КОТЕНКО С.В.

канд. тех. наук, доцент, ст. наук. співробітник,
Інститут проблем ринку та економіко-екологічних досліджень НАН України
Французький б-р, 29, м. Одеса, Україна, 65044
E-mail: kotenko_ua@yahoo.com
ORCID: 0000-0003-2977-095X

КАСЬЯНОВА В.А.

канд. мат. наук, доцент,
Одеський технологічний університет «ШАГ»
вул. Садова, 3, м. Одеса, Україна, 65000
E-mail: borzolerka@gmail.com
ORCID: 0000-0002-6302-366X-095X

КОЛОСОК В. М.

д-р. ек. наук, доцент,
завідувачка кафедри транспортного менеджменту і логістики,
Приазовський державний технічний університет,
вул. Університетська 7, Маріуполь, Україна, 87500
E-mail: kolosok.v.m@gmail.com
ORCID: 0000-0002-6657-933X

ВИЗНАЧЕННЯ ВПЛИВУ ФАКТОРІВ КОНКУРЕНТОСПРОМОЖНОСТІ НА ВАНТАЖНІ ПЕРЕВЕЗЕННЯ ВОДНИМ ТРАНСПОРТОМ

Актуальність. Актуальність проведеного дослідження обумовлюється тим, що в умовах сучасної кризи, яка викликає значні зміни навіть в традиційних видах господарської діяльності, з'являються нові фактори впливу, виявляються мультиколінеарні групи чинників, які посилюють вплив один одного, і ці тенденції також ще не достатньо розкриті в науковій літературі. Тому постає вкрай актуальна задача, пов'язана не з традиційною оцінкою ваги впливу відомих факторів, а виявлення нових чинників, з'ясування наявності тенденцій до кореляції впливу двох і більше факторів. Це може бути критичним при формуванні релевантних прогнозів.

Мета та завдання. Основною метою дослідження статті є розроблення математичних методів виявлення як ідентифікованих, так і не ідентифікованих на вході в задачу факторів впливу на показники конкурентоспроможності водного транспорту.

Для досягнення цієї мети поставили наступні завдання: розроблення математичної формалізації виокремлення аперіодичних та фонових впливів на результуючу функцію; створення формальних підходів до обробки первинних даних та результатів отриманих за використання розробленої математичної моделі для зменшення відносної похибки та отримання релевантних результатів.

Результати. Досліджено теоретико-прикладні положення підвищення ефективності вантажоперевезень водним транспортом з урахуванням чинників його конкурентоспроможності. На відміну від традиційних підходів, які спираються на виявлений заздалегідь комплекс факторів впливу на результуючу функцію завданням дослідження була розробка математичних методів виявлення як ідентифікованих, так і не ідентифікованих факторів впливу на показники конкурентоспроможності водного транспорту за його видами. Для цього було використано оригінальну модифікацію методу часових рядів. За використання розробленої математичної моделі проведено аналіз обсягів перевезення вантажів водним транспортом за його видами. Були застосовані додаткові методичні засоби для ад'єктивування прогнозних значень на наступний період часу. Використання розроблених підходів вказало на їх практичну цінність для нівелювання фонових впливів сторонніх факторів та аперіодичних гармонік, що дозволило лінеаризувати досліджені динамічні ряди, виділити групи факторів впливу та конкретизувати найбільш вагомі чинники які дозволяють використати конкурентні переваги водного транспорту України чи перешкоджають їх використанню.

Висновки. Аналіз результатів проведеного дослідження дозволяє зробити наступні висновки: представлена математична модель та запропоновані методи формалізації дозволяють розробити за використання динамічних рядів та наявних в первинних даних фонових та аперіодичних гармонік релевантні прогнозні дані; впровадження розробленої математичної моделі дозволить виявляти вплив на результуючу функцію ефективності вантажоперевезень чинників, не ідентифікованих при постановці задачі. Вказане

дозволить отримати релевантні прогностичні дані на наступні періоди, ефективно сприяти впровадженню заходів використання конкурентних переваг та нейтралізувати загрози.

Ключові слова: вантажні перевезення, конкурентоспроможність, водний транспорт, математична модель, алгоритм, часові ряди.

KOTENKO S.V.

