O. Latysheva[*][1],
orcid.org/0000-0001-6626-1420,
V. Rovenska[1],
orcid.org/0000-0002-9412-878X,
I. Smyrnova[1],
orcid.org/0000-0002-6941-1276,
M. Tripak[2],
orcid.org/0000-0001-6924-5469,
M. Tepliuk[3],
orcid.org/0000-0001-6823-336X

1 – Technical University "Metinvest Polytechnic" LLC, Zaporizhzhia, Ukraine
2 – Educational and rehabilitation institution of higher education "Kamianets-Podilskyi state institute", Kamianets-Podilskyi, Ukraine
3 – Kyiv National Economic University named after Vadym Hetman, Kyiv, Ukraine
* Corresponding author e-mail: olena.latysheva@mipolytech.education

ENSURING OPERATIONAL EFFICIENCY OF MINING AND METALLURGICAL ENTERPRISES ON THE BASIS OF SUSTAINABLE DEVELOPMENT

Purpose. To improve dynamic management of operational efficiency (DMOE) to ensure the sustainable development (SD) of the enterprise in the conditions of challenges. The task of the article is: to investigate external influences on the functioning of mining and metallurgical enterprises (MME); to identify prerequisites for DMOE, directions for improvement of operational efficiency of management tools.

Methodology. The method of content analysis made it possible to determine SD of enterprises in the conditions of dynamic challenges as a balanced quasi-sustainable development. The dialectical method was to establish the fact that risks of war also create windows of opportunity for enterprises. The method of critical analysis established the fact that the significant dynamism of challenges determines the dynamism of adaptive management. The method of analysis and synthesis was to propose a systematic and fragmentary approach to implementing measures to improve operational efficiency. The method of mathematical analysis made it possible to propose a transition from using not factors, but their derivatives, for modeling DMOE.

Findings. The effects of modern challenges on the functioning MME were studied. Prerequisites for the introduction of dynamic adaptive management of operational efficiency were determined. Areas of improvement of DMOE tools were determined. An approach of operational coordination of operational efficiency with dynamic changes in the internal and external environment is proposed. The management of the operational efficiency of one of the mining enterprises was studied.

Originality. The need for DMOE as a tool for sustainable functioning of the enterprise is substantiated. It is proposed to define SD at a significant level and dynamics of changes in external influences as a balanced consistent set of quasi-steady states, which increases the effectiveness of management measures.

Practical value. The proposed approaches increase the relevance of the evaluation of DMOE, which increases the effectiveness of management and the possibility of achieving balanced development of MME.

Keywords: *sustainable development, operational efficiency, mining and metallurgical enterprises*

Introduction. Under economic instability and war risks, mining and metallurgical companies should focus not only on the amount of profit, sales volumes, etc., but also form the prerequisites for their own sustainable development. Enterprises, even in the face of significant challenges together with integrating sustainability and operational efficiency, must use natural mineral resources by combining extraction with processing to ensure not only uninterrupted functioning, but also economic growth of enterprises.

The sustainable development of enterprises opens up prospects for investing in the modernization of production substantiated by the market and the corporate policy of risk neutralization, which, in turn, will lead to a decrease in operating costs and an improvement in operational efficiency indicators, that is, it contributes to the formation of a positive multiplier effect.

Smelting operations require strict adherence to technological conditions and, at the same time, wartime conditions lead to a broadening of the operational risk profile. In particular, an unstable supply of electricity can lead to catastrophic consequences due to damage to technological equipment. Disruptions in work due to rocket and bomb attacks worsen working conditions, increase depreciation costs, and worsen the main economic indicators of production activity. The mobilization and migration of the labor force leads to an increased risk of losing skilled personnel and forces an increase in labor costs, which, accordingly, worsens operational efficiency.

The degree of coordination of smelting operations with the extraction and supply of mineral raw materials decreases due to the deterioration of logistics processes, which also increases the risks for the sustainable functioning of enterprises, as it reduces productivity and increases operating costs.

This increases the need for proactive approaches to managing the sustainable development of enterprises, the introduction of new methods of labor organization using modified information and software tools. Also, with significant variability of external conditions, the need for forecasting the effects on the sustainable development of enterprises, predicting future market trends and, which becomes important in the conditions of economic instability and war, in the circumstances of changing the level of risks and the appearance of new threats, is growing.

