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MAKING MANAGERIAL DECISIONS BASED ON BUSINESS ANALYSIS AND MATHEMATICAL MODELLING FOR THE SUSTAINABLE DEVELOPMENT OF AN IT ENTERPRISE

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INTRODUCTION

Sustainable development in the 21st century is not merely a global strategy but a critical necessity for economies undergoing transformations due to wars, crises, and digital revolutions. For Ukraine, which is simultaneously facing military challenges and post-war reconstruction, forming strategic approaches to modernize key economic sectors, particularly the IT industry, is paramount. In the context of globalization, IT enterprises not only ensure technological sovereignty but also serve as catalysts for the country's innovation ecosystem. However, integrating the Sustainable Development Goals (SDGs) into the operations of these enterprises demands scientifically grounded and analytically robust solutions.

The search for effective management solutions at the intersection of economic feasibility, social responsibility and environmental safety requires the use of modern analytics tools. Business analysis, combined with mathematical modeling, allows IT companies to form sustainable strategies adapted to the changing environment, resource constraints and political uncertainty. This is especially true in the war and post-war periods, when there is a high level of risks, scarcity of resources and fluctuations in demand force enterprises to act in a balanced manner and based on verified data[1].

Globally, several approaches have been developed to integrate Data-Driven management tools into strategic planning. Business analytics involve systematically collecting, processing, and visualizing data. Mathematical modeling formalizes the relationships between factors affecting sustainable development. However, in Ukrainian realities, especially in the field of IT, such approaches are not yet widely implemented, which reduces the effectiveness of management decisions and long-term viability of enterprises[2].

In the context of global economic transformations, the coordination of national strategies with sustainable global development goals is of particular

[1] World Bank. Resilience and Recovery in Ukraine's IT Sector. 2023. URL: https://doi.org/10.1596/it-sector-resilience

[2] Chepurna O., Razinkin N. Optimisation of strategies for working with counterparties and risk management at utility infrastructure enterprises. *Three Seas Economic Journal*. 2024. Vol. 5, no. 3. P. 61–65. DOI: https://doi.org/10.30525/2661-5150/2024-3-8

importance. The paper focuses on SDG 9 (industrialization, innovation and infrastructure), SDG 12 (rational consumption and production) and SDG 13 (combating climate change), which are directly relevant to IT business. These objectives require not only declarative inclusion in strategies, but also their real monitoring and evaluation through quantitative methods.

The purpose of this study is to substantiate methodological approaches to managerial decision-making in IT enterprises based on the integration of business intelligence and mathematical modeling with a focus on long-term sustainable development. Within the framework of the presentation, the theoretical foundations of sustainable development, applied models of decision support, digital analytics tools are considered, as well as the directions of their implementation in the system of strategic management of the enterprise are outlined.

Thus, the formation of an integrated decision-making system in the IT sector is a prerequisite for ensuring not only competitiveness, but also the resilience of the Ukrainian economy in the face of global threats and local challenges[3].

1. Theoretical and methodological foundations of sustainable development of IT enterprises

The operating conditions of IT enterprises in the first quarter of the XXI century are characterized by a high degree of dynamics, technological complexity and growing pressure of external constraints – from regulatory to resource and environmental. In such conditions, the concept of sustainable development loses its decorative character and acquires features of operational necessity: its integration into management circuits is due not only to institutional obligations within the framework of the UN Sustainable Development Goals, but also to the requirements for the stability of business models in the conditions of multifactorial uncertainty. For the rapidly growing IT sector and at the same time demonstrating increased vulnerability to energy, social and political risks, the concept of sustainability is moving into the plane of real strategic[4] modeling.

Sustainable development in the context of IT entrepreneurship acquires specific content, which includes ensuring the flexibility of business processes, energy efficiency of digital infrastructure, ethical data management, promoting digital inclusion, improving the skills of human capital and

[3] Cherevko Y., Chepurna O., Kuleshova Y. On Information Geometry Methods for Data Analysis. *Geometry Integrability and Quantization*. 2024. Vol. 29. P. 11–22. DOI: https://doi.org/10.7546/giq-29-2024-11-22

[4] Elkington J. Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Capstone, 1997.

transparency of supply chains. These aspects are not covered by traditional financial and economic approaches, and therefore require the involvement of system analysis, multi-criteria assessment and adaptive planning[5].

The scientific literature is dominated by three approaches to the interpretation of sustainable development of enterprises: normative, institutional and instrumental. The first focuses on value guidelines and global ethical imperatives, the second – on the role of regulatory and institutional environments, the third – on management practices that ensure a balance between economic efficiency, social responsibility and environmental sustainability[6]. In the IT sector, an instrumental approach based on quantitative ESG (Environmental, Social, Governance) metrics, KPI analytics data, as well as automated monitoring and forecasting mechanisms prevails.

