17	Marinos T. et al.	2022	<i>Research in Transportation Economics</i>	The spatial spillover effect of transport infrastructures in the Greek economy (2000–2013): A panel data analysis [17]	Assessment of the spatial effects of transport infrastructure on the Greek economy	Panel Analysis	Transport infrastructure, economy	Installed spatial effects

№	Authors	Year	Journal	Name	Purpose	Methodology	Factors	Outcomes
18	Mohmand Y. T. et al.	2021	<i>Research in Transportation Economics</i>	Investigating the causal relationship between transport infrastructure, economic growth and transport emissions in Pakistan [22]	To explore the link between infrastructure, growth, and emissions in Pakistan	Causal analysis	Infrastructure, emissions	Significant causal relationships found
19	Pokharel R. et al.	2021	<i>Journal of Transport Geography</i>	Spatio-temporal evolution of cities and regional economic development in Nepal: Does transport infrastructure matter? [36]	To study the impact of transport infrastructure on the development of cities and regions	Spatio-temporal analysis	Infrastructure, development	The impact of infrastructure is established
20	Salimova D. R., Ponomarev Yu. Yu.	2021	<i>Applied Econometrics</i>	Assessment of the impact of transport infrastructure development on the geography of exports of Russian regions [42]	To study the impact of transport infrastructure on the geography of exports	Econometric analysis	Infrastructure, export	Positive effects found
21	Saidi S. et al.	2020	<i>Transportation Research Part A</i>	Dynamic linkages between transport, logistics, foreign direct investment, and economic growth: Empirical evidence from developing countries [35]	To explore the dynamic links between transport, logistics, FDI, and growth	Econometric analysis	Transport, logistics	Meaningful connections established
22	Serkov L. A., Petrov M. B., Kozhov K. B.	2021	<i>Journal of New Economy</i>	Cluster econometric tools for research Heterogeneities of Russian Regions [43]	To develop cluster methods to study regional differences	Econometric analysis	Regional differences	New methods of analysis are proposed
23	Shafique M. et al.	2021	<i>Transport Policy</i>	Investigating the nexus among transport, economic growth and environmental degradation: Evidence from panel ARDL approach [23]	To explore the relationship between transport, growth, and environmental degradation	ARDL panel analysis	Transport, degradation	Significant connections found
24	Tang Z. et al.	2020	<i>Sustainability</i>	Spatial econometric analysis of the relationship between urban land and regional economic development in the Beijing–Tianjin–Hebei coordinated development region [37]	To study the relationship between land use and regional development	Spatial econometrics	Land use, development	Connection confirmed

№	Authors	Year	Journal	Name	Purpose	Methodology	Factors	Outcomes
25	Tolcha T. D., Bråthen S., Holmgren J.	2020	<i>Journal of Transport Geography</i>	Air transport demand and economic development in sub-Saharan Africa: Direction of causality [28]	Investigate the causality between air transport and development	Econometric analysis	Air transport, growth	Causality established
26	Ullah, A., et al.	2021	<i>PLOS One</i>	Nexus of regional integration, socio-economic determinants and sustainable development in belt and road initiative countries [7]	To explore regional integration and sustainable development in the countries of the initiative	Spatial analysis	Integration, development	Significant connections found
27	Wang C., Kim Y. S., and Kim C. Y.	2021	<i>Transport Policy</i>	Causality between logistics infrastructure and economic development in China [50]	To study the cause-and-effect relationship between logistics infrastructure and economic development in China	Econometric analysis	Logistics infrastructure, economic development	Positive cause-and-effect relationships were found