PhD, senior researcher

Institute of market problems and economic&ecological research of the National Academy of Sciences of Ukraine, Frantsuzkyiboulevard, 29, Odesa, Ukraine, 65044

E-mail: kotenko_ua@yahoo.com

ORCID: 0000-0003-2977-095X

KASIANOVA V.A.

PhD, Associate Professor

Private institution of higher education «Odessa University of Technology «Shah»», Sadova Street, 3, Odesa, Ukraine, 65000

E-mail: borzoilerka@gmail.com

ORCID: 0000-0002-6302-366X

KOLOSOK V. M.

Doctor of Economic Sciences, Associate Professor

Head of the Department of Transport Management and Logistics,

Priazovsky State Technical University,

7 Universitetska str, Mariupol, Ukraine, 87500

E-mail: kolosok.v.m@gmail.com

ORCID: 0000-0002-6657-933X

DETERMINATION OF INFLUENCE OF COMPETITIVENESS FACTORS ON FREIGHT TRANSPORTATION BY WATER TRANSPORT.

Topicality. The relevance of the study is due to the fact that in the current crisis, which causes significant changes even in traditional economic activities, there are new factors of influence, there are multicollinear groups of factors that increase each other's influence, and these trends are not yet sufficiently disclosed in scientific literature. Therefore, there is an extremely important task, not related to the traditional assessment of the weight of the influence of known factors, but the identification of new factors, finding out the tendency to correlate the influence of two or more factors. This can be critical in making relevant predictions.

Aim and tasks. The main purpose of the study is to develop mathematical methods for detection both identified and unidentified at the entrance to the problem factors influencing the competitiveness of water transport. To achieve this goal, the following tasks arose: development of a mathematical formalization of the separation of aperiodic and background effects on the resulting function; creation of formal approaches to the processing of primary data and results obtained using the developed mathematical model to reduce relative error and obtain relevant results.

Research results Theoretical and applied provisions of increase of efficiency of cargo transportations by water transport taking into account factors of its competitiveness are investigated. In contrast to traditional approaches, which are based on a previously identified set of factors influencing the resulting function, the task of the study was to develop mathematical methods for detection both identified and unidentified factors influencing the competitiveness of water transport by its types. For this purpose, the original modification of the time series method was used. Using the developed mathematical model, the analysis of volumes of cargo transportation by water transport by its types is carried out. Additional methodological tools were used to adjust the forecast values for the next period of time. The use of the developed approaches indicated their practical value for leveling the background effects of external factors and aperiodic harmonics, which allowed to linearize the study time series, identify groups of influencing factors and specify the most important factors that allow to use the competitive advantages of water transport in Ukraine.

Conclusion. Analysis of the results of the study allows us to draw the following conclusions: the presented mathematical model and the proposed methods of formalization allow us to develop using time series and available in the primary data of background and aperiodic harmonics relevant forecast data; the introduction of the developed mathematical model will reveal the impact on the resulting function of the efficiency of freight transportation of factors not identified in the problem. (возможно лучше такой вариант перевода Analysis of the results of the study allows us to draw the following conclusions: the presented mathematical model and the proposed methods of formalization allow us to develop using time series and available in the primary data of background and aperiodic harmonics relevant forecast data; introduction of the developed mathematical model will allow to reveal influence on the resulting

function of efficiency of cargo transportation of the factors which have not been identified at statement of a problem. This will provide relevant forecast data for future periods, effectively promote the implementation of measures to use competitive advantages and neutralize threats.

Key words: freight transportation, competitiveness, water transport, mathematical model, algorithm, time series.

Problem statement and its connection with important scientific and practical tasks. Water transport, in particular, sea and river - are highly efficient modern types of cargo transportation. Not all factors of influence for them, especially in their totality, are studied in full. In addition, in the current crisis, which affects all aspects of life and activities of man and society, causes significant changes, even in traditional economic activities, there are new factors of influence, there are multicollinear groups of factors that increase each other's influence, and these trends are also not yet sufficiently disclosed in the scientific literature. Therefore, it provides a new task - not a traditional assessment of the weight of the impact of certain factors, but the identification of new factors, finding out the tendency to correlate the impact of two or more factors, as this may be critical in making relevant forecasts. In this case, the identification of the nature and nature of the influencing factor gives way in the algorithm for estimating its weight to the very determination of the presence of influence.

