різних рецептур комбікормів, дозволяє зробити висновок про можливість і доцільність пошуку оптимального положення регулюючого органу для подачі пари до змішувача прес-пеллет. При цьому необхідно, щоб продуктивність преса прагнула до максимуму в залежності від положення регулюючого органу подачі пари на прес, а також величини поточного навантаження двигуна головного приводу, що в основному визначає енергоємність процесу, була обмежена в заданому діапазоні значень при обнулінні відповідної рецептури комбікорму: Приріст часу заповнення колони охолодження між циклами розвантажувального пристрою, що характеризує продуктивність преса - гранулятора, може бути використаний для опосередкованої його оцінки та використаний як вихідний показник у системі керування процесом гранулювання. Алгоритм пошуку оптимального режиму грануляції складається з двох частин: алгоритму покрокового запуску (переведення системи в зону пошуку) та алгоритму пошуку оптимального режиму грануляції. Запропоновано використовувати систему SMART-INDIVIDUAL, яка оснащена модулем з регулюванням моніторингу параметрів обладнання за паспортними характеристиками. При цьому система веде архів і контролює терміни обслуговування.

Ключові слова: прес-гранулятор, продуктивність, стабілізація, оптимізація, алгоритм пошуку, технологія SMART.

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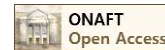
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FORECASTING GRAIN CARGO HANDLING AT PORT ELEVATORS SOUTH-EASTERN REGION OF UKRAINE

Abstract
The results of a study of the state and possibilities of increasing the capacity of grain transshipment in the ports of Ukraine and substantiation based on the developed trend models of forecast volumes of grain cargo transshipment in Berdyansk and Mariupol seaports of the South-Eastern region of Ukraine until 2025 are presented. The studies established the characteristics of grain cargo flows in the seaports of Ukraine, the SWOT analysis revealed the strengths and weaknesses, advantages and threats of the Mariupol Sea Trade Port, developed trend forecast models for grain transshipment volumes in the ports of the South-Eastern region of Ukraine and substantiated the forecast volumes of transshipment grain cargo until 2025. A rather uneven loading of the Mariupol port during the year is shown. August and all summer months are especially critical, when both industrial and agricultural goods

need to be exported from the nearby region at the same time. The urgent need to increase the capacity of elevators for the ports of Chornomorsk, Reni and Olvia, as well as the ports of the Sea of Azov, in particular, the construction of a new elevator in the port of Mariupol, which is a timely strategic decision, has been substantiated. It was noted that at present most of the country's seaports are expected to increase the transshipment of food cargo of all kinds. To predict the volumes of transshipment of grain cargo at the Berdyansk and Mariupol seaports, based on the analysis of data from the state enterprise "Administration of the Sea Ports of Ukraine", forecast models (trends) are proposed that contribute to the growth of production capacity and competitiveness of agricultural products of the adjacent agro-industrial region. It is shown that the forecast for the next 2-4 years is optimistic – subject to a good grain harvest, the transshipment of grain cargo by 2025 in the Berdyansk and Mariupol ports can reach 2,000 and 1,300 thousand tons, respectively, that is, increase compared to 2021, respectively, 5 and 1.3 times. The conducted SWOT-analysis made it possible to identify and evaluate the factors influencing decision-making on the possibility of developing the Mariupol seaport. On the basis of analytical data, a long-term forecast was made for the further development of the transport and logistics component of the seaports of the South-East region of Ukraine, which will expand and improve port services aimed at increasing its throughput. Among the most important measures is the construction of an elevator in the Mariupol seaport, which will help increase the quality and safe transportation of agricultural products in the chain from the producer to the end consumer. The main measures aimed at increasing the competitiveness of the Mariupol port were identified, including: construction of complexes for transshipment of grain, containers, vegetable oil; dredging, construction of hydrotechnical bank protection structures; reconstruction of berths 2-4 and 14-15 of the port; reconstruction of the nearby railway station Mariupol-Port.

Key words: region, seaport, grain cargoes, innovations. elevator, statistical analysis, trend model, forecast

Formulation of the problem

The development of the agro-industrial complex and, first of all, the grain economy is one of the areas that ensures socio-economic progress and determines the country's food security. According to the level and condition of the grain economy and the grain market, they judge the efficiency of the functioning of the economy of the agro-industrial complex and the reliability of the country's grain forage supply.

In recent years, grain yields in Ukraine have consistently exceeded the optimistic expectations of experts. Increasing volumes have significantly actualized the issue of preserving grain reserves in the country, and domestic agricultural producers have acutely felt a shortage of high-quality storage capacities.

