



Modeling and Forecasting the Post-war Economic Recovery of Ukraine's Transport Potential

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Abstract. The article's purpose is to model and forecast the post-war economic recovery of Ukraine's transport potential. The construction of dynamic models and forecasting of the constituent parameters of Ukraine's transport potential in the system of global socio-economic development was carried out. The characteristics of the periods and predictive estimates of ex-post-war dynamic models of the development of transport potential are offered. The authors developed systematic approaches to eliminate the subjectivity of the obtained results, using statistical data from the State Statistics Service of Ukraine and modern tools of the Microsoft Excel application program. It was determined that to build ex-post war dynamic models and forecast the constituent parameters of the national transport potential in the system of socio-economic development, it is proposed to carry out research based on grouping the characteristics of the transport potential according to its resource capabilities and production results, by distinguishing the following groups of indicators: material resources, human resources, investment resources, production results. Grouping and building ex-post war dynamic models are proposed, which allow structuring the resources of the transport system to achieve maximization or optimization of the production results of the transport system in the context of national socio-economic development and to determine forecast estimates for certain parameters of the transport potential of Ukraine.

Keywords: post-war economic recovery · transport potential · modeling and forecasting · post-war dynamic models

1 Introduction

The effectiveness of the socio-economic development of Ukraine largely depends on the transport potential, the unique role of which is actualized in martial law conditions and in the post-war period of reconstruction of the economy of Ukraine. Opportunities to

carry out various types and volumes of transportation are essential for socio-economic development and the country's defense capability needs. Great attention should be paid to the possibilities of restoration and development of the national transport potential of Ukraine based on the use of forecasting tools, which will allow optimizing the structural relations not only of transport subsystems but also of the processes of production of the gross national product, systematizing product, passenger, investment and information flow at the level of the country and its regions.

The analysis of previous results of scientific research shows that a lot of attention at the national and regional levels is paid to the evaluation of the transport system and transport potential [1, 2], however, most of the published results are based on expert assessments, which are subjective and cannot be extended over time, especially in extreme conditions of military aggression. The impact of globalization processes on the development of socio-economic systems is determined separately [3–6].

Thus, to date, there are no uniform methodological approaches to the evaluation of the transport potential of Ukraine and the possibilities of forecasting its constituent components. In our opinion, using available statistical data and modern tools of applied programs is essential for predicting the constituent parameters of the national transport potential based on dynamic models in the system of socio-economic development. For the

Table 1. Essential definition of the categories “potential”, “transport potential” and “logistic potential”

Authors	Definition
Definition A.I. Anchyshkin [7]	“potential” means certain opportunities, reserves, means that can be used to implement goals, tasks, and plans.”
Marks K. [8]	“means, objects of work and labor are only opportunities, that is, potential” (interpretation of potential as a system of material and labor factors, conditions, and components that ensure the achievement of production goals)
Ansoff I. [9]	“the potential is the ability of the resource complex of the economic system to implement the tasks assigned to it” (the potential is considered as a complete system with the unity of the structure and functions of the object and their interconnection)
Alkema V.G. [10]	“transport potential of the country - quantitative and qualitative properties and resources of the country's transport system, as well as its ability to increase the level of efficiency of functioning and ensure the proper level of transport service to consumers, taking into account the interests of the state and the entire society
Uvarov S. A. [11]	“Logistics potential includes elements of the infrastructure complex of logistics that contribute to the achievement of the goals of enterprises in the field of organizing regional and interregional supplies”

objectivity of the substantiation of the proposed methodological approaches to building dynamic models of the national transport potential and making predictive assessments, it is necessary to investigate the fundamental techniques for defining the categories “potential” and “transport potential” and “logistics potential” (Table 1).

So, it is possible to generalize that the transport potential covers all possibilities (material, human resources, investment resources, etc.) that can be used to transport anyone or anything, that is, to obtain the results of the production of the transport system, which is an essential component of the national production infrastructure.

2 Discussion

To build dynamic models and forecast the constituent parameters of the national transport potential in the system of socio-economic development, we propose to carry out research based on grouping the characteristics of the transport potential according to its resource capabilities and production results, highlighting the following groups of indicators (table):

- material resources;
- human resources;
- investment resources;
- production results.