Analysis of recent publications on the problem. The problem of identifying factors influencing the transportation of goods, estimating their weight, is widely studied in the scientific literature. Thus, in the work of Ilchenko [1] the parametric features and criteria of linear transportations are investigated. Wang [2] uses the fuzzy Delphi method to estimate the parameters of multimodal transportation using the stage of sea transportation of goods. Chao [3] applied equation modeling (SEM) to test the structural model of the transport system to identify and estimate impact factors. Woo [4] found the model parameters and coefficients of the structural equation as a result of the analysis of the supply chain and factors influencing the routes of cargo transportation. Liu Song [5] analyzed and evaluated the factors influencing the choice of multimodal freight. Litman [6] formed an algorithm for selecting effective solutions for multimodal transportation based on factor estimation of impact parameters. In the dissertation of Sossoe [7] the approach with use of algorithm of the analysis of large structured networks is realized. Kramarz [8] used the method of coevolution to create an efficient transboundary transport ecosystem. Panayides [9] proposed the definition of key variables that form a structure of higher order, the so-called "Terminal Supply Chain Integration (TESCI)", which is detailed using factor analysis. The authors also have work on this problem, in particular, Kotenko [10] on the prediction of multimodal traffic based on the assessment of the impact of stochastic, fuzzy and deterministic factors, and this article is a continuation of these studies. A review of the scientific literature indicates that scientists have developed a significant body of work to address this problem. In the scientific literature there are a large number of algorithms and mathematical models that implement certain approaches to identify factors influencing the solution of the problem and further optimization of multimodal transport.

Allocation of previously unsolved parts of the general problem. Methods of mathematical formalization of detection of influence of heterogeneous factors on indicators of competitiveness of water transport need further research.

Formulation of research objectives (problem statement). The aim of the article is to develop mathematical methods for identifying both identified and unidentified at the entrance to the problem factors influencing the competitiveness of water transport.

An outline of the main results and their justification. For modeling and forecasting of transportations by water transport the method of time series which is sometimes still called by names of authors by a method of Box-Jenkins was used as a mathematical basis [11]. This method has been used many times in economic research and consists in the fact that the algorithm is first executed: detection of the dependence of a certain factor on time (so-called time series formation); assessment of factors influencing this factor; diagnosing the formed model; if iterative repetition of the first steps of the algorithm to increase the relevance of its results; using the model of the appropriate level of relevance of forecasting for the next period. The Box-Jenkins method is known to be an implementation of both autoregressive analysis and the method of sliding or so-called "moving" mean. The mathematical model that mathematically formalizes this method is known to be called the ARMA (p, q) model, because it combines AR and MA models. The AR-part belongs to the simulation of the stationarity of a variable parameter, and the MA-segment simulates the so-called "White noise", which in our interpretation is interpreted as a background effect [11]. This method was modified not only to form a relevant forecast, but also to identify among the factors such that the nature of the impact on the main functional dependence of the time series would differ from others in the strength of the impact (amplitude), direction of impact, etc. This approach allows to identify among the factors those

whose influence, in their entirety, is hereinafter referred to as background and the factors whose influence in our previous studies is called absorptive, because their weight is greater than the total weight of the whole set of background factors. That is, there is a problem of identifying among the background effects of structured aperiodic harmonics. This approach expands the possibilities of the method of detection of obvious absorption factors to the detection of background harmonics of lower power (amplitude). The advantage of the method is that there are opportunities that are a priori impossible with known methods, for example, in factor analysis. In factor analysis, a set of parameters influencing the objective function or the resulting factor is formed as input information into the algorithm. And then the presence or absence of the influence of each of the predetermined factors on the resulting function, the weight of the influence of each factor on the specified function. But this approach does not allow to detect the influence of a parameter that is not predetermined in the vector of factors. The proposed method allows to detect the influence of the parameter not identified at the input to the problem, ie, in contrast to factor analysis, to detect its presence.