Storage of grain of different crops is an important stage in the implementation of international transportation and transportation of products in the food supply chain from producer to consumer. Therefore, it is necessary to constantly assess the ability of seaports to serve the flow of goods, especially grain, which, under improper storage conditions, can quickly deteriorate.

Literature review

The availability of modern elevator capacities in the seaports of Ukraine for the intermediate storage of grain products that are exported is very important. This allows you to temporarily accumulate the necessary batches of grain and minimize costs in general, which positively affects the export opportunities of ports [1].

According to the Elevatorist.com website [2], certified elevator capacities in Ukraine are about 45–50 million tons. Currently, 65–70% of elevators are morally and physically obsolete and do not meet modern requirements for grain storage, acceptance and shipment efficiency.

Against the backdrop of a record harvest of more than 100 million tons, the shortage of elevators exceeds 50%. According to various estimates for 2021, it is about 30 million tons and will only increase with the growth of yields. Given the trend of the last five years to an increase in modern elevator capacities of about 1.5 million tons per year, the trend towards an increase in grain storage capacities will continue in the next 3–5 years [2]. It is easy to calculate that with a projected grain harvest of 100 million tons in 2022 and beyond, this deficit will only increase.

In addition to the construction of new transshipment complexes, a very interesting alternative is the transshipment of grain crops into containers in polypropylene liners (liner-runs), which protect the cargo from contact with the container and protect the container from contact with the cargo. The absence of the need for additional transshipment (transshipment) of these cargoes simplifies loading and unloading operations and significantly expands the geography of deliveries [3].

It is known that the development of seaports with the deregulation of cargo transportation is a big problem. In this direction, studies have already been carried out in order to increase the efficiency of the functioning of the transport and technological system of the seaport serving the industrially agrarian East Ukrainian region [4]. A number of projects for the development of Ukrainian ports have been developed, which embody scientific approaches to the design and development of domestic port facilities [5], taking into account all the requirements of regulatory and technical documentation and methodological literature [6, 7].

The general decline, which was observed due to the stagnation of the Ukrainian economy over the past 5-7 years, is almost over, and at present, an increase in the transshipment of food cargo of all types is expected in most of the country's seaports. This general trend can be described by a predictive model – a trend, that is, a certain equation based on the statistical processing of a relatively small amount of data. Extrapolation by trends can also be used as the initial stage of a complex forecasting technique that answers questions about the consequences of continuing the previous development trend [8].

To compile a trend model, you need to select a trend function, find its characteristics, check the adequacy and accuracy. For trends that describe changes in indicators over time (dynamics), polynomial, exponential and S-shaped types of equations are most often used. The resulting adequate trend model is further used for point and interval forecasts [8, 9]. Regarding polynomial trends, there are mutually accurate recommendations – from the use of polynomials not higher than degree 3 [8, 10] to the use of polynomials of degree 6 [9]. Thus, for the possibility of objective forecasting, it is necessary to carry out a certain analysis of the choice of the corre-

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sponding trend equations.

In recent decades, Ukraine has confidently entered the top five world grain exporters, which allows our state to steadily replenish its gold and foreign exchange earnings [11]. These achievements would not have been possible without the proper development and well-functioning of seaports. Their further development is a strategic task that requires deepening research to find reserves to improve the efficiency of seaports for grain transshipment, in particular, the promising South-Eastern region of Ukraine. The above determined the purpose and objectives of our research.

The purpose of the research was to study the state and possibilities of increasing the capacity of grain transshipment in the ports of Ukraine and substantiate, on the basis of the developed trend models, the forecast volumes of grain cargo transshipment in Berdyansk and Mariupol seaports of the South-Eastern region of Ukraine until 2025.

According to the objectives of the research, it was to establish the characteristics of grain cargo flows in the seaports of Ukraine, to identify the strengths and weaknesses, advantages and threats of the Mariupol Sea Port, to develop trend forecast models of grain transshipment volumes in the ports of the South-Eastern region of Ukraine and to substantiate the forecast volumes of grain cargo transshipment to them up to 2025.

Materials and methods of research

The research materials were statistical data on the performance of the ports of Ukraine for 2015-2021 for the transshipment of all types of cargo and, in particular, grain cargo. The work used graphic-analytical and statistical methods of research, mathematical description, modeling and evaluation of the results of the analysis.

In the tasks of approximating observational data (volumes of grain transshipment) and compiling trend mathematical models (equations), the MS Excel 2007 environment was used, in particular its procedure "Search for a solution" (Excel Solver), by which the empirical coefficients in the equations were determined by the least squares method (LSM) trends models.

