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ANALYSIS OF INTERMODAL TRANSPORT DEVELOPMENT IN EUROPEAN COUNTRIES AND UKRAINE

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Abstract. *This article examines the intermodal freight markets in Europe and Ukraine, emphasizing the importance of rigorous analysis for guiding policy and investment decisions. The analysis reveals weak and statistically insignificant relationships in the EU intermodal transport volumes, calling for a more comprehensive dataset and consideration of other factors. In Ukraine, a complex Polynomial Regression model fits the data perfectly, but overfitting is a concern. This model captures intricate relationships, demanding careful interpretation. Further research is needed to address limitations, improve data consistency, explore innovative strategies, assess the financial sustainability of intermodal systems, and investigate the impact of regulatory frameworks, stakeholder collaboration, and emerging technologies on the intermodal freight sector.*

Key words: *intermodal freight, intermodal freight market, OLS Regression, polynomial regression, freight mode*

Introduction.

In the ever-strengthened landscape of global trade and transportation, the efficient movement of goods stands as a pivotal driver of economic growth and prosperity. At the heart of this movement lies the intermodal freight market — a dynamic network that seamlessly integrates multiple modes of transportation to optimize the flow of cargo. In Europe and across the world, intermodal and multimodal transport systems have emerged as key catalysts for enhancing connectivity, reducing transportation costs, and minimizing environmental impact.

As countries strive to forge stronger links in their logistical chains, the importance of comprehensive analysis cannot be understated. Understanding the intricacies of intermodal freight markets, both in Europe and specifically within Ukraine, becomes not only relevant but imperative in fostering a competitive and resilient economy. For Ukraine, a nation endowed with a strategic geographical location and burgeoning trade potential, a well-calibrated intermodal freight strategy is not only aligned with global trends but also deeply intertwined with its national transport and development strategy up to 2023.

Ukraine's aspiration to harness the power of intermodal freight systems is anchored in its broader vision for robust and sustainable economic growth. The need to augment intermodal and multimodal transportation capabilities resonates not only with international best practices but also with the country's own strategy to elevate its position as a key player in regional and global trade. The ongoing analysis of intermodal freight dynamics both in Europe and Ukraine serves as a compass guiding policy makers, industry stakeholders, and investors toward strategies that optimize efficiency, boost competitiveness, and foster environmentally conscious choices.

In a comprehensive exploration of intermodal freight markets, a collection of articles was examined to unravel key insights and trends within the realm of multimodal transport and its impact on various aspects of transportation and logistics. These articles delved into diverse facets, ranging from the development of intermodal transport in individual EU countries to the challenges faced by the European rail freight sector. While each article offered valuable perspectives, a systematic analysis has revealed common threads and discernible limitations across the research landscape.

Through an in-depth review of these articles, several prominent conclusions emerge, shedding light on the current status, challenges, and potential avenues for enhancing intermodal freight transport:

Insufficient methodological detail: some articles lack in-depth descriptions of the methodologies used for data collection, analysis, or audits, affecting the credibility of the research [4, 6, 8, 10]

Data inconsistencies: multiple articles note data inconsistencies or lack of disaggregated data, limiting the accuracy and reliability of their findings [4, 5, 8]

Lack of comparative analysis: some articles do not sufficiently compare intermodal transport with other modes or analyze the advantages and disadvantages in a broader transport context [6, 7, 9]

Inadequate future outlook: a few articles lack discussions about future trends, potential developments, or how research findings might evolve over time [1, 2, 4, 7, 9]

Scope and sample size: limited geographic coverage, small sample sizes, or focus on specific segments hinder the generalizability of findings to larger regions or the entire intermodal transport industry [4, 5, 7, 9.]

Limited economic analysis: few articles discuss economic impacts, cost-effectiveness, or financial sustainability of the proposed solutions or recommendations [3, 8, 9.]

Infrastructure focus: some articles emphasize infrastructure issues without comprehensive analysis of existing infrastructure, development strategies, or the relationship between infrastructure and modal shift. [7, 10]

Based on the research and analysis of current investigations of European and Ukrainian markets, our analysis could potentially address the following limitations:

Data inconsistencies: our research could contribute to solving the limitation of data inconsistencies by conducting a thorough investigation into the availability and quality of data related to intermodal freight transportation. By identifying data gaps and proposing methods to improve data collection, standardization, and sharing, our research could promote the use of accurate and reliable data for informed decision-making and policy formulation.

