Correlation analysis of factors affecting piggyback transportation in Uzbekistan

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Abstract. Rail transport is traditionally used in the implementation of international and intercontinental piggyback transportation. Despite a significant level of computerization and informatization, the level of delays in the delivery of goods in the field of piggyback intermodal transportation is not decreasing. The unsatisfactory speed of piggyback trains is a significant factor in these delays. This situation has developed due to the lack of effective approaches to building management systems that would demonstrate a high level of efficiency in the face of uncertainty, which is a natural component of the transportation process. The article is devoted to the correlation analysis of factors affecting the cargo turnover of piggyback transportation in the Republic of Uzbekistan. The main factors affecting the cargo turnover of piggyback transportation were identified; the degree of the effect was established by statistical methods. Based on data obtained for the last ten years, a correlation matrix and a regression model of cargo turnover were built. The results obtained make it possible to build forecasts for the cargo turnover of piggyback transportation for 2–4 years with a 95% confidence interval.

1 Introduction

The most common types of cargo transport in the Republic of Uzbekistan are road and rail transportation. The road and railway networks are the foundations for the development, specialization, and concentration of industrial production, mining and agriculture. To accomplish this task, not only new modern sections of roads and railways should be built on the territory of the republic but also transport hubs, container terminals, and appropriate infrastructure [1, 2]. In addition, the national transport system, in particular, Uzbek railways - the main railway company in the republic, should master modern logistics technologies, such as intermodal transportation, a significant part of which is piggyback transportation, the characteristic features of which are studied in this article.

The history of piggyback transportation on the railway network in the Republic of Uzbekistan is not so long and the first stage was limited to transit piggyback transportation.

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Over time, investments in this sector of the economy made it possible to equip several piggyback yards in container terminals, and at the end of 2021, such yards were built in 24% of terminals [3, 4]. This has enabled national transport companies to participate in piggyback schemes, leading to appreciable savings in transport costs (as has long been proven by successful piggyback runs in other countries), and to a reduction in the carbon footprint of the industry, as the carbon footprint of products (CFP) transported by road is on average 83 times greater than CFP of rail transport [5-10].

2 Methods

All the analyzed data for further research using the methods of statistical analysis, are shown in Table 1.

Table 1. Initial data for analysis.

Year	**Variables**		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Piggyback cargo turnover, million tons	dependent variable	**pb**	0.30	0.32	0.35	0.34	0.32	0.35	0.36	0.38	0.30	0.35
Cargo turnover of railway transportation, million tons	independent variables (regressors)	**rt**	61.5	63.7	65.7	67.2	67.6	67.9	68.4	70.1	70.6	72.0
Cargo turnover of road transport, million tons		**at**	733	801	869	943	1003	1013	1102	1178	1238	1282
GDP transport services, billion USD		**vt**	16.5	20.6	23.8	26.8	30.6	36.2	44.2	54.5	53.7	67.2
Railway tracks, thousand km		**rd**	90.6	90.6	89.1	89.1	90.6	95.7	96.9	96.1	97.0	95.5
Paved motor roads, thousand km		**ad**	59.1	59.0	58.7	58.7	58.7	58.9	58.6	58.6	58.5	58.4
Foreign trade turnover, billion USD		**vo**	90.6	90.6	89.1	89.1	90.6	95.7	96.9	96.1	97.0	95.5
Foreign trade turnover in transport services, billion USD		**vu**	59.1	59.0	58.7	58.7	58.7	58.9	58.6	58.6	58.5	58.4

Source: compiled by the author based on data from [11].

Based on the data in Table 2, the Spearman correlation matrix is calculated, as ten observations (the number of observations is 10) are not enough to construct an adequate Pearson correlation matrix [12].

Table 2. Spearman's correlation matrix.

	pb	vu	vo	ad	rd	vt	at	rt
pb	—							
vu	-0.509	—						
vo	0.295	-0.530	—					
ad	-0.509	1.000	-0.530	—				
rd	0.295	-0.530	1.000	-0.530	—			
vt	0.648	-0.902	0.702	-0.902	0.702	—		
at	0.552	-0.914	0.726	-0.914	0.726	0.988	—	
rt	0.552	-0.914	0.726	-0.914	0.726	0.988	1.000	—

Source: calculated by the author using the jamovi statistical package.