Literature review. In a thorough review of the literature on the specified issue, Katina, et al. [1] stated that advanced manufacturing (AM) or production with a perspective of strategic development requires a special management of operational efficiency – "advanced manufacturing management" (AMM), which requires a new level of thinking, new approaches from the management of enterprises to the formation of decisions and the introduction of management actions. Also, Katina, et al. [1] indicated that the potential ambiguity of management decisions remains a problem area for the use of AMM. This worsens the level of adaptation of enterprises to changes in external conditions.

At the same time, even after recognizing the problems associated with rapid changes in the economic environment during the crisis, scientists ignore the need for dynamic changes in the organization of operational efficiency management [2]. A typical example is the method of strategic efficiency management using four balanced scorecards (BSC), which is named in

the article by Hristov, et al. [3] "dynamic", but which does not involve changes in the main factors in real time.

When identifying the factors that determine operational efficiency, even in war conditions, the risks of martial law are often not mentioned [2], which, in our opinion, are one of the main factors influencing the development of enterprises in this period. The thesis about the brand of the company as an exclusively positive factor of operational efficiency [2] in the conditions of war also needs correction, since, for example, the emphasized non-participation of the company in helping the army leads to a negative evaluation of the brand by internal consumers, and the absence of a policy of corporate social responsibility affects negative perception of brand in foreign markets. Ignoring the risks of war is common in scientific works on this issue. Thus, despite a detailed enumeration of operational efficiency management directions, the need to neutralize dynamic threats and risks is not indicated in the article by Ignatieva, et al. [4].

The policy of reducing carbon emissions also creates new risks for the metallurgical and mining (first of all, coal) industries. This policy requires mining and metallurgical enterprises to make substantial financial expenditures, not only for updating production technologies, but also for restructuring their activities [5]. Since in metallurgy the main share of costs is made up of energy carriers, measures to increase operational efficiency in energy consumption management require significant investments [6], which is a problem even for enterprises in the metallurgical industry of Poland [6], therefore these risks form significant obstacles to the sustainable development of Ukrainian enterprises.

For iron ore mining enterprises and mining and beneficiation plants, ~85 % of energy is provided by fossil fuels, and the need for energy is increasing because the iron content of the ore in the existing deposits is decreasing. At the same time, the terms of implementation of projects to reduce carbon emissions are coming to an end. These projects should double the limit value of the emission indicator. This value for mining and beneficiation plants should be ~0.3 kg/t, and for mining enterprises ~0.041 kg/t [7]. At the same time, in order to determine the need for a review of approaches to managing the efficiency of mining and ore plants and ensuring their sustainable development, Bondarchuk, et al. [8] did not take into account the changes in the approaches of developed countries regarding the import of products with a carbon footprint, considering energy efficiency issues, did not take into account the risk of a complete shutdown of electricity supply during the war. Therefore, in particular, the structure of the cost price of commercial products of MPP given in [8], as a basis for evaluating its operational efficiency, needs a radical revision.

Programs to reduce carbon emissions require large financial costs and this reduces the possibility of financing production modernization projects to neutralize the challenges of the war for the optimization of operational activities [7], which creates additional risks to the sustainable development of enterprises.

To assess the level of influence of operational efficiency on the sustainable development of industrial enterprises, Wang [9] proposed a three-stage data envelopment analysis (DEA) model. The specified model, as proved by Wang [9], is effective in conditions of non-dynamic influences of the external environment. The implementation of the "relative operational efficiency" assessment stage [9] opens up the possibility of further adaptation of the three-stage DEA model to the operating conditions of Ukrainian mining and metallurgical enterprises.

The specified scientific work differs in the adaptability of the approach to operational efficiency management from a wide range of scientific works cited in the review article by Ravi, et al. [10], which rely on the traditional use of the DEA method. The conclusion of Ravi, et al. [10] regarding urgently needed innovative projects to improve operational efficiency, primarily regarding energy management practices, is expanded in the presented article.

The war significantly worsened the state and conditions of activity of metallurgical enterprises. Not only the immediate destruction of their infrastructure, but also the deterioration of access to sales markets, raw materials, etc. limited the possibilities of sustainable development of metallurgical enterprises [11]. Also, a significant factor for the sustainable development of enterprises in the conditions of war was the uncertainty of most of the factors on which operational efficiency improvement projects are based [11]. The significance of the uncertainty is enhanced by the lack of a unified method for assessing the operational efficiency of an industrial enterprise [12]. The impact of uncertainty on the relevance of forecasts regarding operational efficiency improvement projects is significant even for conditions of relatively stable operation of China's metallurgical industry [13]. This is taken into account in the presented article.