Inadequate future outlook: our research could provide valuable insights into the future outlook of intermodal freight transportation in Europe and Ukraine. By analyzing emerging trends, technologies, and market dynamics, your article can offer predictions and recommendations that contribute to informed decision-making and strategic planning in the intermodal transport sector.

Research and analysis.

Before we started the analysis, we had several assumptions of dependencies between the volumes of EU intermodal transport and other indicators:

• Funding and volumes: the hypothesis is that increased funding of transport volumes may lead to higher volumes of intermodal transport volume as it can support infrastructure development and operational improvements.

• GDP and volumes: The hypothesis is that economic growth, as represented by GDP, may have a positive impact on intermodal transport volumes as it reflects increased trade and economic activity.

• Mode shares and volumes: this can help identify if certain modes, such as rail or trucking, have experienced significant changes in their market shares over time and if those changes align with changes in overall volumes.

The question is whether all these variables have a mutual impact on the dependent variable — EU intermodal freight volumes.

By performing Multiple Linear Regression on these variables, we identified patterns, trends, and potential causal relationships over time. It's important to note that the specific dependencies discovered depend on the data and the time period being analyzed. The analysis may provide insights into how different factors, such as funding and economic conditions, impact the growth and dynamics of EU intermodal freight transportation.

For the analysis we used data derived from the Special report Intermodal freight transport [10] and European Commission website [12]. As for the dependent variable, it was 'Goods transported' in intermodal transport units. Independent variables selected for the analysis were: 'Gross Domestic Product (GDP)', 'Road vehicles (accompanied)', 'Founded projects and investments related to intermodal transport', 'Railways & inland waterways', 'Railways, Roads, Inland waterways' — which refer to shares of different transport modes. The time period — 10 years from 2012-2022 (Table 1).

Based on the provided OLS regression results (Figure. 1), here are some key observations.

1. R-squared: the R-squared value of 0.122 indicates that the selected variables (GDP, road vehicles, and railways) explain only a small portion (12.2%) of the variation in intermodal transport volumes. This suggests that there are other likely factors influencing intermodal transport volumes that are not captured in the current model.

2. Coefficients: the coefficients represent the estimated effect of each variable on intermodal transport volumes. In this case, the coefficient for GDP is -0.0102, for road vehicles it is 0.2068, and for railways it is -30520. These coefficients suggest a weak or negligible relationship between these variables and intermodal transport volumes. However, none of the coefficients are statistically significant ($P>|t| > 0.05$), indicating that the relationships observed could be due to random chance.

3. Adjusted R-squared: the adjusted R-squared value of -0.317 indicates that the inclusion of the selected variables actually worsens the model's fit. This suggests that the selected variables may not be appropriate predictors of intermodal transport volumes or that there may be multicollinearity issues among the variables.

4. Other statistics: The statistics such as F-statistic, p-values, AIC, BIC, omnibus, and Durbin-Watson are additional measures of model fit, significance, and goodness-of-fit. However, in this case, none of these statistics provide strong evidence of a meaningful relationship between the variables.

Table 1 - EU intermodal freight transportation market data

Variables	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
GDP	15.207.863	15.353.133	15.821.900	16.712.834	16.832.668	17.282.585,80	13.533.331,00	14.018.762,00	13.461.663,70	14.532.191,10	15.806.899,30
Road vehicles	N/A	558.653,00	390.615,00	270.502,00	256.877,00	265.147,00	241.954,00	347.293,00	167.443,00	236.611,00	128.490,00
Goods transported	N/A	245.381,00	231.327,00	233.226,00	243.345,00	253.628,00	277.125,00	281.702,00	259.514,00	289.798,00	34.771,00
Founded projects and investments	32.385.602,00	N/A	12.848.647,00	68.779.100,00	275.527.016,00	18.419.524,00	19.144.401,00	59.607.636,00	36.537.283,00	1.118.000.000,00	N/A
Railways, inland waterways, %	25,40	25,20	25,20	24,80	24,30	23,50	24,40	23,70	22,60	22,70	N/A
Railways	18,50	18,30	18,40	18,30	18,00	17,50	18,60	17,70	16,80	17,00	N/A
Roads	74,60	74,80	74,80	75,20	75,70	76,70	75,60	76,30	77,40	77,30	N/A
Inland waterways	6,80	6,90	6,80	6,50	6,20	6,00	5,80	6,00	5,80	5,60	N/A

Sources:[10], [12]

Overall, based on these results, it is difficult to establish a strong and statistically significant relationship between intermodal transport volumes and the selected variables (GDP, road vehicles, and railways). Further analysis with a larger dataset and consideration of other potential factors may be necessary to gain a more comprehensive understanding of the relationships.