28	Wang C. et al.	2020	<i>Transportation Research Part A: Policy and Practice</i>	Railway and road infrastructure in the Belt and Road Initiative countries: Estimating the impact of transport infrastructure on economic growth [32]	To study the impact of railway and road infrastructure in the countries of the Belt and Road Initiative on economic growth	Econometric analysis	Transport infrastructure, economic growth	Positive impact of infrastructure on economic growth found
29	Wang H. et al.	2021	<i>Research in Transportation Economics</i>	The relationship between freight transport and economic development: A case study of China [20]	To study the relationship between cargo transportation and economic development in the example of China	Econometric analysis	Cargo transportation, economic growth	Significant positive associations are identified
30	Washington, S. et al.	2020	<i>Chapman and Hall/CRC</i>	Statistical and econometric methods for transportation data analyses [14]	To provide tools for vehicle data analysis	Econometric and statistical analysis	Econometric methods of analysis	Methods of data analysis are proposed
31	Yang, et al.	2021	<i>Energy Reports</i>	How does technological progress impact transportation green total factor productivity: A spatial econometric perspective [51]	To study the impact of technological progress on the environmental productivity of transport	Spatial econometrics	Technological progress, environmental performance	The positive impact of technology is established

№	Authors	Year	Journal	Name	Purpose	Methodology	Factors	Outcomes
32	Zhang F., and Graham D. J.	2020	<i>Transport Reviews</i>	Air transport and economic growth: A review of the impact mechanism and causal relationships [29]	Overview of the impact of air transport on economic growth	Review of studies	Air transport, economic growth	The mechanisms of influence are indicated
33	Zhang, G., et al.	2021	<i>Journal of Cleaner Production</i>	Environmental regulation, economic development and air pollution in the cities of China: Spatial econometric analysis based on policy scoring and satellite data [52]	To investigate the relationship between environmental regulations, development, and air pollution	Spatial econometrics	Environmental regulations, air pollution	Reduced pollution due to standards
34	Zhu F., Wu X., and Peng W.	2022	<i>Transportation Letters</i>	Road transportation and economic growth in China: Granger causality analysis based on provincial panel data [21]	To study the impact of road transport on economic growth in China	Granger analysis of causality	Road transport, economic growth	A causal relationship is found
35	Ianoş I., Cochei R. M., Petrişor A. I.	2024	<i>Urban Science</i>	Exploring the Relationship between the Dynamics of the Urban–Rural Interface and Regional Development in a Post-Socialist Transition [1]	To investigate the relationship between the dynamics of the urban interface and regional development	Data analysis	Urbanization, regional development	Significant connections found
36	Karpenko E., Rasseko Y.	2021	<i>University Economic Bulletin</i>	Gross regional product: study of influencers [5]	To study the factors influencing the gross regional product	Econometric analysis	GRP, influencing factors	Key determinants identified
37	Lindgren E., Pettersson-Lidbom P., Tyrefors B.	2021	<i>IFN Working Paper</i>	The causal effect of transport infrastructure: Evidence from a new historical database [10]	To investigate the causal influence of transport infrastructure on economic development	Historical data analysis	Transport infrastructure, economic development	Significant infrastructure impact established
38	Tsiotas D., Geraki M., Niavis S.	2020	<i>arXiv preprint</i>	Transportation networks and their significance to economic development [11]	To study the importance of transport networks for economic development	Spatial analysis	Transport networks, development	The importance of networks for economic growth was confirmed

References

