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FORECASTING THE STRATEGIC DEVELOPMENT OF THE UKRAINIAN PORT INDUSTRY

An estimation variant of port development based on comparison of the cargo flows structure through the port with the port infrastructure was developed. The influence of external conditions on the activity of ports is shown. With the help of the criterion of structural correspondence between the cargo flow and the capacity of the port, the ways of development of Ukrainian ports are indicated. The possibility of using the criterion to predict the development of the port depending on the forecast of changes in the structure of the cargo flow is shown.

The integral criterion of structural correspondence between the cargo flow and the throughput of the ports allows to evaluate the activity of the ports in the current and forecast periods. For the ports of Ukraine there is a structural mismatch between the cargo flow and the installed transshipment capacity. The paper shows the possibility of predicting the development of the technical equipment of ports, depending on the change in the size and structure of cargo flows through the ports.

The use of the integral criterion of structural correspondence between the cargo flow and the capacity of the ports in predicting the development of ports allows to increase the efficiency of the port economy. Future research should consider forecasting the development of individual ports to improve the efficiency of the country's port economy as a whole. The high intensity of Ukrainian ports operation now gives hope for their competitive ability in the future.

Keywords: *seaport, cargo flow, structural compliance criterion, port development forecast.*

Formulation of the problem. «The maritime port industry is directly linked to the development of the world and domestic economy, its efficiency depends on the efficiency of logistics of large export-oriented enterprises, its improvement not only reduces the cost of purchases of imported goods and sales of finished products, but also allows to increase revenues through expansion transit»[1]. For the comparative analysis of the activities of ports in different countries and economic conditions, according to some researchers, it is considered appropriate to use natural efficiency indicators. One such indicator is the ratio of seaport cargo turnover to port capacity. As an integral indicator, this criterion does not take into account the structure of the cargo flow of the port.

To evaluate the status and prospective planning of port traffic from different types of cargo, a criterion is proposed that allows to identify the capacity of the port for different categories of cargo structure of freight flow through the port.

The criterion of compliance of the port capacity by cargo categories to the structure of the cargo flow can be useful not only for the analysis of the technical condition of the port, but also for predicting the development of the port when changing the structure of the cargo flow.

Analysis of recent publications and research. N. K. Nikolaeva and A. L. Davidova offer the efficiency coefficient of the seaport work to calculate taking into account the technical equipment of the port, adaptability of the port to innovations and to environmental conditions [2].

The adaptability of the port to the innovations and environmental conditions are interconnected, as innovations are often caused by changes in the environment. For this reason, the numerator formulas for calculating the efficiency of the seaport, the coefficients of adaptability of the port to the

innovations and environmental conditions are summarized. The authors of the study do not specify how to properly assess the port's aforementioned suitability.

The coefficient of the technical equipment of the port can be calculated in the presence of detailed information about all the technical means of the port, which in some cases is difficult or impossible at all. Ports reference literature would at best provide information on port crane equipment without specifying the characteristics of the warehouse equipment, which sufficiently strongly affects the port's technical equipment.

Article [3] proposes a comprehensive use of logistic enterprise performance indicators. The author shows that to create a system of indicators of enterprise activity requires the creation of a database. After creating a database and performance metric, the researcher recommends that a benchmarking procedure be used to analyze the activity of the enterprise.

Of particular note is the proposal of the author to divide the performance indicators of the enterprise into indicators that characterize the enterprise and indicators that reflect the activity of the enterprise. In assessing the port's performance, this approach may be useful in some cases [2].

P.E. Zhelezkova recommends to use the following indicators when evaluating the port's performance: technical equipment, turnover, profitability, liquidity [4].

The efficiency of the seaports has been evaluated using criteria that establish the relationship between the output obtained and the resources spent to achieve this result. The criterion is usually expressed in relative quantities. Thus, in the numerator of the relative value is the achieved result of work, and in the denominator is the cost of achieving the result of work. A larger value of the indicator corresponds to a higher efficiency in this case [5].