Mathematical formalization of the classical ARMA (p, q) - the task is as follows:

$$\varphi_t = \sum_{i=1}^n a_i \varphi_{t-i} + \sum_{i=1}^n b_i \varepsilon_{t-i} \quad (1)$$

де p – autoregression order; q – the order of the sliding or "moving" average; t - discrete value of the time interval on which the factor is determined; $i = 1, 2, 3 \dots, n$ – ordinal index value of the time interval in the order of its increase; a_i – autoregression coefficients; b_i – coefficients of sliding or "moving" average, ε_{t-i} – background (random) harmonics.

The proposed mathematical formalization is as follows:

$$\varphi_t = \sum_{i=1}^n a_i \varphi_{t-i} + \sum_{i=1}^n (\varepsilon_i + b_i \varepsilon_{t-i}) \quad (2)$$

Non-random harmonics are introduced into the structure of the equation ε_i . And now there is a problem of detection of the specified harmonics. They are determined by the variance of "errors" of mathematical implementation using the Malowz criteria, AIC and BIC [12]. Usually these criteria are used to adjust the relevance of the description of the mathematical model of the real process. We have proposed the opposite - their use to identify inconsistencies in the background effect. These discrepancies characterize non-random harmonics. But this algorithm requires significant computer resources and time. To reduce these costs, the following algorithm is proposed: the temporal functional dependence of the factor is linearized. In the case where the specified functional dependence is mathematically "smooth", this obviously means that non-random harmonics do not differ from the background - that is, they are part of the background. In the case when the specified functional dependence is a broken line or is characterized by peak values - these deviations from linearized smooth functions are non-random harmonics. Their frequency and amplitude are their characteristic features. In the case of using smaller samples (for example, annual) to detect the effect of nonrandom harmonics, it is proposed to estimate the dual curves of the multidimensional space of variables or, in the case of a flat, dual variant of the graphical representation of the problem. This is the first sign that non-random harmonics are present and their identification requires more detailed analysis. However, in the case of a small sample, as the analysis shows, a multiplicative integral effect of the harmonic group is possible. Therefore, if necessary, to identify the influence of each of the non-random harmonics, it is advisable to return to factor analysis and algorithms for the variance of "errors" using the Malowz criteria, AIC and BIC. Using the presented model, we will analyze the volume of cargo transportation by water transport (see Fig. 1). To objectify the analysis of the integrated assessment of the competitiveness of the respective type of water transport (see Fig. 1, Fig.2, Fig.3) relative rather than absolute characteristics were applied - the ratio of the share of traffic by the respective type of water transport from the total volume of traffic for the studied year. This allowed to eliminate the background effects on freight and to objectify the forecast values for the next period of time.

The results, in particular for maritime transport, can be approximated by the equation

$$y = 0,3421x^6 - 11,496x^5 + 148,34x^4 - 927,06x^3 + 2921,7x^2 - 4633,5x + 7133,8 \quad (1)$$

For river, respectively:

$$y = 0,0004x^4 - 927,06x^3 - 0,0012x^2 + 0,0014x + 0,0024 \quad (2)$$

Even a cursory analysis indicates the dynamics of significant fluctuations in the volume of water transport by its types.

Fig.1. The share of water transport in the total volume of traffic

Source: Compiled by the authors based on data [14,15]

Using equation (1) to generate a forecast for subsequent periods will result in a significant relative error that is greater than 8.15% for the first of the forecast periods and increases for subsequent periods. This is due to the growing relative influence of non-random harmonics. At the next stage, we fragment the problem into smaller time intervals, perform linearization of the cleaning effect of aperiodic harmonics (see Fig.2, Fig.3 and Table 1). This makes it possible to reduce the relative error of the forecast to 1.5-2%, which is a significant result for practical tasks. The tangent of the angle of inclination of the linearized dependence of the dynamics of the share of transportation of water transport in the total volume of traffic indicates the general characteristics of the trend of competitiveness of the respective type of water transport in the corresponding time interval. The tangent of the trend of the slope of river transport is equal to ~ 0 at a time interval 2015-2021 years indicates stagnation in the development of this mode of transport. Tangents of angles with a negative sign indicate the practical inability of the respective mode of transport to use competitive advantages in the studied period of time.

Fig.2. Linearization of cargo transportation by types of water transport in the interval 2010-2014 years.

Source: Compiled by the authors based on data [14,15]

Fig.3. Linearization of cargo transportation by types of water transport in the interval 2015-2021 years.
Source: Compiled by the authors based on data [14,15]

Table 1

The result of linearization of the dynamics of the share of transportation of water transport in the total volume of traffic.