According to a systematic review of literary sources in the article by Miranda, et al. [14] it is indicated that the structure of sustainable mining should be aimed at improving the sustainability of the entire chain of production processes from mining to processing. Given the fact that mining activity is polystructured, the modernization of enterprises in the mining industry may involve modification of certain operational aspects [14]. This can only be agreed with the implementation of the systematic coordination of the mentioned operational aspects, which is used in the presented article.

External coal markets, primarily the EU market, today experience significant turbulence due to geopolitical risks, which lead to an increase in the use of energy carriers [15]. This opens a window of opportunity for financing the modernization of production by Ukrainian coal enterprises due to the optimization of operational activities.

This requires a change in approaches to the management of the operational efficiency of domestic coal enterprises, therefore it requires a study of the tools and methods for managing the operational efficiency, projecting its increase in the conditions of economic instability and war risks. The task of researching the management of sustainable development as a process of dynamic provision of equilibrium and balance of operational activity, which is implemented using optimization information and software tools in real time based on dynamic management of resources of all kinds, arises.

The purpose of the article is to explore the possibilities of dynamic management of operational efficiency as a tool for ensuring the sustainable development of the enterprise in the conditions of modern challenges.

The tasks that need to be solved are the study of: the effects of modern challenges on the functioning of mining and metallurgical enterprises; prerequisites for dynamic management of operational efficiency; directions for improvement of operational efficiency management tools; implementation of the approach of systematic operational coordination of operational efficiency relationships with dynamic changes in the internal and external environment.

Methods. When performing the research, general and special methods of cognition were applied. The method of content analysis made it possible to determine the balanced state of the enterprise under dynamic changes in conditions and risks as a quasi-steady state, and their consistent set as a quasi-steady development.

The dialectical method is to establish that the risks of war not only complicate the functioning of Ukrainian enterprises, but also create windows of opportunity for some enterprises to implement measures to increase operational efficiency. Therefore, one of the tasks of management is to use the specified windows of opportunity for the development of the enterprise.

The method of critical analysis is to establish that the significant dynamism of external challenges forms the prerequisites for dynamic management of operational efficiency as a tool for the sustainable functioning of the enterprise. The method of analysis and synthesis is to propose a systemic and

fragmentary approach to implementing projects to improve operational efficiency.

The method of mathematical analysis made it possible to propose a transition from using not factors for modeling dynamic processes, but their derivatives in time, which can allow the use of standard and proven software products for modeling dynamic processes. Then the vectors of the model proposed by Wang [9] can be interpreted as tangents to the response surface of the objective function, and the method for filtering insignificant effects should be narrowed down to filtering the factors of influence in short periods of time.

In this case, the methodology for determining the operational efficiency of an industrial enterprise [9] is proposed to be supplemented with a two-dimensional derivative comparison procedure using the DirectXMath procedure

$$\text{XMVector2Greater} \left(\frac{\delta y_i}{\delta t_1} ; \frac{\delta y_j}{\delta t_2} \right) \text{ when } t_1 \in \Delta t_1; t_2 \in \Delta t_2,$$

where y is parameter, $i = 1, 2, ..., n$ − parameter index, n − number of parameters; t − time, Δt_1, Δt_2 − time intervals during which the parameter is examined, and the time interval Δt_1 precedes the time interval Δt_2.

It also needs to be established whether the second derivative takes on value

$$\frac{\delta^2 y_i}{\delta t^2} = 0,$$

because then the direction of change in the indicator becomes opposite.

An additional condition also needs to be applied

$$\left\{ \frac{\delta y_n}{\delta t} \right\} \Vdash \Psi \rightarrow \vec{A} \rightarrow opt,$$

which means that for all output variables y_n control should be applied, which will allow their derivatives to pass through a single area Ψ belonging to the objective function, which will mean the achievement of an urgent operational goal, followed by the formation of an integral vector of development $\vec{A}$, which will ensure the achievement of the strategic goal of management.

This is a mathematical formalization of the system operational coordination of operational efficiency relationships with dynamic changes in the internal and external environment and solves the problem of increasing the value of adaptive operational management for the sustainable functioning of enterprises in crisis conditions.