The adequacy of the obtained trend models and their suitability for forecasting the volumes of grain transshipment was carried out according to a simplified method [10], which provides for their assessment according to statistical criteria:

– the index (coefficient) of determination R^2 and the correlation coefficient r_{xy}, showing the tightness of the time series of observational data with the trend curve on the Chaddock scale;

– the autocorrelation coefficient of M. Ezekiel and K. Fox r_{ai} and the Durbin-Watson D-test DW, which allow assessing the absence of autocorrelation of residuals;

– the average relative approximation error A, which gives an estimate of the accuracy of the forecast.

To detect autocorrelation of residuals based on the Durbin-Watson D-test, such an algorithm was used. The formulas given in [10] were used to calculate the values of the autocorrelation coefficient r_{xy} and the D-criterion DW. Further, according to special tables [12], for a given number of observations n, the number of independent variables of the model m and significance level α=0.05, the critical values of the D-criterion were determined – its lower d_1 and upper limit d_2.

When the condition DW > d2 is met, it is concluded that there is no autocorrelation of residuals (in case of negative autocorrelation of residuals, not DW, but 4–DW is compared with tabular values). The closer the actual value of the Durbin-Watson criterion to 2, the greater the confidence in the absence of autocorrelation in the residuals and the possibility of using the found trend in forecasting.

Results and discussion.

Characteristics of grain cargo flows. The volumes of cargo transshipment passing through the Mariupol port over the past 7 years, plotted according to [13] as a percentage, are given in table 1 and table 2.

According to table 1 and table 2, it is obvious that the loading of the Mariupol port during the year is rather uneven. August and all summer months are especially critical, when both industrial and agricultural goods must be exported from the nearby region at the same time. Therefore, in order to meet the growing demand for the export of grain cargo through the logistics system of the industrial and agrarian region of Eastern Ukraine, it is proposed to build a new elevator on the territory of the Mariupol Commercial Sea Port with a total capacity of up to 2 million tons of grain per year. The construction of an elevator in the port will help reduce the queues for idle transport for unloading grain, to a greater extent in the summer.

Table 1 – Results of the total transshipment of all types of cargo through the port of Mariupol,%

Year	Month											
	Jan	Feb	March	April	May	June	July	August	Sept	Octob	Nov	Decem
2015	64.44	66.58	88.03	74.30	89.40	68.37	83.73	87.63	86.95	**100.00**	42.93	48.39
2016	46.58	37.40	47.21	57.31	72.48	85.69	94.59	**100.00**	86.26	77.16	70.58	53.08
2017	41.02	47.02	55.72	65.71	**100.00**	78.18	82.06	33.99	46.52	93.28	62.94	69.33
2018	77.24	60.53	88.16	81.84	87.49	**100.00**	96.26	81.18	85.48	91.13	64.71	83.57
2019	43.41	49.11	71.98	51.14	66.62	46.43	69.70	**100.00**	95.44	91.58	65.95	89.38
2020	72.35	74.34	70.56	73.17	62.48	71.01	87.38	**100.00**	89.39	71.70	80.88	69.45
2021	72.80	80.91	73.59	90.95	84.62	63.59	63.44	92.13	**100.00**	76.79	77.86	78.00

Table 2 – The results of the total transshipment of grain cargo through the port of Mariupol,%

Year	Month											
	Jan	Feb	March	April	May	June	July	August	Sept	Octob	Nov	Decem
2015	50.13	7.90	20.73	28.95	22.37	0.00	25.84	**100.00**	78.50	69.86	30,89	83.37
2016	17.74	19.81	43.42	43.87	56.65	39.10	67.55	**100.00**	56.45	48.31	47.15	61.13
2017	28.00	47.80	38.09	21.27	31.72	16.62	39.49	**100.00**	45.10	37.94	23.25	61.78
2018	34.88	56.56	**100.00**	54.10	50.82	12.57	93.33	84.56	82.38	49.04	49.45	86.72
2019	31.90	27.14	30.76	23.48	30.76	5.89	50.33	**100.00**	76.92	68.45	60.84	55.37
2020	31.37	28.34	52.66	48.61	27.62	8.96	61.76	**100.00**	51.22	34.38	25.68	16.38
2021	27.29	31.01	22.45	37.63	33.33	37.74	46.60	**100.00**	73.42	74.94	33.67	54.21

The particles of each seaport of Ukraine as a percentage of the total volume of transshipment of grain cargo for 2021 are shown in fig. 1. It can be seen that the main ports reloading more grain cargo in Ukraine are the ports of Chornomorsk, Mykolaiv, Yuzhny and Odesa. The ports of Mariupol and Berdyansk, although they are not competitors of these powerful ports, play an extremely important role in servicing the nearby region of South-Eastern Ukraine. On the part of agricultural enterprises, there is a certain demand for the services of these ports, which makes it possible to optimize transport and logistics costs in the overall supply chain.