The limitations of the Multiple Linear Regression method for our particular case may be solved with the help of another method — Polynomial Regression, which we used for another set of variables and with the aim of discovering dependencies between the volumes of intermodal freight transport in Ukraine and other indicators:

Population density: Higher population density in an area may lead to increased demand for intermodal transport.

Trade volume: The volume of international trade can have a direct impact on the demand for intermodal transport services.

Infrastructure investments: The level of investments in transportation infrastructure, such as ports, railways, and roads, can influence the efficiency and capacity of intermodal transport.

Energy prices: Fluctuations in energy prices, especially fuel costs, can affect the operational costs of intermodal transport and, in turn, impact volumes.

OLS Regression Results

Dep. Variable:	Intermodal Volumes	R-squared:	0.837
Model:	OLS	Adj. R-squared:	0.744
Method:	Least Squares	F-statistic:	9.176
No. Observations:	5	Prob (F-statistic):	0.0807
Df Residuals:	1	Scale:	9.051e+09
Df Model:	3		
Covariance Type:	nonrobust		

	coef	std err	t	P>|t|	[0.025	0.975]
const	-7.614e+06	2.616e+07	-0.291	0.859	-3.77e+08	3.63e+08
GDP	0.1665	0.152	1.095	0.464	-2.410	2.743
Road Vehicles	0.0637	0.067	0.953	0.484	-2.903	3.030
Railways	-0.1206	0.117	-1.031	0.454	-2.232	1.990

Omnibus:	nan	Durbin-Watson:	2.800
Prob(Omnibus):	nan	Jarque-Bera (JB):	0.498
Skew:	0.500	Prob(JB):	0.779
Kurtosis:	1.500	Cond. No.	1.14e+06

Figure 1 - OLS Regression Results

Authoring

Manufacturing output: The level of manufacturing activity in an area or country can be an indicator of the need for efficient transportation of goods, potentially driving intermodal transport volumes.

International economic conditions: Factors such as global economic growth, trade agreements, and political stability can influence the demand for intermodal transport on an international scale.

Given the results we obtained during the analysis of the EU market of intermodal freight, to discover the trends of the Ukrainian market we also opted for additional method — Polynomial Regression.

The results (Figure. 2) indicate the output of a multiple linear regression analysis that aims to model the relationship between the dependent variable "Intermodal freight (mln. t)" and several independent variables: "Goods transported by railway (mln. t)," "Population density (mln)," "Import volumes (mln)," "Export volumes (mln)," "Energy prices for non-households (UAH for 1 kWh)," "Industrial Production Index," and "GDP growth (annual %)."

The R-squared value of 1.000 suggests that the model explains 100% of the variance in the dependent variable, indicating a perfect fit. However, such a high R-squared value may be a result of overfitting or collinearity issues, especially with a limited number of observations.

Table 2 - Ukrainian intermodal freight transportation market data

Metrics	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Goods transported by railway, mln. t	457,50	441,80	387,00	350,00	344,10	339,50	322,30	312,90	305,50	314,30	26,20
Intermodal freight, mln. t	4,575	4,418	3,87	3,5	3,441	3,395	3,223	3,129	3,055	3,143	0,262
Population density, thousands	45633,6	45439,822	45410,071	42910,885	42738,07	42584,5	42364,933	42122,657	41879,904	41588,354	41208,106
Population density, mln	45,6336	45,439822	45,410071	42,910885	42,73807	42,5845	42,364933	42,122657	41,879904	41,588354	41,208106
Import volumes, thousands	84.658.059,90	76.963.965,40	54.428.716,90	37.516.443,00	39.249.797,20	49.607.173,90	57.187.578,00	60.800.173,10	54.336.136,68	6.186.613,48	55.295.748,39
Import volumes, mln	84658,0599	76963,9654	54428,7169	37516,443	39249,7972	49607,1739	57187,578	60800,1731	54336,13668	6186,613478	55295,74839
Export volumes, th	68809810,6	63312022,1	53901689,1	38127149,7	36361711,2	43264736	47334987	50054605,8	49191824,52	6020580,676	44135592,46
Export volumes, mln	68809,8106	63312,0221	53901,6891	38127,1497	36361,7112	43264,736	47334,987	50054,6058	49191,82452	6020,580676	44135,59246
Infrastructure investments, mln	N/A	6807,7	4531,2	9070,3	16781,1	23801,9	32731,6	43792,8	34884,6	528802	N/A
Energy prices for non-households (UAH for 1 kWh)	N/A	N/A	N/A	N/A	N/A	N/A	2,19	2,24	1,9	2,25	N/A
Industrial Production Index	98,5	95,2	112,8	94,2	94,3	98,3	102,1	101	96,1	92,8	95,9
GDP growth (annual %)	0,152	0,045	-10,079	-9,773	2,441	2,36	3,488	3,2	-3,753	3,446	-29,1