The Triple Bottom Line (TBL) model, proposed by John Elkington, is the most common basic tool for the operationalization of sustainable development in business practice. It provides for the equivalent accounting of three dimensions: economic (income, costs, profitability), environmental (energy consumption, emissions, waste management) and social (working conditions, diversity, impact on local communities). In the case of IT enterprises, this model needs to be adapted due to the specifics of digital products, minimal material footprint, but high energy consumption and impact on human capital[7]. Table 1.1 demonstrates the comparative characteristics of the main components of the TBL model in traditional and IT companies.

Table 1.1

Comparative characteristics of the main components of the TBL model in traditional and IT companies

Component	Traditional enterprise	IT enterprise
Economic	Proceeds from the sale of goods, capital expenditures	Monetization of digital services, SaaS models, scalability
Environmental	Emissions, water consumption, physical waste	Energy consumption of data centers, digital footprint
Social	Employment rate, social infrastructure	Working conditions in the online environment, digital ethics, inclusion

[5] Cherevko Y., Chepurna O., Kuleshova Y. On Information Geometry Methods for Data Analysis. *Geometry Integrability and Quantization*. 2024. Vol. 29. P. 11–22. DOI: https://doi.org/10.7546/giq-29-2024-11-22

[6] Lozano R. A holistic perspective on corporate sustainability drivers. *Corporate Social Responsibility and Environmental Management*. 2015. Vol. 22, no. 1. P. 32–44. DOI: https://doi.org/10.1002/csr.1325

[7] Epstein M. J., Buhovac A. R. Making Sustainability Work: Best Practices in Managing and Measuring Corporate Social, Environmental and Economic Impacts. Routledge, 2014.

IT companies, unlike industrial ones, create much less physical pollution, but are significant energy consumers, especially when operating scalable data centers and AI platforms. That is why, since 2022, the share of analytical studies aimed at assessing the energy efficiency of digital products and managing the carbon footprint of the digital economy has increased.

The role of stakeholders in the implementation of sustainable development strategies is equally important. The concept of stakeholders in the IT sector includes not only owners and customers, but also regulatory authorities, public organizations, API providers, and participants in open platforms[8].

In recent years, there has been a strengthening of the institutional framework governing sustainable development in the digital economy. At the level of the European Union, several acts have been adopted that directly or indirectly affect IT business, among which *the CSRD – Corporate Sustainability Reporting Directive*, which obliges companies to provide extended non-financial reporting, stands out. Data Management and Environmental Impact[9].

The answer to these challenges is the introduction of an integrated approach to strategic management, in which elements of business analysis and mathematical modeling form the basis for justifying decisions. In practice, this involves expanding traditional SWOT analysis at the expense of ESG components, formalizing sustainability scenarios, and building models of the dependence of key indicators on institutional or technological changes[10].

The key analytical mechanism in this context is the index assessment of sustainability, which is based on the aggregation of indicators into three groups: economic, environmental and social. For IT companies, sustainability indices may include, for example: average server downtime (as an indicator of resource efficiency), the share of «green» hosting, the percentage of women in technical teams, the volume of voluntary reporting on user data.

It is important to note that traditional financial metrics such as ROI, NPV, or EBITDA do not fully consider the sustainability of the business model. Weighted multi-criteria optimization models, like AHP (Analytic Hierarchy Process) or TOPSIS, are increasingly used to consider factors with different impact weights. As can be seen from Table 1.2, which illustrates an example of such a multi-criteria assessment of sustainability in an IT company using

[8] Freeman R. E., Harrison J. S., Wicks A. C. Managing for Stakeholders: Survival, Reputation, and Success. Yale University Press, 2007.

[9] EUR-Lex: Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022.

[10] Epstein M. J., Buhovac A. R. *Making Sustainability Work*. Routledge, 2014. Saaty T. L. Decision making with the analytic hierarchy process // *Int. Journal of Services Sciences*. 2008. Vol. 1(1). P. 83–98. DOI: https://doi.org/10.1504/IJSSCI.2008.017590

the AHP, the financial criterion has the greatest impact, but the environmental and social components also significantly affect the final index.

Table 1.2

Multi-criteria assessment of sustainability in an IT company using AHP

Criterion	Weight	Value (0–1)	Weighted score
Yield	0,35	0,8	0,28
Carbon footprint	0,25	0,5	0,125
Team diversification	0,15	0,6	0,09
Ethical Data Management	0,15	0,9	0,135
Impact on the local community	0,10	0,4	0,04
General Sustainability Index			**0,67**

This approach allows you to integrate non-financial metrics into the strategic decision-making process[11].

Along with quantitative methods, the development of qualitative scenario modeling, which covers uncertainty and resistance to external shocks, is relevant. For example, the *Foresight Planning methodology*, which is widely used in the practice of the OECD and ITU, provides for the construction of alternative scenarios for the development of the IT ecosystem with the involvement of expert assessment, trend analysis and the impact of technological disruptions[12].