Type of water transport	Interval of years			
	2010-2014		2015-2021	
	The tangent of the angle of inclination	Free coefficient	The tangent of the angle of inclination	Free coefficient
River	-0,0006	0,0042	0,00001	0,0023
Marine	-0,0001	0,0024	-0,0002	0,0022

Source: Compiled by the authors

The next step in the practical implementation of the model was to study the dynamics of the impact on competitiveness, in particular, seaports of cargo types, as integrating groups of factors of influence. For the indicator of competitiveness for objectification of research in this case the target function defined WEF [13] – «Quality of seaports of Ukraine» (see Table 2).

For the use of correlation-regression analysis (see Table 3), confirmed correlation of seaport quality for transit cargo turnover (x_3) and domestic traffic (x_4), with the corresponding coefficients of determination 0,52 and 0,65. Export and import turnover have a weak correlation with the objective function (their coefficients of determination, respectively, 0,22 and 0,26). Thus the directions of the analysis of positive and negative influence of factors of competitiveness on the specified objectified indicator are allocated.

Table 2

Dynamics of the indicator of quality of seaports of Ukraine according to WEF and research of groups of parameters of influence on it

Years	Function	Freight turnover parameters, thousand tons			
	Quality seaports	Export	Import	Transit	Domestic traffic
1	2	3	4	5	6
2010	3,6	84037,60	17440,60	44185,20	2470,30
2011	3,7	84895,00	19417,40	47599,20	3240,40
2012	4	96848,10	16493,70	38780,60	1844,20
2013	3,7	100115,13	17965,06	27224,46	2873,38
2014	3,27	103067,27	15932,23	20338,82	3457,25
2015	3,2	103942,61	17958,75	15904,24	6840,56
2016	3,4	100202,46	15976,45	10328,85	5238,20

continued Table 2

1	2	3	4	5	6
2017	3,5	98517,43	20417,94	11804,98	1838,09
2018	3,8	99034,64	23783,78	10221,37	2131,28
2019	3,9	120988,54	25849,88	11024,54	2138,26
2020	4,0*	122999,76	23669,84	10056,84	2398,69

* forecast indicator

Source: Compiled by the authors based on data [14]

Table 3

Two-dimensional vector of standardized coefficients

Years	Function	Parameters			
		x_1	x_2	x_3	x_4
2010	0,9	0,81	0,91	0,93	0,36
2011	0,92	0,82	0,99	0,99	0,46
2012	0,99	0,93	0,85	0,81	0,27
2013	0,93	0,94	0,91	0,58	0,42
2014	0,82	0,96	0,81	0,43	0,51
2015	0,8	0,99	0,91	0,33	0,58
2016	0,85	0,96	0,79	0,21	0,67
2017	0,87	0,82	0,92	0,34	0,47
2018	0,91	0,95	0,82	0,29	0,29
2019	0,93	0,96	0,91	0,32	0,41
2020	0,85	0,94	0,84	0,33	0,53

Source: own calculations

As the analysis shows, the growth of transit and domestic traffic is facilitated by a group of factors, first of all, the tendency to increase the container capacity of ports and increase the volume of inland waterway transport. This is confirmed, in particular, by the analysis of data on Container port throughput, given in Table 4. This indicator is generally acceptable for assessing the competitiveness of the port. It indicates the number of containers being processed and uses a twenty-foot equivalent as the base unit for data standardization (TEUs). The reduction in the turnover of exports and imports is also multiplied by factors of international markets and the domestic economic situation.

Table 4

Indicators of port infrastructure of Ukraine

Indexes	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Container port capacity, TEU	654 000	756 000	756 000	779 000	665000	480000	588000	698 500	1 178 000	1 340 40

Source: Compiled by the authors based on data [13, 14]