On fig. 2 shows how the shares of grain cargoes have changed in the seaports of Ukraine over the past 7 years as a percentage of the total volume of transshipped cargo.

Over the past 7 years, the share of grain cargo in the total volume of transshipped cargo has increased significantly in the ports of Berdyansk (by 64.5%), Reni (35.8%), Chornomorsk (by 27.4%) and Olvia (by 20.5%) . and grew in the ports of Mariupol (by 9.3%), Kherson (by 7.2%) and Mykolaiv (by 3.9%). Against the backdrop of a drop in the flow of grain cargo in the ports of Izmail (by 1.1%), Yuzhny (by 2.0%) and Odesa (by 7.9%) over 7 years, it was possible to increase this flow of cargo by 6.7%. At the same time, the ports located on the Sea of Azov increased the grain cargo traffic by 17.4%.

The presented analysis shows that there is an urgent need to increase the capacity of elevators for the ports of the Sea of Azov, as well as for the ports of Chornomorsk, Reni and Olvia. Therefore, investment development and construction of a new elevator in the port of Mariupol is a reasonable and timely strategic decision.

Forecasting the size of transshipment of grain cargo in seaports. To assess the change in the flow of grain cargo passing through the seaports of Ukraine, according to [13], we present in graphical form information on the transshipment of this type of cargo in ports over the past 7 years (Fig. 3).

It is clearly seen that two groups of
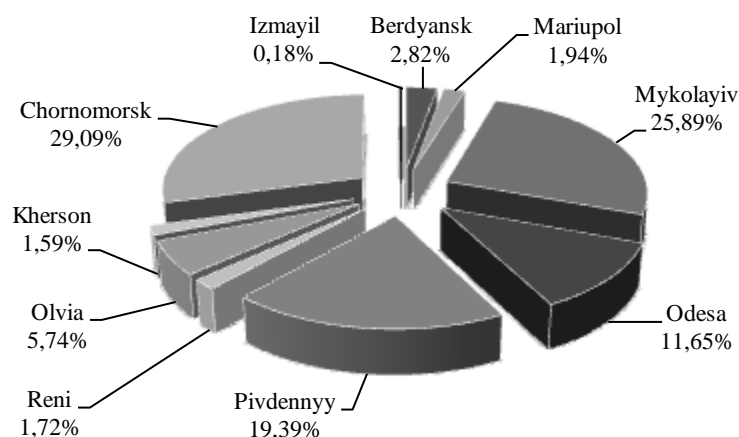
Fig. 1. Shares of Ukrainian seaports in total volume of grain cargo transshipment in 2021