- Ianoş, I.; Cochechi, R.M.; Petrişor, A.I. Exploring the Relationship between the Dynamics of the Urban–Rural Interface and Regional Development in a Post-Socialist Transition. *Urban Sci.* **2024**, *8*, 47. [\[CrossRef\]](#)
- Semenov, D.V. Sustainable Development, Science, Innovation—Three Vectors of Development of the Regional Economy. *Innov. Econ. Inf. Anal. Forecast.* **2024**, 226–230. [\[CrossRef\]](#)
- Marhasova, V.; Tulchynska, S.; Popelo, O.; Garafonova, O.; Yaroshenko, I. Modeling the Harmony of Economic Development of Regions in the Context of Sustainable Development. *Int. J. Sustain. Dev. Plan.* **2022**, *17*, 441. [\[CrossRef\]](#)
- Deng, T. Impacts of transport infrastructure on productivity and economic growth: Recent advances and research challenges. *Transp. Rev.* **2013**, *33*, 686–699. [\[CrossRef\]](#)
- Karpenko, E.; Rasseko, Y. Gross regional product: Study of influencers. *Univ. Econ. Bull.* **2021**, *50*, 129–136. [\[CrossRef\]](#)
- Kwilinski, A.; Lyulyov, O.; Pimonenko, T. Environmental sustainability within attaining sustainable development goals: The role of digitalization and the transport sector. *Sustainability* **2023**, *15*, 11282. [\[CrossRef\]](#)
- Ullah, A.; Pinglu, C.; Ullah, S.; Hashmi, S.H. Nexus of regional integration, socioeconomic determinants and sustainable development in belt and road initiative countries. *PLoS ONE* **2021**, *16*, e0254298. [\[CrossRef\]](#)
- Holmgren, J. The effect of public transport quality on car ownership—A source of wider benefits? *Res. Transp. Econ.* **2020**, *83*, 100957. [\[CrossRef\]](#)
- Alhassan, J.A.K.; Anciaes, P. Public transport investments as generators of economic and social activity. *J. Transp. Health* **2025**, *41*, 101989. [\[CrossRef\]](#)
- Lindgren, E.; Pettersson-Lidbom, P.; Tyrefors, B. *The Causal Effect of Transport Infrastructure: Evidence from a New Historical Database*; IFN Working Paper; Research Institute of Industrial Economics (IFN): Stockholm, Sweden, 2021.
- Tsiotas, D.; Geraki, M.; Niavis, S. Transportation networks and their significance to economic development. *arXiv* **2020**, arXiv:2003.08094.
- Coşar, A.K.; Demir, B.; Ghose, D.; Young, N. Road capacity, domestic trade and regional outcomes. *J. Econ. Geogr.* **2022**, *22*, 901–929. [\[CrossRef\]](#)
- Elburz, Z.; Cubukcu, K.M. Spatial effects of transport infrastructure on regional growth: The case of Turkey. *Spat. Inf. Res.* **2021**, *29*, 19–30. [\[CrossRef\]](#)
- Washington, S.; Karlaftis, M.G.; Mannering, F.; Anastasopoulos, P. *Statistical and Econometric Methods for Transportation Data Analyses*; Chapman and Hall/CRC: Boca Raton, FL, USA, 2020.
- Kikkas, K.N. Modeling the sustainable development of the Arctic region of Russia. *MIR (Mod. Innov. Dev.)* **2015**, *6*, 142–147. [\[CrossRef\]](#)
- Ke, X.; Lin, J.Y.; Fu, C.; Wang, Y. Transport infrastructure development and economic growth in China: Recent evidence from dynamic panel system-GMM analysis. *Sustainability* **2020**, *12*, 5618. [\[CrossRef\]](#)
- Marinos, T.; Belegri-Roboli, A.; Michaelides, P.G.; Konstantakis, K.N. The spatial spillover effect of transport infrastructures in the Greek economy (2000–2013): A panel data analysis. *Res. Transp. Econ.* **2022**, *94*, 101179. [\[CrossRef\]](#)
- Chacon-Hurtado, D.; Kumar, I.; Gkritza, K.; Fricker, J.D.; Beaulieu, L.J. The role of transportation accessibility in regional economic resilience. *J. Transp. Geogr.* **2020**, *84*, 102695. [\[CrossRef\]](#)
- Magazzino, C.; Mele, M. On the relationship between transportation infrastructure and economic development in China. *Res. Transp. Econ.* **2021**, *88*, 100947. [\[CrossRef\]](#)
- Wang, H.; Han, J.; Su, M.; Wan, S.; Zhang, Z. The relationship between freight transport and economic development: A case study of China. *Res. Transp. Econ.* **2021**, *85*, 100885. [\[CrossRef\]](#)
- Zhu, F.; Wu, X.; Peng, W. Road transportation and economic growth in China: Granger causality analysis based on provincial panel data. *Transp. Lett.* **2022**, *14*, 710–720. [\[CrossRef\]](#)