Source:[13]

Each coefficient estimates the change in the dependent variable associated with a one-unit change in the corresponding independent variable, assuming all other variables remain constant. The coefficients have extremely small values (e.g., 10^-12 or 10^-15), which might indicate a problem with the scale of the data or potential multicollinearity.

The p-values for most of the coefficients are not significant, suggesting that the independent variables do not have a statistically significant effect on the dependent variable in this model.

The F-statistic is enormous (1.536e+25), but the probability (Prob F-statistic) is very low (2.53e-38), suggesting that at least one of the coefficients is significant. However, since the p-values for individual coefficients are not significant, this result should be interpreted with caution.

The Omnibus test (Prob(Omnibus)) and the Jarque-Bera test (Prob(JB)) assess the normality assumption of the residuals. In this case, the residuals may not be normally distributed as the p-values for these tests are greater than the typical significance level of 0.05.

OLS Regression Results

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Dep. Variable: Intermodal freight (mln. t) R-squared: 1.000

Model: OLS Adj. R-squared: 1.000

Method: Least Squares F-statistic: 1.536e+25

Log-Likelihood: 307.27

No. Observations: 11

AIC: -598.5

Df Residuals: 3 BIC: -595.4 Df Model: 7 Covariance Type: nonrobust

==

coef std err t P>|t| [0.025 0.975]

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const -1.091e-12 1.33e-11 -0.082 0.940 -4.34e-11 4.12e-11

Goods transported by railway (mln. t) 0.0100 8.66e-15 1.15e+12 0.000 0.010 0.010

Population density (mln) 3.575e-14 4.54e-13 0.079 0.942 -1.41e-12 1.48e-12

Import volumes (mln) -5.421e-19 7.66e-17 -0.007 0.995 -2.44e-16 2.43e-16

Export volumes (mln) 6.234e-19 9.87e-17 0.006 0.995 -3.13e-16 3.15e-16

Energy prices for non-households (UAH for 1 kWh) 7.327e-15 2.14e-13 0.034 0.975 -6.73e-13 6.88e-13

Industrial Production Index -3.83e-15 4.8e-14 -0.080 0.941 -1.57e-13 1.49e-13

GDP growth (annual %) 5.343e-15 5.78e-14 0.092 0.932 -1.79e-13 1.89e-13

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Omnibus: 4.210

Durbin-Watson: 0.035

Prob(Omnibus): 0.122

Jarque-Bera (JB): 2.244

Skew: 1.105

Prob(JB): 0.326

Kurtosis: 2.886

Cond. No. 9.50e+06

Figure 2 - OLS Regression Results

The Durbin-Watson statistic is very close to 0, indicating potential positive autocorrelation among the residuals, which may violate one of the assumptions of linear regression.

The condition number (Cond. No.) indicates that there might be strong multicollinearity or other numerical problems, which can affect the reliability of the coefficient estimates.

In summary, the current model with these variables may not be suitable for predicting intermodal freight volumes accurately.

Based on the analysis, the correlation between intermodal freight volumes and the selected variables ('Goods transported by railway', 'Population density', 'Import volumes', 'Export volumes', 'Energy prices for non-households', 'Industrial Production Index', and 'GDP growth') is quite complex and might not be straightforward to interpret. The model used for the analysis claims to explain 100%

of the variance in intermodal freight volumes, but this level of fit is unusual and could indicate potential issues with overfitting the data.