3 Research results and discussion

It follows from the values of the Spearman correlation coefficients that the most dependent variable pb {cargo turnover of piggyback transportation, million tons} depends on the variable (regressor) vt {GDP transport services, billion USD} and the significance coefficient $p = 0.049 < 0.05$ (at a 95% confidence interval).

Then, according to the degree of dependence, pb depends on the variables at {cargo turnover of road transport, million tons}, rt {cargo turnover of railway transportation, million tons}, at a measure of significance, $p = 0.104 > 0.1$ (at a 90% confidence interval).

Finally, pb correlates rather weakly with ad {paved highways, thousand km} and vu {foreign trade turnover in transport services, billion USD}, at a measure of significance $p = 0.133 > 0.1$.

The remaining variables have correlation coefficients pb < 0.5, as they do not correlate with the dependent variable.

Considering the correlation coefficients of independent variables, a high degree of correlation and even complete collinearity of some variables (in Table 2 they are marked with color) should be noted. This means that similar variables cannot be simultaneously considered independent regressors.

The values of the correlation coefficients with their calculated significances, distribution density graphs make it possible to establish a connection between the dependent variable and the factors of impact; however, a more explicit connection of this kind can only be made when building a regression model of the dependent variable as a function of regressors.

Before proceeding with the construction of such a model, one should make sure that the time series for the dependent variable pb is stationary. To solve this problem, it is required to construct the autocorrelation function ACF and the partial autocorrelation function PACF depending on the lags, and the number of lags should not be less than 5 (half of the number of observations = 10).

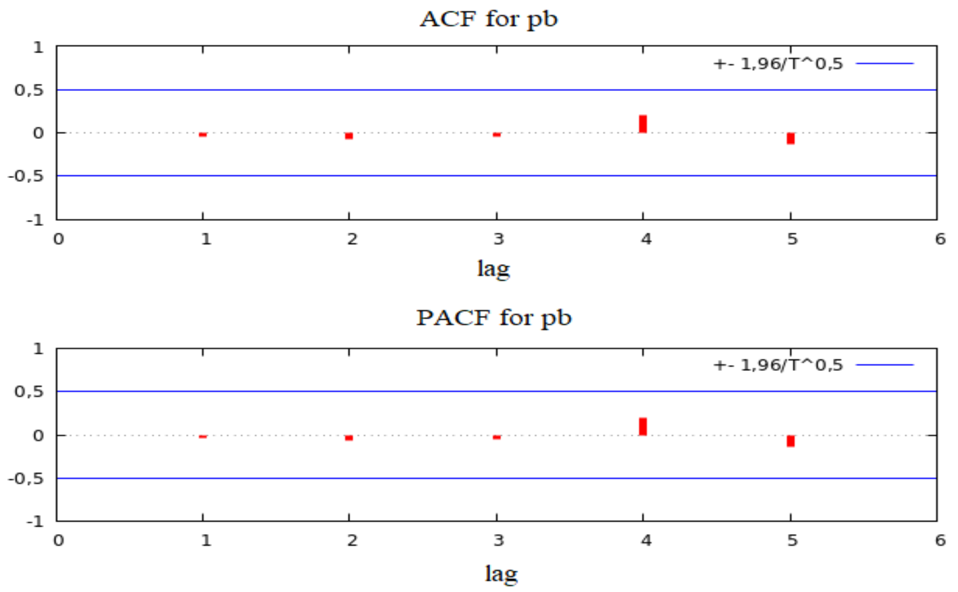

Fig. 1. Graph of the autocorrelation function (partial autocorrelation function) depending on the lags.

The values of ACF and PACF are close to 0 in the interval from 1 to 5 lags with a small spike in the 4th lag, which is explained by a sharp decline and rise in the values of the pb variable in 2020-2021 (Fig. 1), corresponding to the crisis caused by the COVID 19 pandemic. However, even this spike does not go beyond the critical values of ±1.96/T^0.5 (T = 10 observations), which tells us that the hypothesis of stationarity of the time series for dependent variable pb is true.

We construct a regression model using the least squares method (LSM) for the dependent variable pb.

Table 3. Regression LSM model 1.