This can be useful not only in the DEA model [9], but also in other models, in particular, the AS-IS model [16], MES and CMMS systems [17], the MESSAGE model [13], which is used to forecast energy consumption, which is especially important for mining and metallurgical enterprises [18, 19].

Results. In modern conditions, sustainable development of enterprises, ensuring their operational efficiency is possible only with dynamic adjustment of strategic and operational plans in response to constant changes in external challenges. That is, the sustainable development of enterprises requires management to ensure their considerable adaptive capacity. In such conditions, the established definition of "sustainable development" can be interpreted not only as "sustainable" [20], but also as uniform and balanced development.

For uniform and balanced development in conditions of instability, management must introduce methods of dynamic balancing of resources and opportunities. At the same time, since due to the variability of external influences, no acquired state of enterprise functioning can be stable over a long period of time, it can only be defined as a quasi-stable state, and their sequential set as a quasi-stable development. With this approach, stability is acquired in shorter time intervals than with the stable development of enterprises in peacetime conditions and the absence of crisis manifestations.

This requires relying mainly on operational and not only on strategic management, it forms the prerequisites for dynamic management of operational efficiency as a tool for the sustainable functioning of the enterprise.

This confirms the growing importance of operational efficiency in the conditions of war and crisis to ensure the sustainable development of enterprises.

This also means that under project management, the achievement of system balance should not be permanent, as in the conditions of a stable economy [21], but piecewise continuous in nature, i.e. acquire a certain level of balance through the implementation of management measures.

At the same time, management goals for increasing operational efficiency differ significantly for enterprises in different regions of Ukraine. This, in particular, is indicated by the significant differentiation of changes in the regional volumes of metallurgical products produced, calculated in hryvnias, from 2022 to the corresponding indicator of 2021 using data from the State Statistics Service [22]. If for Kharkiv Oblast this indicator was 43.15 %, for Kirovohrad Oblast − 43.53 %, then for Sumy Oblast − 121.9 %, Kyiv − 128.755. Thus, the specified indicator can be used as an indicator of the impact of military actions on activities of metallurgical enterprises in certain regions and the level of war risks for them. The difference in the deviation of the specified indicators from the national average of 47.96 %, for all the negative signs for the state economy, at the same time indicates the opening of a window of opportunity for financing measures to increase the operational efficiency of enterprises, the impact of the war on their activities is smaller, which will accordingly increase them competitiveness and level of sustainability of their functioning in crisis conditions.

The effects of the war create the most significant risks for all spheres of operation of mining and metallurgical enterprises. Since, as indicated in the review of literary sources, there are scientific works that ignore the significance of these risks, the dynamics of the activity indicators of the specified enterprises will be presented.

Fig. 1 shows the dynamics of the number of metallurgical and mining enterprises covering the periods of intensification of hostilities in the East of Ukraine according to the data of the State Statistics Service [22], excluding enterprises that temporarily suspended production. These data show that after the start of the war in 2014, the number of enterprises stabilized in the period 2017−2021 and again underwent drastic changes - by 20.7 % in 2022 (Fig. 1). Unfortunately, the State Statistics Service of Ukraine does not provide data for the following years due to the large-scale war.

Production volumes (Fig. 2) according to the data of the State Statistics Service [22] also underwent drastic changes, in particular, the drop in the volume of products manufactured by the country's metallurgical enterprises is due to the blockade of sea export routes.

This had a corresponding effect on the fluctuations of the Index of industrial products for the extraction of metal ores in
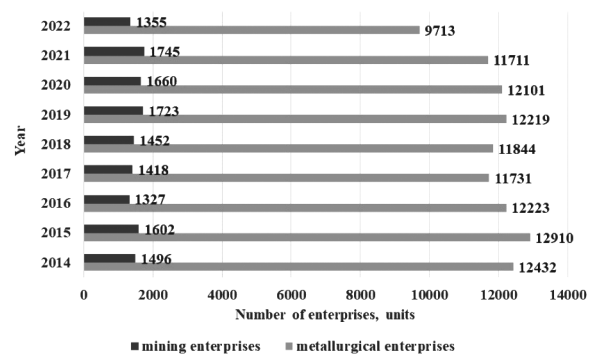