seaports can be divided in terms of grain transshipment volumes – with large volumes in the range of 5–16 million tons per year (Mykolaiv, Chornomorsk, Yuzhny and Odesa) and significantly more than 3,000 thousand tons (all the rest 6 ports are indicated in figure 3). There is also a large variability in grain transshipment volumes over the years. For example, we can note the increase in the volume of grain transshipment in Chornomorsk from 5 to 15 million tons, that is, three times.
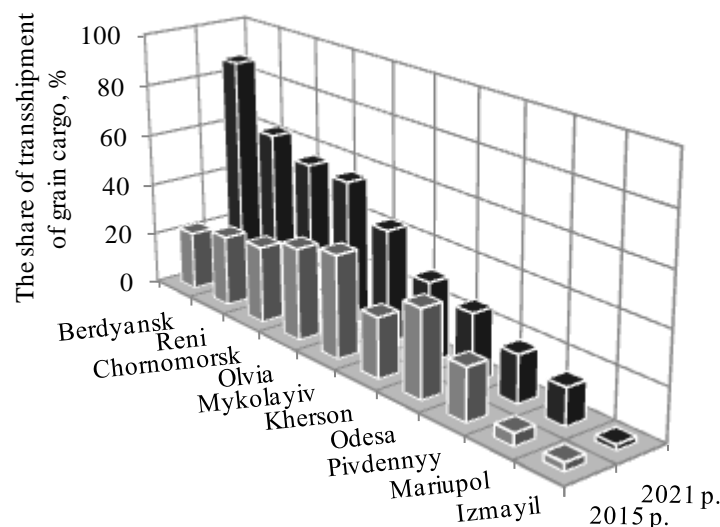
Fig. 2. Shares of grain cargoes of seaports of Ukraine in the total volume of transshipped cargoes in 2015 and 2021
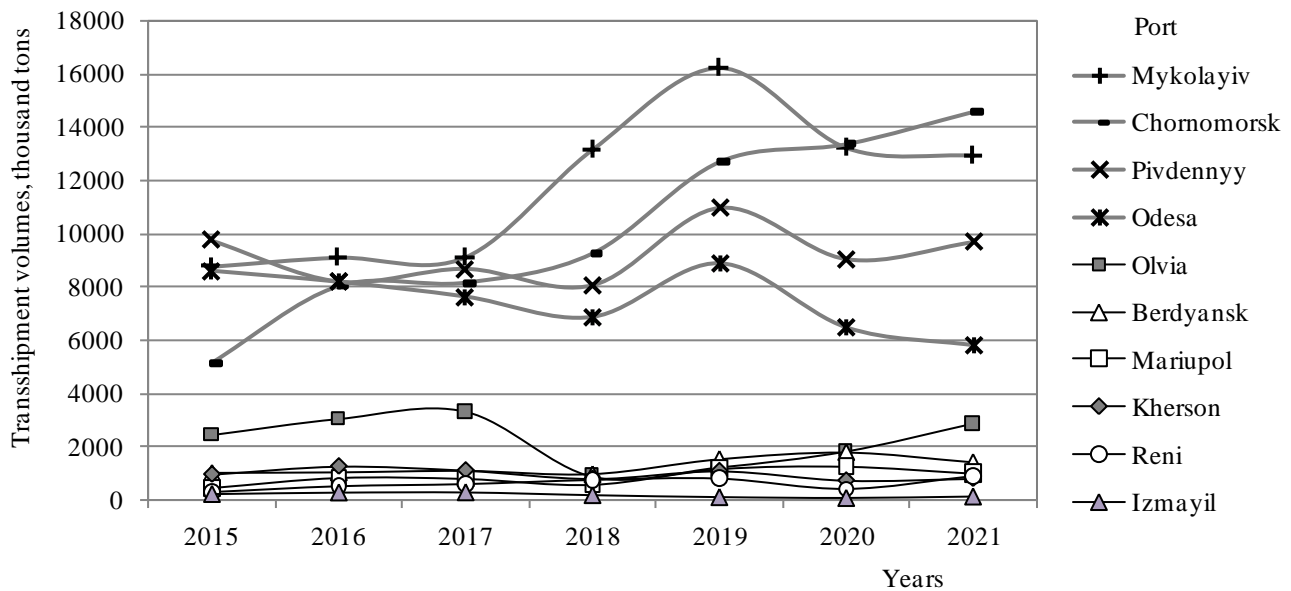
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Fig. 3. Dynamics of the annual transshipment of grain cargo in the seaports of Ukraine in 2015–2021

To predict the volumes of grain transshipment in seaports, it is necessary to develop mathematical models (trend equations) that accurately approximated the observational (reporting) data and could give close to real medium-term forecast values of grain transshipment volumes for the next few years. Due to the presence of a significant number of different types of equations that can be used as mathematical models (trend equations), we analyzed all standard types of trend one-factor equations provided in MS Excel.

Such an analysis of the MS Excel approximation (trend) lines, carried out for two ports of the Sea of Azov (Mariupol and Berdyansk), showed that linear equations give determination coefficients of 0.56–0.59, in exponential equations the determination indices (coefficients) are 0.55–0.61, for logarithmic – 0.56–0.59, which are considered low. Polynomial types of equations (trends) have higher indices (coefficients) of determination: from 0.59 (a second-degree polinom) to 0.94–1.00 (for 4th–6th degrees of polynomials). However, despite the much greater accuracy of describing the volumes of grain transshipment by polynomial trends within the studied years 2015–2021, forecasts for them for the next few years give completely unrealistic results – either negative or too large values. So, for example, the forecast for the port of Mariupol for 2023 according to the 6th degree polynomial gives an increase in grain transshipment volumes by 75 times compared to 2021, which is nonsense.

Subsequent analysis of other types of equations showed that the modified exponential equation [8] can be used as temporary trend models

$$\tilde{y} = k + a \exp(-bx) , \qquad (1)$$

where $\tilde{y}$ – estimated value of grain transshipment, thousand tons;

k, a, b – are empirical coefficients determined by the least squares method;

x – the time factor (year).

The coefficients k, a, b in the proposed modified exponential equation have a certain geometric content. Thus, the graph of function (1) as $\tau{\to}\infty$ approaches the horizontal asymptote $y = k$. Most often, equations are

used as trends when $a<0$ (i.e., the asymptote is located above the trend curve), and $b<1$ (i.e., when the increments in y are constant and decrease with increasing τ).