- Mohmand, Y.T.; Mehmood, F.; Mughal, K.S.; Aslam, F. Investigating the causal relationship between transport infrastructure, economic growth and transport emissions in Pakistan. *Res. Transp. Econ.* **2021**, *88*, 100972. [\[CrossRef\]](#)
- Shafique, M.; Azam, A.; Rafiq, M.; Luo, X. Investigating the nexus among transport, economic growth and environmental degradation: Evidence from panel ARDL approach. *Transp. Policy* **2021**, *109*, 61–71. [\[CrossRef\]](#)
- Huang, G.; Zhang, J.; Yu, J.; Shi, X. Impact of transportation infrastructure on industrial pollution in Chinese cities: A spatial econometric analysis. *Energy Econ.* **2020**, *92*, 104973. [\[CrossRef\]](#)
- Hussain, M.M.; Pal, S.; Villanthenkodath, M.A. Towards sustainable development: The impact of transport infrastructure expenditure on the ecological footprint in India. *Innov. Green Dev.* **2023**, *2*, 100037. [\[CrossRef\]](#)
- Hakim, M.M.; Merkert, R. Econometric evidence on the determinants of air transport in South Asian countries. *Transp. Policy* **2019**, *83*, 120–126. [\[CrossRef\]](#)
- Abam, F.I.; Ekwe, E.B.; Diemuodeke, O.E.; Ofem, M.I.; Okon, B.B.; Kadurumba, C.H.; Archibong-Eso, A.; Effiom, S.O.; Egbe, J.G.; Ukuje, W.E. Environmental sustainability of the Nigeria transport sector through decomposition and decoupling analysis with future framework for sustainable transport pathways. *Energy Rep.* **2021**, *7*, 3238–3248. [\[CrossRef\]](#)

28. Tolcha, T.D.; Bråthen, S.; Holmgren, J. Air transport demand and economic development in sub-Saharan Africa: Direction of causality. *J. Transp. Geogr.* **2020**, *86*, 102771. [\[CrossRef\]](#)
29. Zhang, F.; Graham, D.J. Air transport and economic growth: A review of the impact mechanism and causal relationships. *Transp. Rev.* **2020**, *40*, 506–528. [\[CrossRef\]](#)
30. Alotaibi, S.; Quddus, M.; Morton, C.; Imprialou, M. Transport investment, railway accessibility and their dynamic impacts on regional economic growth. *Res. Transp. Bus. Manag.* **2022**, *43*, 100702. [\[CrossRef\]](#)
31. Cascetta, E.; Cartenì, A.; Henke, I.; Pagliara, F. Economic growth, transport accessibility and regional equity impacts of high-speed railways in Italy: Ten years ex post evaluation and future perspectives. *Transp. Res. Part A Policy Pract.* **2020**, *139*, 412–428. [\[CrossRef\]](#)
32. Wang, C.; Lim, M.K.; Zhang, X.; Zhao, L.; Lee, P.T.W. Railway and road infrastructure in the Belt and Road Initiative countries: Estimating the impact of transport infrastructure on economic growth. *Transp. Res. Part A Policy Pract.* **2020**, *134*, 288–307. [\[CrossRef\]](#)
33. Alam, K.M.; Li, X.; Baig, S.; Ghanem, O.; Hanif, S. Causality between transportation infrastructure and economic development in Pakistan: An ARDL analysis. *Res. Transp. Econ.* **2021**, *88*, 100974. [\[CrossRef\]](#)
34. Huang, Y.; Hong, T.; Ma, T. Urban network externalities, agglomeration economies and urban economic growth. *Cities* **2020**, *107*, 102882. [\[CrossRef\]](#)
35. Saidi, S.; Mani, V.; Mefteh, H.; Shahbaz, M.; Akhtar, P. Dynamic linkages between transport, logistics, foreign direct investment, and economic growth: Empirical evidence from developing countries. *Transp. Res. Part A Policy Pract.* **2020**, *141*, 277–293. [\[CrossRef\]](#)
36. Pokharel, R.; Bertolini, L.; te Brömmelstroet, M.; Acharya, S.R. Spatio-temporal evolution of cities and regional economic development in Nepal: Does transport infrastructure matter? *J. Transp. Geogr.* **2021**, *90*, 102904. [\[CrossRef\]](#)
37. Tang, Z.; Zhang, Z.; Zuo, L.; Wang, X.; Hu, S.; Zhu, Z. Spatial econometric analysis of the relationship between urban land and regional economic development in the Beijing–Tianjin–Hebei coordinated development region. *Sustainability* **2020**, *12*, 8451. [\[CrossRef\]](#)
38. Uskova, T.V. Transport infrastructure as a factor of territorial development and connectivity of economic space. *Probl. Territ. Dev.* **2021**, *25*, 7–22.