An analysis of publications and research conducted on the topic of port performance evaluation shows that most researchers pay attention to the economic criteria of the evaluation. Technical criteria for port performance are considered by researchers less frequently and in many cases are not adapted to assess port performance due to the lack of sufficient information. Assessment of the status and forecasting of port development by the structure of processed cargoes are not produced.

The purpose of the article is to show the possibility of forecasting the development of the technical equipment of ports depending on changes in the size, orientation and structure of cargo flows through the ports.

Objectives of the study:

• based on the criterion of structural correspondence between the cargo flow and the capacity of the port to evaluate the activity of the ports in the current period;

• to detail the estimation of changes in external operating conditions of the ports;

• to make an estimation of port capacities structural transformations according to the estimation of changes in the port's external conditions.

Presenting main material. The comparison of a number of ports on the port capacity utilization efficiency with the same structure of cargo flow is carried out with the use of a differential indicator of the port operation on cargo transshipment. However, with different cargo flow patterns, this indicator is not sufficient for comparable ports.

The performance of a specialized seaport differs from that of a universal seaport. The comparison of the universal seaports' efficiency is connected with the need to take into account the structure of cargo handled by the ports. Therefore, the performance of the seaport must take into account the specificity of the different ports and ensure compatibility of ports of different specialization and structure.

As a criterion for evaluating or optimally designing the capacity of a universal seaport, a criterion is proposed that reflects the structural conformity of the cargo stream to the structure of the port capacity. The integral criterion of correspondence between the structures of port capacities and the cargo flow is the variance of the differential indicator of the port operation from transshipment of different types of cargoes, taking into account the employment rate of the berth for each type of cargo.

Let us consider the differential performance of the port transshipment of a certain type of cargo. The differential indicator of port's performance on transshipment of the i-th cargo is calculated by the formula:

$$k_{di} = \frac{P(i)}{Q(i)}, \quad (1)$$

where: $P(i)$ – annual turnover of the seaport by the i-th cargo,

$Q(i)$ - the annual capacity of the seaport on the i-th cargo.

The indicator quantifies the cargo turnover of the port for a specific cargo, related to the capacity of the port for the same cargo. In other words, the indicator characterizes the degree of use of port capacity in the current period by the i-th cargo. For each type of cargo, the k_{di} indicator will have its value. The indicator not only allows to evaluate the efficiency of using the installed

capacity in the seaport for transshipment of the i-th cargo, but also the possibility of the port if the urgent increase of the transshipment of the i-th cargo is necessary.

In order to improve port capacity utilization as a whole, it is necessary to increase in port those capacities that are close to unity and, accordingly, do not develop or re-profile capacities which are close to zero.

Simple ships and land transport significantly increase the transportation costs of cargo, so when planning cargo flows through the port, the port for occupying the berths of the port is introduced. The occupancy factor of the pier k_{zi} takes into account the need to use the installed capacity of the pier from transshipment of the i-th cargo without creating a queue of ships on the road, as well as without idle rail and road transport.

The technical standards of design of seaports stipulate that the employment rate of universal berths should be within 0.6 - 0.7 (60 - 70% of the time of use of berths). For container terminals, the employment rate is 0.4-0.5 [6].

Adjusted to take into account the employment rate of the berth, the value of the indicator of the installed capacity of the port from the transshipment of the i-th cargo is calculated by the formula:

$$k_{odi} = \frac{k_{di}}{k_{zi}} = \frac{P(i)}{Q(i) \cdot k_{zi}}, \qquad (2)$$

where: k_{di} – degree of utilization of port facilities by the i-th cargo,
k_{zi} – occupancy rate of berth for the i-th cargo.

The comparison of the ports efficiency at different structure of cargo flows should be made taking into account the variance of the indicator. A smaller value of the variance of the indicator indicates a better match of the structure of the installed port capacities to the structure of the cargo flow.