As practice shows, the use of the numerical value of the year as a time factor in trend time series can lead to significant discrepancies between the observational data and the data predicted by the obtained equation. This is due to the significant remoteness of the current values of years in relation to the initial ("zero") reference point of the time factor (years). Therefore, instead of years, it is more expedient to take the ordinal numbers of the time scale (series of years) as a time factor. Using this approach and reporting (observational) data on annual volumes of grain cargo transshipment in 2015–2021 [13], we obtained trend equations describing the generalized nature of deregulation changes in annual grain flows in the ports of Berdyansk and Mariupol:

– for Berdyansk

$$\tilde{y} = 1388{,}89 - 1085{,}48 \exp(0{,}188849x), \ R^2{=}0{,}589; \qquad (2)$$

– for Mariupol

$$\tilde{y} = 25551{,}3 - 24758{,}9 \exp(0{,}00471517x), \ R^2{=}0{,}573, \ (3)$$

where x – serial number of the year (2015 year – 1; 2016 year – 2 etc).

R^2 – index (coefficient) of determination.

The numerical values of the empirical coefficients of the trend equations were determined by the least squares method using the procedure "Search for solutions".

The assessment of the adequacy of the obtained trend models and their suitability for forecasting the volumes of grain transshipment was carried out according to the above simplified method [10], for which the following statistical criteria were calculated:

– correlation coefficient r_{xy} to estimate the tightness of a series of observed data with a trend curve;

– autocorrelation coefficient of M. Ezekiel and K. Fox r_{ai} and D-test of Durbin-Watson DW to assess the absence of autocorrelation of residuals;

– the average relative approximation error A for estimating the accuracy of the forecast.

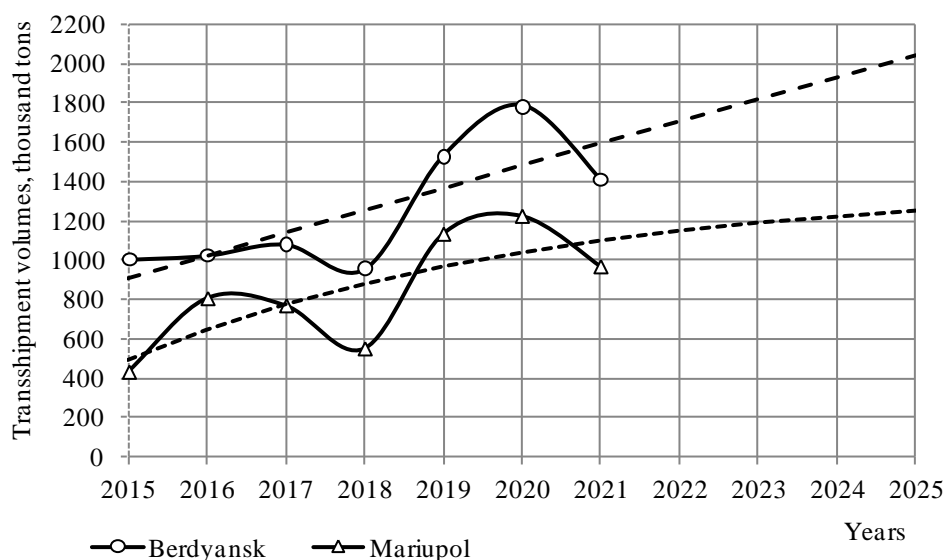Using the formulas given in the sources [10, 8],

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Fig. 4. Trend models for the forecast of transshipment of grain cargo in the seaports of the Sea of Azov for the period 2015-2025

the following values of the necessary statistical criteria were obtained:

– for Berdyansk

$r_{xy} = 0.77$; $r_{ai} = -0.147$; $DW = 2.126$; $A = 12.54\%$;

– for Mariupol

$r_{xy} = 0.76$; $r_{ai} = -0.263$; $DW = 2.432$; $A = 19.44\%$.

An analysis of these data showed that for both ports, the annual volumes of grain transshipment and serial numbers of the considered 2015–2021 years have correlations within 0.76–0.77, which is estimated as a high level according to the Chaddock scale [10] (0.7–0.9) and allows you to use trend models for forecasts.

The low values of the autocorrelation coefficients r_{ai} indicate the possibility of using trend equations for forecasts. However, the final conclusion was given by a comparison of the Durbin-Watson DW criteria with their critical limits d_1 and d_2, determined from the table [12] for the number of observations n=7, the number of independent variables in the model m=1 and the accepted significance level α=0.05. For these characteristics, the

critical values of the D-criterion are – the lower limit d_1=0.700, the upper limit d_2=1.356. Considering that the autocorrelation coefficients r_{ai} have a minus sign, according to [10], the following relations can be written:

– for Berdyansk

$DW = 4–2.126 = 1.874 > d_2 = 1.356$;

– for Mariupol

$DW = 4–2.432 = 1.568 > d_2 = 1.356$,

which indicate the absence of autocorrelation of residues.

Average relative approximation errors equal to 12.54–19.44% do not exceed the recommended [10] allowable limits of 10–20%.

Thus, according to the set of requirements, confirmed by the corresponding statistical characteristics, the trend models obtained by us can be used for point and interval forecasts.