There is a relationship between the selected indicators for forecasting the components of the national transport potential: material, human and financial resources, as components of the transport potential, affect the results of the production of the transport system. Taking such interrelationships into account allows structuring the help of the transport system to achieve maximization or optimization of the production results of the transport system in the context of national socio-economic development.

One of the essential tasks of regulation of the transport potential in the design of national socio-economic development is the determination of estimated values of the necessary resources to achieve the expected (or predicted) production results of the transport system. The socio-economic development of Ukraine is characterized by the presence of natural factors (intensification of military aggression) and conditions of uncertainty. That is why it is necessary to use mathematically based means and tools to forecast the main parameters of the transport potential. A forecast in the economic sphere is considered a scientifically or expertly based definition of estimated numerical values of economic indicators, their trends, and patterns of change for future periods.

An important forecasting task for the management and administration system is to predict the consequences (results) depending on the difference in the input parameters of the influencing factors. Forecasts formulated based on experts' subjective opinions, despite having some experience, still cannot be considered objective. That is why the need to use the tools of modern application programs for making forecasts, which ensures the formalization of relationships between individual parameters of predictive dynamic models, is becoming urgent. The forecast values of the parameters of the national transport potential in the system of socio-economic development should be based on the patterns identified in previous periods and be implemented through the extrapolation (extension) of the levels of the series of dynamics for the selected indicators.

Table 2. Characteristics of groups of hands for building dynamic models and forecasting the components of the national transport potential in the system of socio-economic development

Group of indicators	Component indicators of the group
Material resources	<ul style="list-style-type: none"> - Initial (revalued) cost of fixed assets by type of economic activity “Transport, warehousing, postal and courier activities”, UAH million (MR1); - The cost of new fixed assets received during the year, by type of economic activity “Transport, warehousing, postal and courier activities”, million hryvnias (MR2)
Human resources	<ul style="list-style-type: none"> - The average number of full-time employees of enterprises of the economic activity “Transport, warehousing, postal and courier activities”, is thousands of people (LR1)
Investment resources	<ul style="list-style-type: none"> - Capital investments by type of economic activity “Transport, warehousing, postal and courier activities” (IR1)
Production results (financial and transport-production)	<ul style="list-style-type: none"> - Profitability of all activities of enterprises of the type of economic activity “Transport, warehousing, postal and courier activities”, percentages (P1); - Volume of sold products (goods, services) of enterprises by type of economic activity “Transport, warehousing, postal and courier activities”, UAH million (P2); - Export of transport services and telecommunication services, thousands of dollars. USA (P3); - import of transport and telecommunication services, thousands of dollars USA (P4)

Source: grouping proposed by the authors

Phenomena and processes characterizing the national transport system have the property of changing over time, they can be described using trend equations $y = f(t) + \xi t$, where $f(t)$ is a functional representation of the primary trend, i.e. the regularity revealed in previous periods, and ξt is the degree of deviation of the actual values from the primary trend. It is believed that the trend equation has the form: “ $y = f(t) + \xi t$, where $f(t)$ is the deterministic non-random component of the process (phenomenon), ξt is the stochastic random component of the process” [11].

The possibilities of building dynamic models and predictive estimates are significantly expanded and simplified due to modern application tools, among which Microsoft Excel is one of the most widely used. With the help of Microsoft Excel, it is possible to perform a functional and graphical representation of the primary trend $f(t)$, as well as to determine estimated values for predictive parameters, that is, to perform extrapolation (continuation) of the series of dynamics for the studied indicators. To extrapolate the levels of the dynamics series, the following prerequisites must be met: - the ranks of

the investigated series of dynamics for previous periods should form the main pattern of change (main trend) $f(t)$ and stochastic deviations ξt ; - the arsenal of mathematical functions makes it possible to present ways of changes in any socio-economic phenomena or processes; - Microsoft Excel tools and methods of mathematical statistics make it possible to minimize stochastic deviations ξt . All the above conditions are satisfied by all groups of indicators for building dynamic models and forecasting the components of the national transport potential in the system of socio-economic development from Table 2.