It is suggested to calculate the integral utilization of the installed capacity of the port from cargo handling according to the variance formula:

$$K_{oI} = \frac{\Sigma_1^n p_{zi} \cdot \left(\frac{k_{odi}}{k_{zi}} - \frac{k_{odsr}}{k_{zsr}}\right)^2}{\Sigma_1^n p_{zi}}, \qquad (3)$$

where: k_{odi} – adjusted port capacity utilization for i-th cargo,
k_{zi} – occupancy rate of berth for the i-th cargo,

k_{odsr} – corrected port capacity utilization by port, determined by the weighted arithmetic formula,

k_{zsr} – weighted average employment rate of berths on the port,

p_{zi} – weight factor of impact of the i-th cargo,

n – the number of types of cargo in the port taken into account when considering the efficiency of use of installed port facilities.

$$k_{odsr} = \frac{\Sigma_1^n p_{zi} \cdot \frac{k_{odi}}{k_{zi}}}{\Sigma_1^n p_{zi}}, \quad (4)$$

$$k_{zsr} = \frac{\Sigma_1^n p_{zi} \cdot k_{zi}}{\Sigma_1^n p_{zi}}. \quad (5)$$

As a weighting factor for the i-th cargo p_{zi} it is recommended to accept the volume of the annual i-th cargo transshipment. In this case, in the denominator of formula (3), we will receive the annual volume of cargo port processing after summation, which is taken into account when considering the use efficiency of installed port facilities.

If the weight of the impact of the i-th cargo is taken as the profit from the annual transshipment of the i-th cargo, then in the denominator of formula (3) we obtain the annual amount of the port's profit from the transshipment of cargoes, which are taken into account in the study.

In some circumstances, the weighting factor for the i-th cargo can be taken as a transshipment tariff for that cargo.

A port for which the installed capacity utilization rate is higher, has a large uneven capacity utilization of the port from different types of cargo. "Ideal" in terms of bandwidth compliance with port structure, the port will have a value close to zero. If a port is ineffectively designed on a cargo flow structure relative to a port capacity structure (a capacity structure is opposite to a cargo flow structure), then it will have a value close to 0.25 with an average of about 0.5.

The integrated capacity utilization index can be used to evaluate the efficiency of installed capacity from ports transshipment in the region or the country as a whole. In this case, the correspondence between the structure of a region or country cargo flow and the structure of installed capacity for ports cargoes transshipment of a region or a state as a whole is considered.

Let us consider the application of the integrated port capacity utilization indicator for the example of several seaports of Ukraine. The largest ports of Ukraine today are the ports: Southern, Odessa, Nikolaev, Chernomorsk, which account for 80% of all seaports of the country's ports [7].

The values of the integrated utilization rate of the installed capacity in the port without taking into account the structure of cargo flow for the largest ports of Ukraine are shown in Table 1.

1. The degree of use of the largest Ukrainian ports (2016)

№	The name of the port	Turnover, million tons	Capacity, million tons	k_{di}	k_{zi}	k_{odi}
1	Southern	39,3	61,5	0,639	0,7	0,913
2	Odessa	25,3	56	0,452	0,7	0,645
3	Mykolaiv	22,4	29,6	0,757	0,7	1,081
4	Chernomorsk	15,9	64,3	0,247	0,7	0,353
5	Mariupol	7,6	18,8	0,404	0,7	0,578
	Average	22,1	46,04	0,500	0,7	0,714

The table was created by the authors on the basis of the information given in [8]

The value of the integral indicator of Ukrainian seaports capacity utilization is given in Table. 1 and is in the range of 0.35 - 1.0, taking into account the employment rate of berths corresponds to the full use of the capacity of ports for transshipment of some cargo types and the low utilization of the ports possibilities for other cargo types. The value of the capacity utilization index, taking into account the employment rate of berths for the port of Mykolaiv, exceeds one (1,081), indicates the queues of vessels in the port waiting for processing with the adopted employment rate of the port berths.