Using the obtained adequate equations (2)–(3), graphs of changes in the annual volumes of transshipment of grain cargo and trend lines were constructed, which are generalized and give an idea of the indicative medium-term forecast values for the period 2022–2025 (Fig. 4).

From the data analysis of fig. 4, we can conclude that the trends in the transshipment of grain cargo in the ports of the Azov Sea of Ukraine are now in the process of growth. The medium-term forecast for the next 2–4 years is optimistic – given a good grain harvest, which will grow in these seasons, the transshipment of grain cargo by 2025 in the ports of Berdyansk and Mariupol can reach about 2,000 and 1,300 thousand tons, respectively, i.e. year by 1.5 and 1.3 times.

Table 3 – SWOT analysis of the Mariupol seaport as of 2021

	STRENGTHS	WEAK SIDES
Internal environment	– Proximity to large places of localization of the production of ferrous metals – directly within the city, next to the port, there are powerful metallurgical enterprises of Ukraine – MMK im. Ilyich and MK "Azov-stal". – Proximity to large places of localization of coal mining, clay. – Versatility of berths. – Quality and speed of customer cargo handling.	– Small depths of the approach sea channel; – Limited capacity of the transport infrastructure (railways and railway station, highways). – Lack of specialized transshipment facilities for grain and bulk (oil) cargo. – The possibility of expanding the territory of the port through close proximity to the residential areas of the city and the recreational zone is limited.
	OPPORTUNITIES	**THREATS**
External environment	– Expansion of additional volumes of processing grain and sunflower oil. – Use of a very favorable geographical location of the port for the export and transit direction of goods. – Renewal of technological equipment and application of new technologies.	– Since 2014, there has been a difficult political and economic situation in the South-Eastern region of Ukraine, where the port is located. – Slowdown in the economic development of the region. – Decrease in demand for metallurgical products in the world markets.

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Fig. 5. Modern silos of the grain terminal of the Mariupol Sea Port [16]

port berths No. 2-4, 14-15; as well as the reconstruction of the nearby railway station Mariupol-Port. The said works on modernization of transshipment of grain cargoes are already underway. Thus, according to [15], the construction of a modern grain terminal continues in the Mariupol Commercial Sea Port, the decision to build which was made back in 2016 [16]. But due to a number of objective reasons, the deadlines for implementation were delayed. At present, the project is more than 60% completed and the modern grain transshipment complex (Fig. 5) is scheduled to be completed in March 2022.

SWOT-analysis of the Mariupol seaport.

Even under the most pessimistic scenario of the development of events, the news about the construction of new elevator capacities will encourage producers to increase the sowing of grain crops and increase their export.

The analysis of the data of the map of elevators of the South-East region, including port ones, given in the source [14], showed that the capacities of the elevators existing in this region (Mariupol 20, Zaporiyia 21, Berdyansk 12, etc.) are still not enough to meet all the needs of grain producers and grain traders, especially the Mariupol seaport. This can be seen from the SWOT analysis of the Mariupol seaport.

When comparing the ports of the South-Eastern region of Ukraine with the most competitive ports of the Black and Azov Seas, it can be summarized that the Mariupol port has the following weaknesses:

– small depth of approach channels;

– high wear of hydraulic structures and berths;

– high wear and tear of the port fleet, crane equipment and other technological equipment;

– limited warehouse space;

– limited capacity of the transport infrastructure (roads, railways and railway station).

Outdated technological equipment reduces the efficiency of loading and unloading cargo, and also increases the risk of accidents. Of the 60 portal cranes available in the Mariupol port, 30 of them are older than 30 years, 16 cranes are older than 20 years. More than 40% of forklifts are operated beyond the standard period.

To mitigate these risks, separate technological lanes are being built in the Mariupol port for new and the introduction of obsolete (subrogation) equipment.

The final SWOT analysis of the Mariupol seaport is given in Table. 3.

The main measures aimed at increasing the competitiveness of the Mariupol port should be: construction of complexes for transshipment of grain, containers, vegetable oil; dredging, construction of hydrotechnical bank protection structures; reconstruction of

Conclusions

1. A fairly uneven loading of the Mariupol port during the year has been shown. August and all summer months are especially critical, when both industrial and agricultural goods need to be exported from the nearby region at the same time. The urgent need to increase the capacity of elevators, the ports of Chornomorsk, Reni and Olvia, as well as the ports of the Sea of Azov, in particular, the construction of a new elevator in the port of Mariupol, which is a timely strategic decision, has been substantiated.