In Ukraine's current martial law conditions, it is expedient to talk not just about the need to build dynamic development models but about ex-post military dynamic models. Ex-post - from Latin means "after the fact". In our case, after the end of the war, there is a period of recovery, the end of which is identified with the restoration of the previous development trends established before the war. Regarding the period of forecast estimates, in the current conditions of martial law in Ukraine, we suggest considering three periods: potentially lost, recovery period (ex-post period), and post-recovery periods (Table 3).

Table 3. Characterization of the periods and prognostic assessments of ex-post military dynamic models of the development of transport potential

Brief description period	Predictive assessment
A potentially lost period for economic development	I
Period of recovery of economic development (ex-post period)	II
Post renewable period	III

It is possible to supplement the group of indicators characterizing material resources in the national structure of transport potential with other indicators (for example, the residual value of fixed assets or wear and tear of fixed assets of the transport system), however, to demonstrate the algorithm for calculating the parameters of dynamic models and predictive estimates, it is advisable to limit ourselves to the indicators listed in Table 2.

The same opinion applies to other groups of hands that can be expanded. Most importantly, in the process of modeling, adhere to the grouping of indicators proposed above, which corresponds to the interpretation of the transport potential through the categories of opportunities (material, human resources, investment resources, etc.) and the results of the production of the transport system, which is an essential component of the national production infrastructure. The dynamics of the initial cost of fixed assets by the type of economic activity "Transport, warehousing, postal and courier activities" for 2015–2021 shows a fluctuation of values, which is characterized by a consistent increase and decrease from year to year. And the dynamics of the cost of new fixed assets are also characterized by fluctuating values but without clear systematicity. From 2015–2021, there is an increase in both the initial cost of fixed assets and the annual amount of new fixed assets (Table 4).

Table 4. Material resources in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities”

	2015	2016	2017	2018	2019	2020	2021	Increase 2021–2015
The original (revalued) cost of fixed assets, UAH million (MR1)	7641357	8177408	7733905	9610000	9574186	10577278	10819289	3177932
The cost of new fixed assets received, UAH million (MR2)	216697	202120	237793	306147	437695	376384	462940	246243

Source: data from [12]

During the studied period of 2015–2021, the initial (revalued) value of fixed assets in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities” increased by UAH 3,177,932 million, i.e. on average every year it increased by UAH 529,655.3 million, and the cost of new fixed assets increased by UAH 246,243 million, that is, on average, it grew by UAH 41,040.5 million every year.

For the functional and graphical representation of the regularity of changes in the indicators of dynamic models for the constituent components of the national transport potential in the system of socio-economic development, we will choose the form of the trend equation to which the most significant value of the coefficient of determination R^2 will correspond and whose graphical representation will not deviate sharply from the actual data for the studied period 2015–2021 (Fig. 1).

Modeling the dynamics of material resources in the national structure of transport potential for 2015–2021 made it possible to present the pattern of changes in the original (revalued) value of fixed assets and the importance of new fixed assets with a significant value of the coefficient of determination ($R^2 > 0.9$), which indicates a high level of approximation trend values to actual statistical data and provides grounds for calculating forecast estimates based on the obtained trend equations.

The dynamics of changes in the original (revalued) value of fixed assets by type of economic activity “Transport, warehousing, postal and courier activities” is described by the second-order polynomial $y = 6609.8x^2 + 517472x + 7E + 06$, based on which forecast values for the following are calculated periods The III forecast estimate for the initial cost of fixed assets for the post-recovery period amounted to UAH 12,738,523 million.