39. Mitryukova, K.A. Influence of transport infrastructure on socio-economic development of regions: Practical significance and scientific disagreements. *Econ. Entrep. Law* **2023**, 2399. [\[CrossRef\]](#)
40. Knyazeva, I.S. Statistical study of the process of motorization of the population of the Russian Federation. *Symb. Sci.* **2017**, *1*, 109–111.
41. Titov, I.V.V.; Batischev, I.I. Cargo road transport in Russia: State and prospects of development. Transport of the Russian Federation. *J. Sci. Pract. Econ.* **2011**, *5*, 44–48.
42. Salimova, D.R.; Ponomarev, Y.Y. Assessment of the impact of transport infrastructure development on the geography of exports of Russian regions. *Appl. Econom.* **2021**, *63*, 51.
43. Serkov, L.A.; Petrov, M.B.; Kozhov, K.B. Cluster econometric tools for research Heterogeneities of Russian Regions. *J. New Econ.* **2021**, *22*, 78–96.
44. Rosstat. Federal State Statistics Service. Available online: <https://rosstat.gov.ru/> (accessed on 15 March 2024).
45. Kudryavtseva, T.Y.; Shvediani, A.E. Econometric analysis of regional industry specialization (on the example of the Russian manufacturing industry). *Econ. Anal. Theory Pract.* **2020**, *19*, 1765–1790. [\[CrossRef\]](#)
46. Vakulenko, E.; Mkrtchyan, N.; Furmanov, K. Econometric Analysis of Internal Migration in Russia (Ekonometrijska Analiza Unutrasnjih Migracija U Rusiji). *Montenegrin J. Econ.* **2011**, *7*, 21–33.
47. Serkova, A. Infrastructure in the Context of Regional Development in Russia. *Eur. Proc. Soc. Behav. Sci.* **2022**, 30–37. [\[CrossRef\]](#)
48. Fong, L.S.; Salvo, A.; Taylor, D. Evidence of the environmental Kuznets curve for atmospheric pollutant emissions in Southeast Asia and implications for sustainable development: A spatial econometric approach. *Sustain. Dev.* **2020**, *28*, 1441–1456. [\[CrossRef\]](#)
49. Bychkova, A.A. Possibilities of using econometrical methods in studying of interregional interactions of migration in transportation. *Vestn. Univ.* **2024**, *87*. [\[CrossRef\]](#)
50. Wang, C.; Kim, Y.S.; Kim, C.Y. Causality between logistics infrastructure and economic development in China. *Transp. Policy* **2021**, *100*, 49–58. [\[CrossRef\]](#)
51. Yang, X.; Jia, Z.; Yang, Z. How does technological progress impact transportation green total factor productivity: A spatial econometric perspective. *Energy Rep.* **2021**, *7*, 3935–3950. [\[CrossRef\]](#)
52. Zhang, G.; Jia, Y.; Su, B.; Xiu, J. Environmental regulation, economic development and air pollution in the cities of China: Spatial econometric analysis based on policy scoring and satellite data. *J. Clean. Prod.* **2021**, *328*, 129496. [\[CrossRef\]](#)

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