Fig. 1. Dynamics of the number of mining and metallurgical enterprises, unit
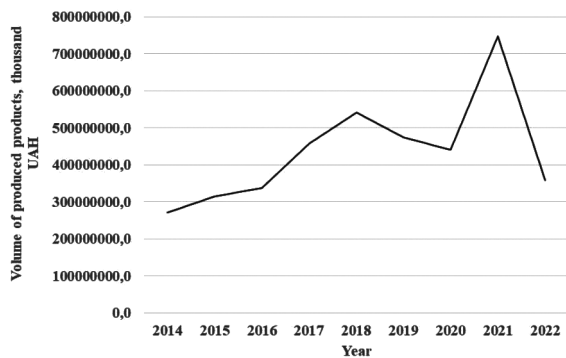
Fig. 2. Dynamics of the volume of products manufactured by the country's metallurgical enterprises, thousand hryvnias

2023–2024 [23] due to the relatively less variable trend of the Index of industrial products for the production of cast iron, steel and ferroalloys, although for a certain period there was an accumulation of warehouse stocks of raw materials (Fig. 3). The growth of the volume of metal ore extraction in 2023 was also influenced by the state of the European market, in particular by the factors given in the article by Brodny, et al. [15], which opened a window of opportunity for the export of metal ores.

This confirms the significant dynamism of external challenges, which leads to the unstable operation of metallurgical and mining companies, the unstable operation of their technological equipment, which generally reduces operational efficiency, since the suspension of production leads to an increase in costs and a decrease in productivity. It can also result in a decrease in product quality.

The operational efficiency of enterprises at that time was also influenced by the organization of their management. In particular, during the implementation of the risk management system at some enterprises, threats related to military operations did not even appear in the list of key risks [24].

Increasing the efficiency of management is also required due to the lack of financial resources, the economic crisis, and significant risks of war. This also requires a radical change in the approaches of traditional project management in the modernization of enterprises as a necessary prerequisite for their development. In particular, a reduction in the time of implementation of projects and the time of their payback, since the risks of war significantly increase the amount of operating costs due to the inappropriate state of technological processes.

The shortage of resources of all kinds — organizational, personnel, financial requires a departure from the linear in time execution of project stages, or even a partially combined
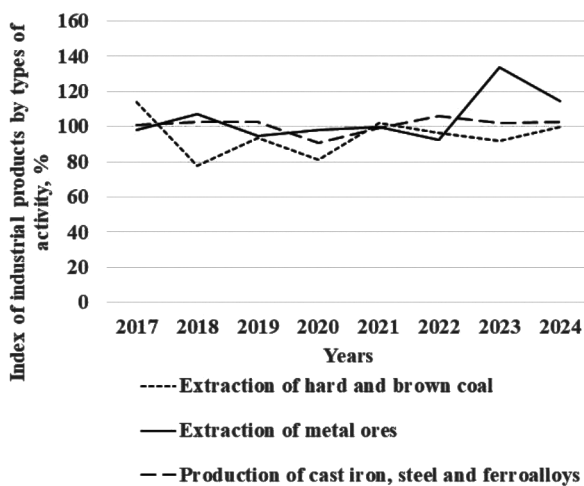
option with parallel execution of some stages, to a system-fragmented one. The system-fragmentary approach consists in the complex coordination of subprojects, which are fragments of the main project, according to their aperiodic implementation, with the acquisition of a synergistic effect from the implementation of groups of subprojects. This makes it possible to solve the problem not only of minimizing project costs, but also, which becomes important due to dynamic changes in the level and types of threats, the overall minimization of costs and time of project implementation, because an increase in time increases not only the costs and risks of the enterprise, but also the level of uncertainty of the introduced management actions.

This also requires a fundamental change in operational efficiency management tools, namely:

- target operating model, so called TOMtm should not be immutable but adaptable to challenges;
- the architecture of business processes must be variable;
- coordination of actions with business partners should be carried out in real time;
- the change in operational efficiency management structures should not be defined as development, but as a changed radical restructuring;
- the indicator management system should ensure operational restructuring, since even a set of indicators can change significantly.

This also shows that the conditions of the crisis require a departure from resource-based and other traditional approaches to evaluating the effectiveness of operational activities, in particular, in the implementation of investment projects and the transition to a system of variable target-evaluation indicators. It also requires a narrowing of the use of gross profit as a factor for evaluating the effectiveness of management and an expansion of the use of this operating profit.

Even the approaches to assessing the effectiveness of the use of resources, as one of the traditional elements of the effectiveness of operational activities, during wartime require changes. For example, labor resources should be evaluated taking into account the factors of personnel mobilization and migration, provision of raw materials and components — taking into account the risks of bombing logistics routes, etc.