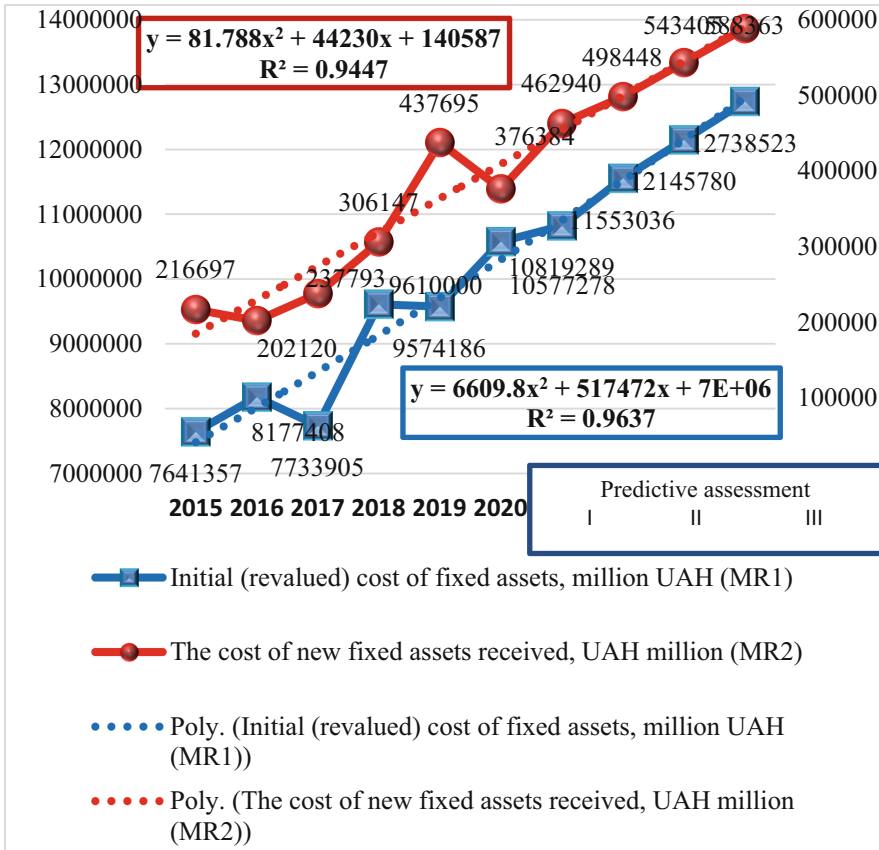


Fig. 1. Modeling the dynamics of material resources in the national structure of transport potential

Taking into account the fact that in 2022 the economy of Ukraine was greatly affected by Russian aggression, it is possible to claim that the forecast estimates for 2022 and 2023 are not realistic since the war considerably changed the main socio-economic patterns. The year 2022 can be considered potentially lost from the point of view of building dynamic models of the socio-economic sphere. After the end of the war, during the period of recovery of the country’s economy, the task of restoring the previous trends and reaching the levels of the predetermined (pre-war) forecast estimate, which was derived for the years 2015–2021, that is, for the period before the beginning of Russia’s invasion of Ukraine, is actualized.

Thus, it is possible to claim that the end of the period of recovery and reconstruction of the economy of Ukraine after the Russian aggression should be identified with the achievement of the level of most economic indicators, which will correspond to the predicted estimates determined based on extrapolation of trend equations constructed for regularities for the years 2015–2021 because the potential should be restored.

Of course, it is possible to change the length of the recovery period and forecast periods, but the calculation algorithm is preserved. The same can be said about the remaining parameters of the national transport potential of Ukraine, which characterize human resources, investment resources, and production results in the transport system (Tables 5, 6 and 7).

Table 5 Human resources in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities” The same can be said about the remaining parameters of the national transport potential of Ukraine, which characterize human resources, investment resources and production results in the transport system (Tables 5, 6 and 7).

Table 5. Human resources in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities”

	2015	2016	2017	2018	2019	2020	2021	Increase 2021–2015
Average registered number of full-time employees, thousand persons (LR1)	661,4	659,9	655,2	648,4	635,1	625,8	614,3	–47,1

Source: data from [12]

During the studied period of 2015–2021, the average number of full-time employees in the system of the national transport potential of Ukraine by the type of economic activity “Transport, warehousing, postal and courier activities” decreased by a total of 916.8 thousand people, that is, on average every year the average registered number of full-time employees decreased by 7,8 thousand people. Such a reduction in the number of employees was achieved due to optimization processes in the transport system and warehouse management.

The regularity of changes in the average accounting number of full-time employees in the system of the national transport potential of Ukraine can also be represented using the second-order polynomial $y = -0,0927x^2 - 6,3863x + 671,51$ (Fig. 2).