Model 1: LSM, observations in 2012-2021 (T = 10)
Dependent variable: pb

	coefficient	*Statistic error*	*t-statistics*	*P-value*	
const	4.46419	6.64645	0.6717	0.5386	
at	−0.00106408	0.000421920	−2.522	0.0652	*
vt	0.00303548	0.00195071	1.556	0.1947	
rt	0.0359625	0.0137036	2.624	0.0585	*
ad	−0.108604	0.114260	−0.9505	0.3957	
vo	0.00851596	0.00516440	1.649	0.1745	

Dependent variable mean	0.337601	Stat. deviat. of dependent variable	0.026022
Sum of sq. residues	0.001605	Stat. error of the model	0.020031
R-square	0.736648	Corr. R-square	0.407458
F(5, 4)	2.237760	P-value (F)	0.227614
Log likelihood	29.49675	Akaike crit.	−46.99351
Schwartz crit.	−45.17800	Hannan-Quinn crit.	−48.98512
Parameter rho	−0.130545	Stat. Durbin-Watson	2.215015

Source: calculated by the author using the Gretl statistical package

Breusch-Pagan test on heteroscedasticity - Null hypothesis: no heteroscedasticity Test statistic: LM = 4.05887 p-value = P(Chi-square(5) > 4.05887) = 0.540972 Breusch-Pagan test on heteroscedasticity (robust option) - Null hypothesis: no heteroscedasticity Test statistic: LM = 6.76632 p-value = P(Chi-square(5) > 6.76632) = 0.238607

The resulting model does not adequately describe the behavior of the variable pb. This statement is based primarily on the p-value of the Fisher statistic > 0.1 (at a 90% confidence interval). Also unsatisfactory are the p-values of Student's statistic for the regressors, only two of which have this value of less than 0.1. This is most likely due to the presence of heteroscedasticity (heterogeneity of observations, expressed in a non-constant variance of the random error of the regression model). However, both Breusch-Pagan tests do not indicate the presence of heteroscedasticity. This possible contradiction can be explained by the presence of some heteroscedasticity, revealed by the mechanism of auxiliary regression of higher degrees (greater than 2 degrees) of residuals that the test does not take into account. A more general White's test will fail because the number of variables is very large for such a small number of observations. However, in the Gretl statistical package, there is a mechanism for constructing a least squares model corrected for heteroscedasticity.

This model satisfies the criterion for p-values < 0.05 for all variables, dependent and independent, R-square is close enough to 1, and the log-likelihood criteria, Akaike, Schwartz, and Hannan-Quinn modulo are less than 100, which indirectly confirms the adequacy of the model. However, the Durbin-Watson statistic < 1 indicates the presence of some 1st order autocorrelation, but such a result should not be too disconcerting, since it is characteristic of a series with a small number of observations. The adequacy of the model is confirmed by the graph of the observed and calculated values of variable pb (Fig. 2), and by the residual correlogram (Fig. 3).

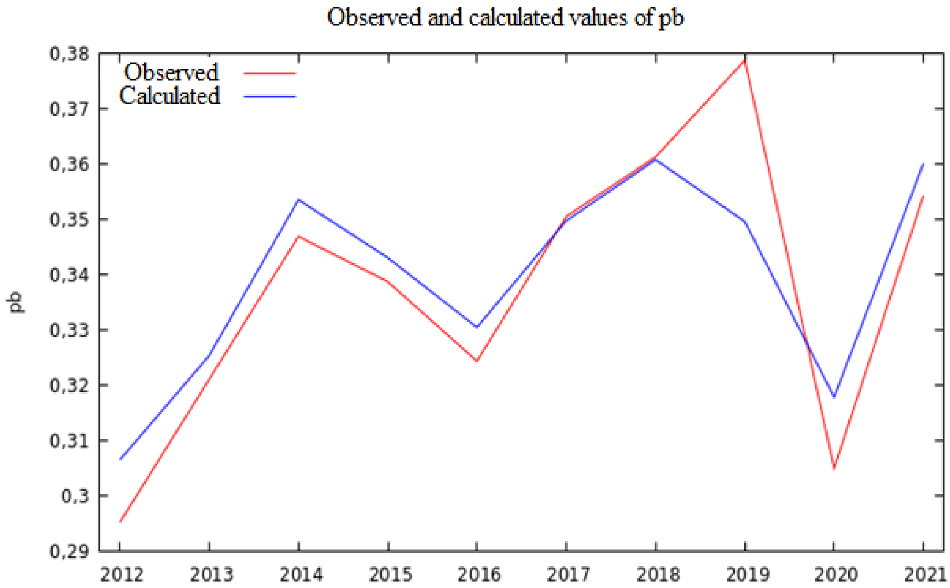

Fig. 2. Graph of observed and calculated values of variable pb. Source: calculated by the author using the Gretl statistical package.