Significant (by times or even by order) dynamic changes in the severity of risks, the emergence of new types of threats, the growth of the impact of challenges due to their unexpected mutual reinforcement reduces the effectiveness of risk management software products recognized in the world and tested by Ukrainian manufacturers in optimizing business processes. An example of such a software product, in particular, is Aris [16], which is used by Metinvest enterprises to form and support structural and functional models. The specified software products require an additional block of dynamic risk forecasting and the formation of variable structural and functional models, i.e. branched "decision trees" for the restructuring of organizational, production, sales and other activities of mining and metallurgical enterprises in the conditions of modern challenges as a tool for ensuring their sustainable development.

This limits the use of other proven tools and methods of business process management, for example, "integration definition for function modeling" (ref. IDEF0) on the basis of Performance Management [16], since the methodology of data flow diagrams does not foresee dynamic changes in indicators in short periods of time and, which is also important, unforeseeable significant changes in indicators.

This is confirmed by a comparison of operating expenses of PJSC "Poltava Mining and Processing Plant" in 2023 and 2022 (Table 1). The results of the comparison according to the financial statements of the company [25] indicate that with a significant decrease in net income from sales of products in 2023 — by 33 %, operating expenses were reduced by only 24 %, and with the coincidence of the values of the weight of material costs for 2022–2023 year, at the same time, the weight of depreciation expenses increased by 25 %, labor costs — by

Fig. 3. Index of industrial products for the mining industry by types of activity, %

Comparison of operating costs of 2023 and 2022 of PJSC "Poltava Mining and Processing Plant"

Parameter	Indicator 2022 year, thousand UAH	Weight of the parameter in the net income	Indicator 2023 year, thousand UAH	Weight of the parameter in the net income	The ratio of the indicators of 2023 and 2022
Net income from the sale of products	22,513,941	–	15,066,927	–	0.669227
Material costs	2,748,400	0.122075	1,939,938	0.128755	0.705843
Labor costs	1,401,331	0.062243	1,285,180	0.085298	0.917114
Deductions for social events	261,521	0.011616	237,072	0.015735	0.906512
Amortization	1,806,486	0.080239	1,611,748	0.106973	0.892201
Other operating expenses	13,276,567	0.589704	9,766,090	0.648181	0.735588
Total	19,494,305	0.865877	14,840,028	0.984941	0.761249

27.1 %, the weight of other operating expenses − by 10 % (Table 1). That is, the specific values of the indicators of operating costs of PJSC "Poltava Mining and Processing Plant" in 2023 have increased. This is a consequence of negative external influences and management measures to neutralize them.

At the same time, the relative coincidence of the weight of material costs for the years 2022−2023 (Table 1) hides the unevenness of resource and energy provision of the enterprise in war conditions. This should be taken into account, since management activities at this time should be directed to those projects to improve operational efficiency that will prevent the influence of this factor.

A comparison was made of the whole-value specific indicators of operating costs of PJSC "Poltava Mining and Processing Plant", which were calculated relative to the net income from the sale of products. It was determined that the second derivative of specific aggregate operating costs became zero with the beginning of a full-scale war. After this period, derivatives of specific material costs show growth at a rate (ratio of derivatives of the next and previous evaluation time) of 0.14; specific labor costs − growth at a rate of 1.87; specific costs for depreciation − growth at a rate of 0.52; specific other operating costs - growth at a rate of 9.26. This indicates a constant trend of decreasing operational efficiency of PJSC "Poltava Mining and Processing Plant".

The unstable supply of electricity in wartime conditions makes it difficult to use the traditional approach of ensuring operational efficiency by reducing the share of fixed assets that are not used, at the same time, it leads to an increase in the load on equipment for the restoration of electricity supply; an increase in repair costs, an increase in the level of depreciation deductions. For example, FERREXPO PLC production costs for the first half of 2024 increased by 11 % compared to the same period in 2023 (Table 2) due to rising electricity prices.

This situation worsened in the second half of the year due to the adoption by the Cabinet of Ministers of Ukraine of Resolution No. 661, according to which the company must purchase at least 80 % of its own electricity consumption on the EU energy market. Since electricity prices in the EU are higher than in Ukraine, this exacerbates the problems of ensuring operational efficiency. It will not be possible to compensate for this negative impact by increasing production.