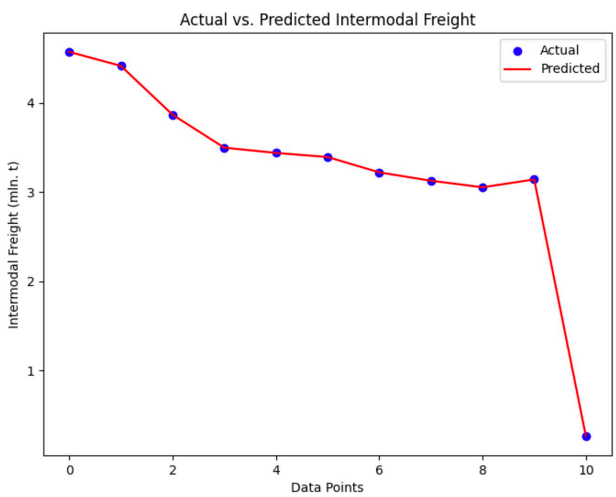
Using alternative statistical methods like Polynomial Regression can be beneficial when dealing with complex relationships and nonlinear patterns in the data. Linear regression assumes a linear relationship between the dependent variable and independent variables, but in many real-world scenarios, the relationships may be more intricate. Polynomial regression extends linear regression by introducing polynomial terms to capture nonlinear relationships. This can be useful when the relationship between the variables is curvilinear.

The polynomial regression model with an R-squared value of 1.0 (Figure. 3) perfectly fits the data, which means it describes a relationship between intermodal freight volume and the other variables that perfectly explains the observed variations in the data. However, due to the high complexity of the polynomial model and the possibility of overfitting, the specific functional form of the relationship may not be straightforward to interpret.

In general terms, the polynomial regression model captures not only linear relationships between intermodal freight volume and other variables but also nonlinear relationships. This means that the model can describe complex dependencies between intermodal freight volume and the variables considered.

The model considers various interactions between the input features (variables) and their higher-order terms, which allows it to adapt to curvilinear patterns and more intricate relationships. Consequently, the model may describe scenarios where the impact of certain variables on intermodal freight volume varies non-linearly with their values.

[3.82445334e-18 7.57905714e-12 2.42540162e-13 -1.45939402e-09
-1.12451237e-09 7.49922487e-10 1.05311486e-13 4.63650794e-13
4.11778527e-12 4.25190898e-09 4.21988977e-10 8.01014858e-08
1.05617676e-07 -8.09524699e-08 2.65394315e-11 1.04905472e-09
1.22061089e-09 2.16412597e-11 -4.57580436e-08 -3.21539671e-08
2.54976705e-08 4.27267728e-12 5.05799843e-11 1.72532797e-10
9.52556473e-11 -1.05469356e-09 4.33455461e-10 9.13339292e-09
-7.07281410e-08 1.36267657e-07 4.77810807e-10 -2.17255941e-10
7.25812080e-09 -3.73989911e-08 1.34212145e-07 3.61969700e-11
1.16332596e-08 4.81139489e-08 4.78771205e-08 2.76971145e-13
9.97503145e-12 2.64191882e-13 1.20227208e-10 3.59460288e-10
-3.93919503e-11]



Intercept: 2.4636766792491382

R-squared value of the polynomial regression: 1.0

Root mean squared error (RMSE): 1.8261243633040052e-15

Figure 3 - Polynomial Regression results: actual vs predicted intermodal freight volumes in Ukraine

Summary and conclusions.

In an ever-evolving global trade landscape, the article emphasizes the vital role of intermodal freight markets in optimizing the movement of goods. It underscores the importance of rigorous analysis in guiding policy makers, stakeholders, and investors toward strategies that enhance connectivity, competitiveness, and sustainability. By delving into the intermodal dynamics of both Europe and Ukraine, the article identifies complexities and potential trends that have implications for future developments in the intermodal freight sector.

The results of the Multiple Linear Regression analysis indicate that the selected variables, including GDP, road vehicles, and railways, explain only a small portion of the variation in EU intermodal transport volumes. The coefficients are generally weak and statistically insignificant, suggesting that the relationships observed may be due to chance. The analysis underscores the need for a more comprehensive dataset and consideration of other potential factors.

The Polynomial Regression analysis for the Ukrainian intermodal freight market reveals a model with an R-squared value of 1.0, indicating a perfect fit to the data. However, such a high R-squared value raises concerns about overfitting. The model captures complex relationships between intermodal freight volumes and variables like population density, trade volumes, energy prices, and economic conditions. While the results offer insights into nonlinear patterns, the high complexity of the model calls for cautious interpretation.

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