Modeling the dynamics of human resources in the federal structure of the transport potential for 2015–2021 made it possible to present the pattern of changes in the average accounting number of full-time employees with a significant value of the coefficient of determination $R^2 = 0,9854$, which indicates a high level of closeness of trend values to actual statistical data and provides grounds for calculation of forecast estimates.

The forecast estimate III for the post renewable period for the average registered number of full-time employees in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activity” amounted to 6768.7 thousand people. The next group of indicators of the study of the national transport potential is investment resources, represented by the indicator of capital investment by type of economic activity “Transport, warehousing, postal and courier activities” (Table 6).

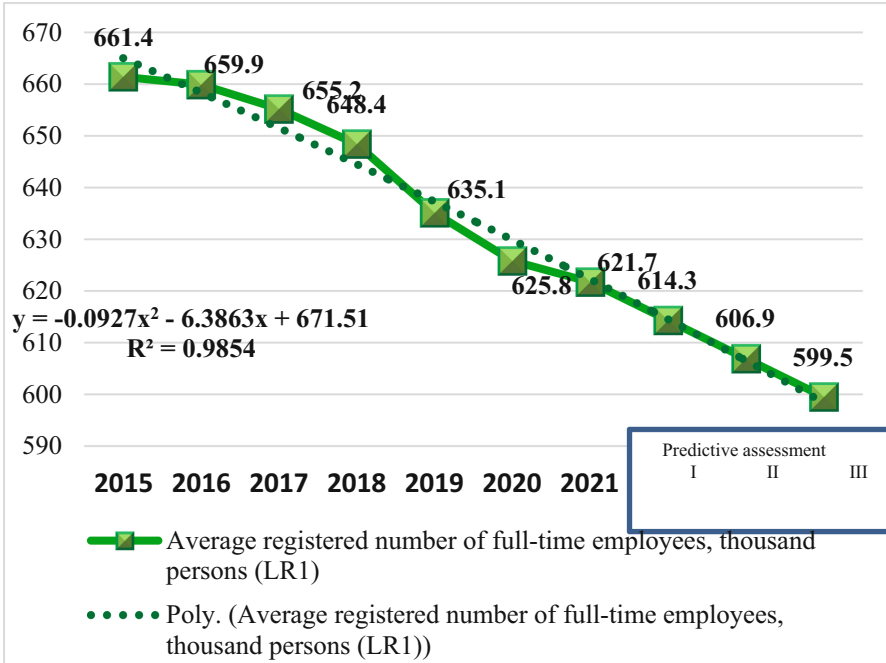


Fig. 2. Modeling the dynamics of human resources in the national structure of transport potential

Table 6. Investment resources in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities”

	2015	2016	2017	2018	2019	2020	2021	Increase 2021–2015
Capital investments, UAH million (IR1)	273116,4	359216,1	448461,5	578726,4	623978,9	508217,0	685291,7	412175,3

Source: data from [12]

Over the studied period of 2015–2021, capital investments in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities” increased by UAH 412,175.3 million, that is, on average, capital investments increased by UAH 68,695.9 million.

The regularity of changes in the level of capital investments in the system of the national transport potential of Ukraine can also be represented using the second-order polynomial $y = -1610.2x^2 + 77896x + 219856$ (Fig. 3).