The values and criteria calculated in Table 3, the graphs of the calculated and observed values in Fig. 2 tell us about the sufficient realism of the constructed model, expressed as a regression equation:

$$pb = -1{,}03 - 0{,}000832*at + 0{,}00457*vt + 0{,}0303*rt \tag{1}$$

The piggyback cargo turnover forecast for the next 3 years calculated using equation (1) has the following form (Fig. 3):

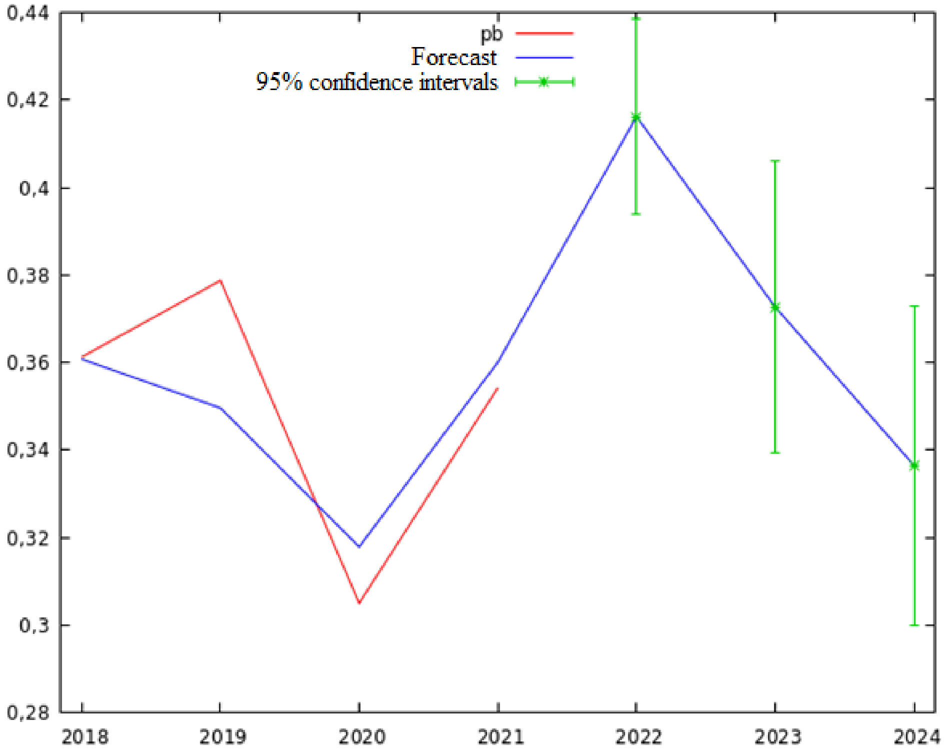

Fig. 3. Forecast of cargo turnover of piggyback transportation in 2022 - 2024, million tons.

4 Conclusions

The correlation analysis of the factors chosen, which affect the amount of piggyback cargo turnover and the construction of a realistic multiple regression equation (1), allows us to draw the following conclusions:

The piggyback cargo turnover

- directly depends on the value of GDP for transport services;
- inversely depends on the turnover of road transportation, which is quite obvious, since road transportation is the strongest alternative to piggyback transportation (it is interesting to note that the correlation analysis shows a direct relationship, while a more accurate multiple regression equation (1) shows an inverse relationship);
- directly depends on the cargo turnover of railway transportation, which does not contradict the logic, since piggyback transportation is a part of railway transportation;
- inversely depends (to a weak degree) on the length of paved roads, which is justified, since these roads are used for competing road transport;

- inversely depend (to a weak degree) on the amount of foreign trade turnover in transport services, which is an illogical result, probably due to the weakness of the correlation and the small number of observations.

Thus, when making forecasts for the future development of piggyback transportation in the Republic of Uzbekistan, one should take into account the degree and direction of the influence of the factors we have chosen.

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