2. It is shown that at present most of the seaports of the country are expected to increase the transshipment of food cargo of all kinds. To predict the volumes of grain cargo transshipment at the Berdyansk and Mariupol seaports, based on the analysis of data from the state enterprise "Administration of the Sea Ports of Ukraine", forecast models (trends) are proposed that will contribute to the growth of production capacities and competitiveness of agricultural products of the adjacent agro-industrial region. It is shown that the forecast for the next 2–4 years is optimistic – subject to a good grain harvest, the transshipment of grain cargo by 2025 in the Berdyansk and Mariupol ports can reach 2,000 and 1,300 thousand tons, respectively, that is, increase compared to 2021, respectively, 5 and 1.3 times.

3. The conducted SWOT-analysis made it possible to identify and evaluate all the factors influencing decision-making on the possibility of developing the Mariupol seaport. On the basis of analytical data, a long-term forecast was made for the further development of the transport and logistics component of the seaports of the South-East region of Ukraine, which will expand and improve port services aimed at increasing its throughput. Among the most important measures is the construction of an elevator in the Mariupol seaport, which will help

increase the quality and safe transportation of agricultural products in the chain from the producer to the end consumer.

4. The main measures aimed at increasing the competitiveness of the Mariupol port were identified, including: construction of complexes for transshipment of grain, containers, vegetable oil; dredging, construction of hydrotechnical bank protection structures; reconstruction of port berths No. 2-4, 14-15; as well as the reconstruction of the nearby railway station Mariupol-Port.

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ПРОГНОЗУВАННЯ ПЕРЕВАЛКИ ЗЕРНОВИХ ВАНТАЖІВ НА ПОРТОВИХ ЕЛЕВАТОРАХ ПІВДЕННО-СХІДНОГО РЕГІОНУ УКРАЇНИ

Анотація

Наведено результати дослідження стану та можливостей збільшення потужностей перевалки зерна у портах України та обґрунтування на основі розроблених трендових моделей прогнозних обсягів перевалки зернових вантажів у Бердянському та Маріупольському морських портах Південно-Східного регіону України до 2025 року. У дослідженнях встановлено характеристик потоків зернових вантажів у морських портах України, у SWOT-аналізі виявлено сильні та слабкі сторони, переваги та загроза Маріупольського морського торгівельного порту, розроблено трендові прогнозні моделі обсягів перевалки зерна у портах Південно-Східного регіону України та обґрунтовано прогнозні обсяги перевалки на них зернових вантажів до 2025 року. Показано досить нерівномірне завантаження Маріупольського порту протягом року. Особливо критичними є серпень і всі літні місяці, коли з прилеглого регіону одночасно потрібно вивозити і промислові і аграрні вантажі. Обґрунтована нагальна потреба в нарощуванні потужностей елеваторів для портів Чорноморськ, Рені і Ольвія, також портів Азовського моря, зокрема будівництва нового елеватору в порту Маріуполь, що є своєчасним стратегічним рішенням. Відмічено, що наразі у більшості морських портів країни очікується зростання перевалки харчових вантажів всіх видів. Для прогнозування обсягів перевалки зернових вантажів на Бердянському та Маріупольському морському портів, основі аналізу даних державного підприємства «Адміністрація морсь-

ких портів України» запропоновані прогнозні моделі (тренди), які сприятимуть зростанню виробничих потужностей та конкурентоздатності сільськогосподарської продукції прилеглого агропромислового регіону. Показано, що прогноз на найближчі 2-4 роки є оптимістичним – за умов хорошого врожаю зернових, перевалка зернових вантажів до 2025 року у Бердянському та Маріупольському портах може досягти відповідно 2000 та 1300 тис. тонн, тобто зрости порівняно з 2021 роком відповідно у 1,5 та 1,3 рази. Проведений SWOT-аналіз дозволив виділити та оцінити чинники, що впливають на прийняття рішень з можливості розвитку Маріупольського морського порту. На основі аналітичних даних складено перспективний прогноз подальшого розвитку транспортно-логістичної складової морських портів Південно-Східного регіону України, що дозволить розширити та поліпшити послуги порту, спрямовані на підвищення його пропускної спроможності. Серед найбільш важливих заходів є будівництво елеватору в Маріупольському морському порту, що сприятиме збільшенню якісного та безпечного транспортування аграрної продукції в ланцюгу від виробника до кінцевого споживача. Визначено основні заходи, спрямовані на підвищення конкурентоспроможності Маріупольського порту, серед яких: будівництво комплексів з перевалювання зерна, контейнерів, олії; дноpoglibлювальні роботи, будівництво гідротехнічних берегозахисних споруд; реконструкція 2-4 та 14-15 причалів порту; реконструкція прилеглої залізничної станції Маріуполь-Порт.

Ключові слова: регіон, морський порт, зернові вантажі, інновації. елеватор, статистичний аналіз, трендова модель, прогноз.

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