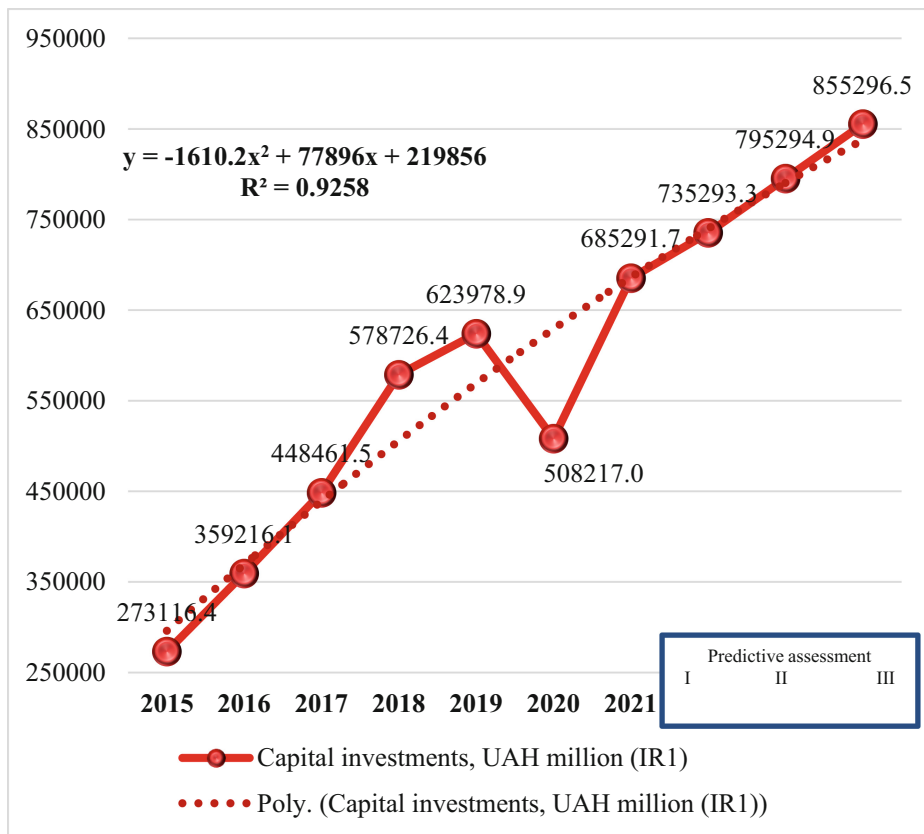


Fig. 3. Modeling the dynamics of investment resources in the national structure of transport potential

Modeling the dynamics of investment resources in the national structure of transport potential for 2015–2021 made it possible to present the regularity of changes in the number of capital investments with a significant value of the coefficient of determination $R^2 = 0.9258$, which provides grounds for calculating forecast estimates. The III forecast estimate for the post-recovery period for capital investments in the system of the national transport potential of Ukraine by the type of economic activity “Transport, warehousing, postal and courier activities” amounted to UAH 855,296.5 million. As the resulting indicators of the use of all kinds of resources in the system of national transport potential, it is possible to use several indicators, including value measurement of the volume of products sold (goods, services), profitability, export, and import of transport services, etc. (Table 7).

Table 7. Production results in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities”

	2015	2016	2017	2018	2019	2020	2021	Increase 2021–2015
Profitability of all activities, interest (P1)	−4,9	1,8	−3,5	−4,3	1,4	1,6	1,7	6,6
Volume of sold products (goods, services), million UAH (P2)	5318957,7	6387872,7	7862695,2	9388092,1	9841060,7	10273152,5	11844231	6525273,3
Export of transport services, thousands of dollars. USA (P3)	5263155,3	5300545,6	5861405,6	5851423,3	9109918,8	4988433,7	7066933	1803777,7
Import of transport services, thousands of dollars. USA (P4)	1153393,5	989274,8	1213073,6	1464807,2	1559143,8	1061043,8	1390082	236688,5

Source: data from [12]

Over the entire period of 2015–2021, there was an increase in the level of profitability of all production activities in the system of the national transport potential of Ukraine by the type of economic activity “Transport, warehousing, postal and courier activities”, a consistent increase in the volume of sold products was also observed (+6525273.3 million UAH), export of transport services (+1803777.7 thousand USD).

The export of transport services decreased in 2016 compared to 2015. In 2017–2019, exports increased, and in 2020, there was a decrease again. In general, for 2015–2021, imports increased by 236,688.5 thousand dollars. Analogous to the above calculations, it is possible to determine forecast estimates of production results in the system of the national transport potential of Ukraine (Table 8) in terms of each indicator given in Table 7.