This has the consequence for the FERREXPO PLC company in 2024, according to the data of the London Stock Exchange [26] shown in Table 2, that with a significant increase in production volumes and, accordingly, an increase in the income indicator, there will be a reduction of one third of the net cash flow from the operating activity and closing of net funds − by 15 %. Further, as announced by institutional structures, the increase in the cost of electricity and the increase in the risks of unstable energy supply may lead to a deterioration of the indicators specified in Table 2. At the same time, additional capital expenditures to ensure their own energy con-

sumption from alternative energy sources (~$0.95 million per megawatt of electric energy) and taking into account the experience of FERREXPO PLC management in the construction of solar power plants could reduce the risks of instability of external energy supply and protect against a significant reduction in net income from product sales (Table 1). In particular, additional energy supply in the amount of ~7 MW, which will require $6.3 million and, at the same time, constitutes a significant share of the production of PJSC Poltavaoblenergo CHPP and requires expenses in the amount of only 35 % of the reduction of cash flow from operating activities in 2024 relative to 2023 (Table 2), would allow satisfying not only a significant share of its own needs, and in case of a critical situation, to provide assistance to the region.

Based on a retrospective analysis, it can be indicated that the change in the orientations of production modernization from the project of the press filtration complex to projects of autonomous supply of electricity using alternative sources would help reduce the risks of unstable electricity supply and avoid the need to shut down two or three granulation lines, as is happening now.

The project of the press filtration complex, aimed at increasing the quality of products, which in a strategic plan can increase the competitiveness of the company, but the energy supply stabilization projects, solving the operational task,

Comparison of the results of the company FERREXPO PLC for the first half of 2024 and 2023

Parameter, $ million (unless otherwise stated)	6 months ended 30.06.24	6 months ended 30.06.23	Change, %
Total pellet production, thousand tons	3,297	1,967	+68
Total sales volumes (pellets and concentrate), thousand tons	3,849	2,085	+85
Average 62 % Fe iron ore fines price, US$/t	117.3	118.3	−1
Revenue, million US dollars	549	334	+64
C1 Cash Cost of production, US$/t	78.8	71.3	+11
Underlying EBITDA, million US dollars	79	64	+24
Diluted EPS, US cents	9.26	4.54	+104
Net cash flow from operating activities, million US dollars	56	80	−30
Capital investment, million US dollars	55	58	−5
Closing Net Cash, million US dollars	112	131	−15

could also contribute to the achievement of the specified strategic goal in the following periods.

Conclusions. It is indicated that, since in the conditions of constant and significant changes in external challenges, no acquired state of operation of the enterprise can be stable for a long time, the definition of "sustainable development" should be interpreted in the conditions of war as uniform and balanced development. It is proposed to define the balanced state of the enterprise as a quasi-steady state, and their consecutive aggregate as a quasi-steady development. This also means that the achievement of the balance of the production system should not be permanent, as in the conditions of a stable economy, but piecewise and continuous in nature, that is, it should acquire a certain level of balance through the implementation of appropriate management measures. This causes an increase in the importance of adaptive operational management for the sustainable functioning of enterprises and provides grounds for using not factors, but their derivatives in time, for modeling dynamic processes. This also simplifies the use of standard software products for modeling dynamic processes of enterprise functioning.

It is noted that the risks of war not only complicate the functioning of mining and metallurgical enterprises, but also, as a result of significant regional differentiation of influence, create windows of opportunity for some enterprises to implement measures to increase operational efficiency, which will accordingly increase their competitiveness and the level of sustainability of their operation in the crisis conditions.

It is indicated that the significant dynamism of external challenges requires not only an operational change in approaches to managing the development of enterprises, but also a real-time change in management goals, combining tactical and strategic priorities, that is, it forms the prerequisites for dynamic management of operational efficiency as a tool for sustainable development of the enterprise.

The shortage of resources of all kinds in the conditions of war and economic crisis requires the use of a system-fragmentary approach to the implementation of measures to increase operational efficiency, that is, comprehensive coordination of management sub-measures for their aperiodic implementation with the acquisition of a synergistic effect from implementation. This makes it possible to solve the problem not only of minimizing the financial costs of the project, but also, which becomes important due to dynamic changes in the level and types of threats, the total minimization of financial costs and the time of implementation of management measures, because an increase in time increases not only the costs and risks of the enterprise, but also the level of uncertainty of implemented management actions.

This also requires a fundamental change in operational efficiency management tools, even the need for constant adaptive changes to the target operating model itself and the variability of the business process architecture. The directions of these changes are indicated.