The capacity of the seaport is determined by the capacity and structure of the cargo devices installed in the port. Table 2 shows the volume and structure of the main cargoes (top 10) processed by Ukrainian ports.

The strategy for port development should be based on strategic cargo flows forecasts. It is necessary to forecast freight flows, taking into account the development of the national economy and relations of Ukraine with other countries.

2. Volume and structure of goods transshipment by Ukrainian ports

№	Type of cargo	2017, thous. tons	2018, thous. tons	percent in 2017	percent in 2018	2017/ 2018
1	Bread	40651	41380	0,3066	0,306	0,998
2	Ore	27464	28061	0,2072	0,208	1,002
3	Ferrous metals	14816	16082	0,1118	0,119	1,065
4	Containers	7883	10935	0,0595	0,081	1,361
5	Coal	10815	8103	0,0816	0,060	0,735
6	Vegetable oil	5545	5544	0,0418	0,041	0,981
7	Construction	5867	4633	0,0443	0,034	0,774
8	Chemicals & Fertilizers	3700	3798	0,0279	0,028	1,007
9	Heavy duty vehicles	1209	1831	0,0091	0,014	1,486
10	Petroleum products	1851	1288	0,0140	0,010	0,682
	Other	12778	13517	0,0964	0,100	1,038
	Total	132578	135171	1,0000	1,000	1,020
	Throughput		240000			

The table was created by the authors on the basis of the information given in [7]

IMF World Economic Outlook reports allow you to make estimates on the development of Ukraine's international trade and economy, and on that basis make forecasts of cargo volumes in seaports. Three variants of the change scenario of annual cargo through Ukrainian seaports are shown in Table 3.

Taking into account the probable scenario of the Ukrainian economy growth, we will make a forecast of the goods transshipment volume by Ukrainian ports in 2022 - 2030. In constructing the forecast of the cargo’s transshipment volume, we will proceed from changes in the conjuncture of the sea transportation market through the ports of Ukraine, described in [8].

The changes in the structure and volume of cargo transshipment are as follows:

- instead of exporting coal to the metallurgical industry, energy coal is imported, which in turn requires the presence of deep-water berths for processing large-capacity vessels of the Capesize type;
- the increase rate of the metal products transshipment has declined, against the background of the world steel consumption growth estimation by 30% by 2030;

3. The estimation of the goods transshipment volume by Ukrainian ports

The average annual growth rate of the economy	Years	Annual turnover
Optimistic scenario		
At the level of fast-growing countries (growth - 7%)	2022	202 million tons, including 870 thousand TEU
	2030	347 million tones, including 1494 thousand TEU
	2038	596 million tones, including 2567 thousand TEU
Pessimistic scenario		
Cyclical periods of decline and growth (growth - 0,5%)	2022	139 million tones, including 597 thousand TEU
	2030	144 million tones, including 621 thousand TEU
	2038	150 million tons, including 647 thousand TEU
Probable scenario		
The world average (2017-2022 - IMF forecast - 3% growth)	2022	165 million tones, including TEU 710 thousand
	2030	209 million tones, including 899 thousand TEU
	2038	265 million tones, including 1,139 thousand TEU

Table borrowed [8]

- the market of cereals and oilseeds has grown, which causes an increase in port facilities for transshipment of grain and vegetable oil;
- there is an increase in the ships size of the transport fleet, which requires the equipment of deep-sea ports;
- there is a low capacity utilization for container handling.

In turn, V.G. Cook [6] indicates that the ports of Ukraine have the largest reserves for oil cargoes in the amount of 11.2 million tons, and there are no reserves for coal (a deficit of 1.7 million tons); the ore and container capabilities of the ports are completely exhausted. The estimated values of the most likely

volume of cargoes transshipment by Ukrainian ports, based on the above considerations, are given in Tables 4 and 5.

The growth rates of different types of cargo transshipment were taken on the basis of a probable economic growth scenario and annual turnover through Ukrainian ports (look at the Table 3).