It should be emphasized again that the estimated forecast values for 2022 and 2023 are not realistic for Ukraine due to Russian aggression. Only after the recovery of Ukraine’s economy will the predictive estimates built on the basis of the revealed regularities of the pre-war period become relevant again. Thus, for the post-restoration period, it is possible to assert the actualization of the issue regarding the forecasted estimates determined on the basis of extrapolation of trend equations constructed for the identified regularities for the years 2015–2021 (Table 7).

Table 8. Predictive estimates of production results in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities”

	Predictive assessment I for a potentially lost period	Predictive assessment II for the recovery period (ex-post period)	Predictive assessment III for the post renewable period
Profitability of all activities, interest (P1)	2,6	3,5	4,3
Volume of sold products (goods, services), million UAH	12891544	13938857	14986169
Export of transport services, thousands of dollars USA	7353920	7640906	7927893
Import of transport services, thousands of dollars USA	1432927	1475773	1518618

Source: author's calculations

Within the framework of building dynamic models of the national transport potential, an interesting question is the study of relationships between its individual parameters: resources (material, investment and human) and production results (Table 9).

There is a close correlation between the above indicators, which are parameters of dynamic models of the national transport potential, which is proven by constructing a correlation table (Table 10).

The results of the calculations prove the presence of a close relationship between all the parameters we have chosen for building dynamic models of the national transport potential because all the values of the correlation coefficients are relative to 1 (Table 10).

Thus, we proved the hypothesis put forward at the beginning that material, human and financial resources, as components of the transport potential, affect the results of the production of the transport system. And the methodological approaches proposed by us to the construction of dynamic models of the national transport potential allow making predictive assessments and structuring of the resources of the transport system to achieve maximization or optimization of the results of the production of the transport system in the context of national socio-economic development.

Table 9. Dynamics of indicators of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities” for the study of interrelationships

	2015	2016	2017	2018	2019	2020	2021
Volume of sold products (goods, services), million UAH (P2) Y	5318957,7	6387872,7	7862695,2	9388092,1	9841060,7	10273152,5	11844232
The original (revalued) cost of fixed assets, UAH million (MR1) X_1	7641357	8177408	7733905	9610000	9574186	10577278	10960292
The cost of new fixed assets received, UAH million (MR2) X_2	216697	202120	237793	306147	437695	376384	453491
The average registered number of full-time employees, thousand people (LR1) X_3	661,4	659,9	655,2	648,4	635,1	625,8	621,7
Capital investments, UAH million (IR1) X_4	273116,4	359216,1	448461,5	578726,4	623978,9	508217,0	675291,7

Source: data from [12]

Table 10. Correlation table of dependence between the volume of sold products and material, human, and investment resources in the system of the national transport potential of Ukraine by type of economic activity “Transport, warehousing, postal and courier activities”

	Y	X_1	X_2	X_3	X_4
Y	1				
X_1	0,974792	1			
X_2	0,968512	0,957138	1		
X_3	0,977419237	0,981358162	0,97768667	1	
X_4	0,980178	0,934403	0,958346	0,92992	1

Source: author's calculations

3 Conclusion

The great importance of the transport potential for the effective socio-economic development of the state, for ensuring the production processes of the gross product, the systematization of goods, passengers, and other flows at the level of the entire country and its regions is indisputable, which actualizes the methodical approaches proposed by us to the construction of dynamic models and the preparation of forecast estimates post-war economic recovery of the national transport potential. To implement the proposed methodological approaches and to eliminate the subjectivity of the obtained results, statistical data of the State Statistics Service of Ukraine and modern tools of the Microsoft Excel application program was used. The category “transport potential” is proposed to be understood as all the possibilities (material, human resources, financial and investment resources, etc.) that can be used to transport anyone or anything, that is, to obtain the results of the production of the transport system, which is a critical component national production infrastructure.

To build ex-post-war dynamic models and forecast the constituent parameters of the national transport potential in the system of socio-economic development, it is proposed to carry out research based on the grouping of the characteristics of the transport potential according to its resource capabilities and production results, distinguishing the following groups of indicators: material resources, human resources, investment resources, production results. The proposed grouping and built ex-post war dynamic models allow structuring the transport system's resources to maximize or optimize the transport system's production results in the context of national socio-economic development and to determine predictive estimates for individual parameters of the national transport potential.

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