The above also shows that the conditions of the crisis require a departure from resource and other traditional approaches to assessing the effectiveness of operational activities in view of the instability and instability of resource provision in conditions of dynamic changes in risks, in particular, in the implementation of management measures to ensure the sustainable functioning of enterprises, and a transition to systems of variable goal-evaluation indicators.

It is also appropriate to narrow down the use of gross profit as a factor in evaluating the effectiveness of management and to expand the use of operating profit for this.

It is indicated that significant dynamic changes in the importance of risks, the emergence of new types of threats, the growth of the impact of challenges due to their unexpected mutual reinforcement reduce the effectiveness of risk management software products recognized in the world and approved by Ukrainian manufacturers in optimizing business processes.

These software products require an additional block of dynamic risk forecasting and the formation of variable structural and functional models, i.e. branched "decision trees" for the restructuring of organizational, production, sales and other activities of mining and metallurgical enterprises in the conditions of modern challenges as a tool for ensuring their sustainable development.

This is confirmed by a comparison of the indicators of operating costs of PJSC "Poltava Mining and Processing Plant".

The approach of systematic operational coordination of the interrelationships of operational efficiency with dynamic changes in the internal and external environment is proposed.

According to a retrospective analysis, it is indicated that the change in orientations for the modernization of the production of the FERREXPO PLC company from the press filtration complex to the direction of autonomous supply of electricity using alternative sources would help reduce the risks of unstable electricity supply and avoid the need to shut down two or three granulation lines, as it is happening now.

Prospects for further research are the development of a system of variable goal-evaluation indicators for evaluating the effectiveness of operational activities, in particular, in the implementation of investment projects.

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Забезпечення операційної ефективності гірничого-металургійних підприємств на засадах сталого розвитку

О. В. Латишева[*1], *В. В. Ровенська*[1], *І. І. Смирнова*[1],
М. М. Тріпак[2], *М. А. Теплюк*[3]

1 — ТОВ Технічний університет «Метінвест політехніка», м. Запоріжжя, Україна

2 — Навчально-реабілітаційний заклад вищої освіти «Кам'янець-Подільський державний інститут», м. Кам'янець-Подільський, Україна

3 — Київський національний економічний університет імені Вадима Гетьмана, м. Київ, Україна

[*] Автор-кореспондент e-mail: olena.latysheva@mipolytech.education

Мета. Вдосконалення динамічного управління операційною ефективністю для забезпечення сталого розвитку підприємства в умовах сучасних викликів. Завдання роботи: дослідити зовнішні впливи на функціонування гірничих і металургійних підприємств; виявити передумови динамічного управління операційною ефективністю, напрями вдосконалення інструментів управління операційною ефективністю.

Методика. Метод контент-аналізу дозволив визначити сталий розвиток підприємств в умовах динамічних викликів як збалансований квазісталий розвиток. Діалектичний метод — встановити, що ризики війни також утворюють для підприємств вікна можливостей. Метод критичного аналізу — встановити, що значний динамізм викликів обумовлює динамічність адаптивного управління. Метод аналізу й синтезу — запропонувати системно-фрагментарний підхід упровадження заходів підвищення операційної ефективності. Метод математичного аналізу дозволив запропонувати перехід від використання для моделювання динамічних процесів не факторів, а їх похідних.

Результати. Досліджені впливи викликів на функціонування гірничо-металургійних підприємств. Визначені передумови запровадження динамічного адаптивного управління операційною ефективністю. Визначені напрями вдосконалення інструментів управління операційною ефективністю. Запропоновано підхід оперативного узгодження операційної ефективності із динамічними змінами внутрішнього й зовнішнього середовища. Удосконалене управління операційною ефективністю одного з гірничих підприємств.

Наукова новизна. Обґрунтована необхідність динамічного управління операційною ефективністю як інструменту сталого функціонування підприємства. Запропоновано визначити сталий розвиток за значного рівня й динамічності зміни зовнішніх впливів як збалансовану послідовну сукупність квазісталих станів, що збільшує ефективність заходів управління.

Практична значимість. Запропоновані підходи збільшують релевантність оцінки операційної ефективності, що підвищує результативність управління й можливість досягти збалансованого розвитку гірничо-металургійних підприємств.

Ключові слова: *сталий розвиток, операційна ефективність, гірничо-металургійне підприємство*