By comparing the data in Tables 2, 4 and 5, it is possible to predict not only the absolute increase in the volume of cargo transshipped through the seaports of Ukraine, but also to analyze the structural changes in the cargo flow. The analysis of information on the structure and volume of cargo flow will allow to predict rationally the necessary changes in the volume and structure of the seaports transshipment capacities (look at the Table 6).

4. The estimation of the cargo’s transshipment volume by Ukrainian ports in 2022

№	Type of cargo	Growth rate	Factor loading berth	Amount, thousand tons	Bandwidth, thousand tons	Percent in 2022
1	Bread	1,1	0,7	45518	65026	0,255
2	Ore	1,4	0,7	39286	56123	0,220
3	Ferrous metals	1,2	0,6	19298	32163	0,126
4	Containers	1,4	0,5	15372	30743	0,120
5	Coal	1,2	0,7	9724	13891	0,054
6	Vegetable oil	1,1	0,7	6098	8712	0,034
7	Construction	1,2	0,6	5560	9266	0,036
8	Chemicals & Fertilizers	1,1	0,7	4177	5968	0,023
9	Heavy duty vehicles	1,4	0,6	2564	4273	0,017
10	Petroleum products	1,1	0,7	1417	2024	0,008
	Other	1,2	0,6	16220	27033	0,106
	Total			165000	255221	1,000

The table was created by the authors on the basis of the information given in [7]

Negative values of the increase in transshipment capacities of seaports for certain types of cargo indicate that there is no need to develop installed

capacities from transshipment of these cargoes. A significant negative increase in seaport transshipment capacity for certain types of cargo requires the conversion of installed capacity to the transshipment of those types of cargo that have a steady increase.

The values of the integral indicator of the utilization of the installed capacity of the K_{oI} cargo transshipment ports and the average value of the differential performance of the k_{odsr} cargo transshipment ports for 2018 and the forecast 2022 and 2030 are shown in Table 8. When calculating the integrated installed capacity utilization indicator ports of transshipment of cargoes as a weighting factor the volume of transshipment of each type of cargo was used.

5. The estimation of the cargo’s transshipment volume by Ukrainian ports in 2030

№	Type of cargo	Growth rate	Factor loading berth	Amount, thousand tons	Bandwidth, thousand tons	Percent in 2030
1	Bread	1,1	0,7	50070	71528	0,240
2	Ore	1,4	0,7	55000	78572	0,263
3	Ferrous metals	1,2	0,6	23158	38596	0,111
4	Containers	1,27	0,5	19463	38927	0,093
5	Coal	1,4	0,7	13613	19448	0,065
6	Vegetable oil	1,1	0,7	6708	9583	0,032
7	Construction	1,2	0,6	6672	11119	0,032
8	Chemicals & Fertilizers	1,4	0,7	5848	8355	0,028
9	Heavy duty vehicles	1,4	0,6	3589	5982	0,017
10	Petroleum products	1,4	0,7	1983	2833	0,009
	Other	1,4	0,6	22708	37847	0,109
	Total			209000	322789	1,000

The table was created by the authors on the basis of the information given in [7]

6. The essential changes in transshipment capacities of seaports, thousand tons

№ п/п	Type of cargo	Increase 2022 to 2018	Increase 2030 to 2022	Increase 2030 to 2018
1	Bread	5911	6503	12414
2	Ore	0	22449	22449
3	Ferrous metals	0	6433	6433
4	Containers	8874	8184	17058
5	Coal	2315	5556	7872
6	Vegetable oil	-528	871	343
7	Construction	1544	1853	3398
8	Chemicals & Fertilizers	-1628	2387	760
9	Heavy duty vehicles	-305	1709	1404
10	Petroleum products	-1196	810	-386
	Other	0	10813	10813
	Total	14988	67568	82556