Conclusions and perspectives of further research. The presented results of research are devoted to increase of efficiency of freight transportations by water transport taking into account factors of its competitiveness. In contrast to traditional approaches, which are based on the identified set of factors, the aim of the work was to develop mathematical methods for identifying both identified and unidentified at the entrance to the problem factors influencing the competitiveness of water transport. A modification of the time series method was used for this purpose. Using the presented model, the analysis of volumes of cargo transportation by water transport by its types was carried out. Additional methodological tools were used to adjust the forecast values for the next period of time. Their use indicated their practical value for leveling the

background effects of external factors and aperiodic harmonics. As the analysis showed, a group of factors contributes to the growth of transit cargo turnover and domestic traffic turnover, first of all, the tendency to increase the container capacity of ports and increase the volume of inland waterway transport. The study revealed the facts of reducing the turnover of exports and imports. These indicators are multiplied by factors of international markets and the domestic economic situation. At the same time, negative trends in reducing the cargo turnover of exports and cargo turnover of imports were revealed. It is indicated that the reduction of these indicators is multiplicatively influenced by groups of factors, in particular, changes in international markets and the domestic economic situation in a crisis. The presented work will require additional research in the direction of creating algorithms for detecting and identifying the full range of influencing factors.

ЛІТЕРАТУРА

1. Ilchenko S. V., Mezina L. V., Mashkantseva S. A., Larina T. F. Parametric features and criteria of the development of the market for linear transportation. *Financial and credit activity: problems of theory and practice*. 2019. T. 4. № 31. C. 184-195. DOI: <https://doi.org/10.18371/fcaptp.v4i31.190832>
2. Wang Y., Yeo G.-T. A study on international multimodal transport networks from Korea to Central Asia. *Asian Journal of Shipping and Logistics*. 2016. № 32(1). C. 41-47. DOI: 10.1016/j.ajsl.2016.03.005
3. Chao P. The Impact of Multimodal Transport Service Value and Relationship on Business Performance – Thai Shippers' Perspective: Ph.D. thesis. – Cardiff, 2011. – 316 c.
4. Woo S., Pettit S. J., Beresford A. K. C. An assessment of the integration of seaports into supply chains using a structural equation model. *Supply Chain Management*. 2013. T. 18. № 3. C. 235-252. <https://doi.org/10.1108/SCM-09-2011-0264>
5. Liu Song, Shao Yiming, Peng Yong. Optimization of Multimodal Transport Paths for Refrigerated Containers Under Carbon Emission Restriction[J]. *Applied mathematics and mechanics*. 2020, № 41(2). C. 204-215. doi: 10.21656/1000-0887.400159
6. Litman T. Introduction to multi-modal transportation planning principles and practices. *Victoria transport policy Institute*. 2011. № 6. 1-12
7. Sossoe K. Modeling of multimodal transportation systems of large networks: dissertation for the degree of doctor of philosophy. Automatic Control Engineering. "University Paris-Est ". – Paris, 2017. – 187 c.
8. Kramarz M., Knop L., Przybylska E., Dohn K. Stakeholders of the Multimodal Freight Transport Ecosystem in Polish–Czech–Slovak Cross-Border Area. *Energies*. 2021. № 14. C. 22-42. <https://doi.org/10.3390/en14082242>
9. Panayides P.M., Song D. Evaluating the integration of seaport container terminals in supply chains. *International Journal of Physical Distribution & Logistics Management*. 2008. T. 38. № 7. C. 562-584. <https://doi.org/10.1108/09600030810900969>
10. Kotenko S., Nitsenko V., Hanzhurenko I., Havrysh V. The Mathematical Modeling Stages of Combining the Carriage of Goods for Indefinite, Fuzzy and Stochastic Parameters. *International Journal of integrated engineering*. 2020. T. 12. № 7(20). C. 173-180. DOI: <https://doi.org/10.30880/ijie.2020.12.07.019>
11. Бокс Дж. Анализ временных рядов, прогноз и управление/ Дж. Бокс, Г. Дженкинс// под ред. В.Ф. Писаренко. – М.: Мир, 1974, кн. 1. – 406 с.
12. Перерва А. С., Ковалюк Т. В. Порівняльний аналіз методів прогнозування стаціонарних та нестаціонарних часових рядів. *Журнал науковий огляд*. 2018. № 3(46),
13. World Economic Forum. Reports: URL: <https://www.weforum.org/reports?year=2020#filter> (дата звернення 07. 07. 2021).
14. Administratsiia morskyykh portiv Ukrainy. Pokaznyky roboty.(2021). [Адміністрація морських портів України. Показники роботи.] URL: <http://www.uspa.gov.ua/pokazniki-roboti> (дата звернення 07. 07. 2021).
15. Державна служба статистики України: URL: <http://www.ukrstat.gov.ua> (дата звернення 07. 07. 2021).