The table is built by the authors

7. Required changes in the structure of transshipment facilities of seaports

№	Type of cargo	Increase 2022 to 2018	Increase 2030 to 2022	Increase 2030 to 2018
1	Bread	0,3944	0,0962	0,1504
2	Ore	0,0000	0,3322	0,2719
3	Ferrous metals	0,0000	0,0952	0,0779
4	Containers	0,5921	0,1211	0,2066
5	Coal	0,1545	0,0822	0,0953
6	Vegetable oil	-0,0352	0,0129	0,0042
7	Construction	0,1030	0,0274	0,0412
8	Chemicals & Fertilizers	-0,1086	0,0353	0,0092
9	Heavy duty vehicles	-0,0204	0,0253	0,0170
10	Petroleum products	-0,0798	0,0120	-0,0047
	Other	0,0000	0,1600	0,1310
	Total	1	1	1

The table is built by the authors

8. The use of installed port capacities

№	Indicator	Years		
		2018	2022	2030
1	The average by type of cargo, k_{odsr}	0,578437	0,654982	0,654479
2	At the ports, K_{oI}	0,009474	0,004336	0,004344

The table is built by the authors

When forecasting cargo flows (see Tables 4 and 5), it was assumed that the berth loading rate in 2022 and 2030 would increase according to the trends in the leading European countries, America and the strategy of ports development of Ukraine for the period until 2038, as well as the national transport strategy until 2030 year.

The increase in average load by type of cargo in 2022 and 2030 compared to 2018 is explained by the equalization of installed capacity load in ports. According to Tables 6 and 7, changes in the magnitude and structure of seaport transshipment capacity in the forecast years 2022 and 2030, compared to 2018, reduce the integrated utilization rate of installed transshipment port capacity (see Table 7) by half. The smaller value of the integrated utilization rate of the installed port capacity indicates, as shown above, the greater correspondence of the port throughput structure to the port cargo turnover structure.

Conclusions and prospects for further research. The integral criterion of structural correspondence between the cargo flow and the throughput of the ports allows to evaluate the activity of the ports in the current and forecast periods. For the ports of Ukraine there is a structural mismatch between the cargo flow and the installed transshipment capacity. The paper shows the possibility of predicting the development of the technical equipment of ports, depending on the change in the size and structure of cargo flows through the ports.

The use of the integral criterion of structural correspondence between the cargo flow and the capacity of the ports in predicting the development of ports allows to increase the efficiency of the port economy. Future research should consider forecasting the development of individual ports to improve the efficiency of the country's port economy as a whole. The high intensity of Ukrainian ports operation now gives hope for their competitive ability in the future.

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А.Я. Казарєзов, Ю.Є. Барабанова, О.А. Іщенко, Клецов Є.С. Прогнозування стратегічного розвитку портової галузі України. Розроблено прогнозний варіант розвитку портів на основі зіставлення структури вантажних потоків через порт з інфраструктурою портів. Показано вплив зовнішніх умов на діяльність портів. За допомогою критерію структурної відповідності між вантажним потоком і пропускною спроможністю порту вказано шляхи розвитку українських портів. Показана можливість використання критерію для прогнозування розвитку порту в залежності від прогнозу зміни структури вантажного потоку.

Ключові слова: морський порт, вантажний потік, критерій структурної відповідності, прогноз розвитку порту.

А.Я. Казарезов, Ю.Е. Барабанова, А.А. Ищенко, Клецов Е.С. Прогнозирование стратегического развития портовой отрасли Украины. Разработан прогнозный вариант развития портов на основе сопоставления структуры грузовых потоков через порт с инфраструктурой портов. Показано влияние внешних условий на деятельность портов. С помощью критерия структурного соответствия между грузовым потоком и пропускной способностью порта указаны пути развития украинских портов. Показана возможность использования критерия для прогнозирования развития порта в зависимости от прогноза изменения структуры грузового потока.

Ключевые слова: морской порт, грузовой поток, критерий структурного соответствия, прогноз развития порта.

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