REFERENCES

1. Ilchenko, S. V., Mezina, L. V., Mashkantseva, S. A., Larina, T. F. (2019). Parametric features and criteria of the development of the market for linear transportation. *Financial and credit activity: problems of theory and practice*, 4, 31. 184-195. DOI: <https://doi.org/10.18371/fcaptp.v4i31.190832> [in English].

2. Wang, Y., Yeo, G.-T.(2016). A study on international multimodal transport networks from Korea to Central Asia. *Asian Journal of Shipping and Logistics*, 32(1),. 41-47. DOI: 10.1016/j.ajsl.2016.03.005 [in English].
3. Chao, P. (2011). The Impact of Multimodal Transport Service Value and Relationship on Business Performance – Thai Shippers' Perspective: Ph.D. thesis. Cardiff. Retrieved from: <http://orca-mwe.cf.ac.uk/54440/1/U584541.pdf> [in English].
4. Woo, S., Pettit, S. J., Beresford, A. K. C.(2013). An assessment of the integration of seaports into supply chains using a structural equation model. *Supply Chain Management*, 18, 3, 235-252.DOI <https://doi.org/10.1108/SCM-09-2011-0264> [in English].
5. Liu Song, Shao Yiming, Peng Yong (2020). Optimization of Multimodal Transport Paths for Refrigerated Containers Under Carbon Emission Restriction [J]. *Applied mathematics and mechanics*, 41(2, 204-215.DOI doi: 10.21656/1000-0887.400159 [in English].
6. Litman, T. (2011). Introduction to multi-modal transportation planning principles and practices. *Victoria transport policy Institute*, 6, 1-12. Retrieved from: https://www.researchgate.net/publication/237820138_Introduction_to_Multi-Modal_Transportation_Planning [in English].
7. Sossoe, K. (2017). Modeling of multimodal transportation systems of large networks: dissertation for the degree of doctor of philosophy. Automatic Control Engineering. "University Paris-Est ". Paris. Retrieved from: <https://tel.archives-ouvertes.fr/tel-01748442/document> [in English].
8. Kramarz, M., Knop, L., Przybylska, E., Dohn, K. (2021). Stakeholders of the Multimodal Freight Transport Ecosystem in Polish–Czech–Slovak Cross-Border Area. *Energies*, 14, 22-42.DOI <https://doi.org/10.3390/en14082242> [in English].
9. Panayides, P.M., Song, D.(2008). Evaluating the integration of seaport container terminals in supply chains. *International Journal of Physical Distribution & Logistics Management*, 38, 7, 562-584.DOI <https://doi.org/10.1108/09600030810900969> [in English].
10. Kotenko, S., Nitsenko, V., Hanzhurenko, I., Havrysh,V. (2020). The Mathematical Modeling Stages of Combining the Carriage of Goods for Indefinite, Fuzzy and Stochastic Parameters. *International Journal of integrated engineering*, 12, 7(20), 173-180. DOI: <https://doi.org/10.30880/ijie.2020.12.07.019> [in English].
11. Boks, Dzh. (1974). *Analyz vremennykh riadov, prohnoz y upravlenye* [Time series analysis, forecasting and management] M.: Myr, 1. [in Russian].
12. Pererva, A. S., Kovalyuk T. V. (2018). Comparative analysis of prediction methods of stationary and nonstationary series. *Journal of Scientific Review*, 3(46), Retrieved from: <http://oaji.net/articles/2017/797-1530622306.pdf> [in Ukrainian].
13. World Economic Forum. Reports. (2021). Retrieved from: <https://www.weforum.org/reports?year=2020#filter> [in Ukrainian].
14. Administratsiia morskikh portiv Ukrainy. Pokaznyky roboty. (2021). [Administration of seaports of Ukraine. Performance indicators] Retrieved from: <http://www.uspa.gov.ua/pokazniki-roboti> [in Ukrainian].
15. State Statistics Service of Ukraine (2021). Retrieved from: <http://www.ukrstat.gov.ua>. [in Ukrainian].