In the IT sector, system dynamics is also of particular importance as a tool for modeling complex relationships between processes covering scalability, user behavior, energy consumption and innovation cycles. With the help of causal impact diagrams, it is possible to model the consequences of strategic decisions to introduce new services or changes in privacy policy that directly or indirectly affect the environmental or social sustainability of the company[13].

Thus, the theoretical and methodological foundations of sustainable development of IT enterprises are formed at the intersection of several disciplines – economics, ecology, sociology, mathematical modeling and information technology. Accordingly, the tools used to justify decisions in this

[11] Hahn R., Figge F., Pinkse J., Preuss L. Trade-offs in corporate sustainability: you can't have your cake and eat it // *Business Strategy and the Environment*. 2010. Vol. 19(4). P. 217–229. DOI: https://doi.org/10.1002/bse.674

[12] United Nations Development Programme. Foresight Manual: Empowered Futures for the 2030 Agenda / Global Centre for Public Service Excellence. Singapore: UNDP, 2018. URL: https://issuu.com/undppublicserv/docs/undp-gcpse_foresightmanual2018

[13] Sterman J. D. Business Dynamics: Systems Thinking and Modeling for a Complex World. New York: McGraw-Hill Education, 2000.

area should be multi-level, adaptive, and capable of interpretation in conditions of uncertainty.

Despite the theoretical completeness of the concepts of sustainable development, their implementation in the management practice of IT enterprises requires a thorough rethinking of traditional approaches to planning, analysis and control. Unlike industrial enterprises, which have well-defined material flows and consumption of resources, digital companies often operate in a virtual environment, which creates additional difficulties in identifying the environmental and social footprint. In this context, the openness of data, transparency of information flows, and the availability of analytical platforms for monitoring the dynamics of sustainable indicators play an important role.

The challenges associated with martial law in Ukraine have only reinforced the need to build adaptive strategies for IT enterprises, which should not only preserve human resources and infrastructure, but also continue to provide services to foreign clients in a competitive global environment. In such conditions, sustainable development should be interpreted not as a result, but as a process of continuous risk assessment, reallocation of resources, revision of strategic benchmarks and building organizational strength. flexibility[14].

In view of this, it is advisable to use methods of system analysis, which allow considering the multidisciplinary nature of managerial decision-making processes. Formalization of such decisions involves the construction of mathematical models that combine quantitative indicators of business processes with qualitative characteristics of the impact on the ecosystem. economic feasibility, but also the level of risks, uncertainty and constraints[15].

In this context, models based on the principles of adaptive management are effective: simulation modeling, agent-based approaches, scenario modeling. They allow you to create an integrated decision support system that responds to changes in real time and provides flexibility for strategic actions[16].

Equally important is the issue of assessing the impact of management decisions on the system in the long term. Traditional methods of Cost-Benefit Analysis are insufficient to consider factors of extreme, reputational risks, technological trends and regulatory constraints. Instead, it is proposed to introduce approaches that combine reflective assessment with visual analytics

[14] Chepurna O., Razinkin N. Optimisation of strategies for working with counterparties and risk management at utility infrastructure enterprises. *Three Seas Economic Journal*. 2024. Vol. 5, no. 3. P. 61–65. DOI: https://doi.org/10.30525/2661-5150/2024-3-8

[15] Tiwari A., Turner C., Sackett P. Modelling the Sustainability of Manufacturing Business. *International Journal of Production Research*. 2007. Vol. 45(18–19). P. 4025–4046. DOI: https://doi.org/10.1080/00207540701440261

[16] Sterman J. D. Business Dynamics: Systems Thinking and Modeling for a Complex World. New York: McGraw-Hill Education, 2000.

(BI platforms), integrate sustainability indicators into the company's KPIs, and form appropriate analytical dashboards[17].

The last actively developing direction is related to digital twins (Digital Twins) of sustainable IT systems. It is about building a digital representation of the enterprise's activities, which allows you to simulate the consequences of decisions before their actual implementation. In combination with machine learning tools, this provides an opportunity to optimize strategies, reduce risks and maintain long-term business value[18].

Thus, the theoretical and methodological basis for the sustainable development of IT enterprises should be based on a combination of several key elements:

1) a systematic vision of the relationship between business processes and stakeholders;
2) the ability to adapt models to conditions of uncertainty;
3) digital business analysis tools;
4) methods of mathematical justification of managerial decisions;
5) integration of ESG parameters into the KPI structure.

This approach creates the basis for building an effective system of strategic management of IT enterprises in the context of a transformational economy and global competition.

2. Modeling of management decisions to ensure the sustainable development of IT enterprises

The process of managerial decision-making in the IT sector is traditionally based on a high speed of adaptation to changes, flexibility of the organizational structure and the ability to scale digital products. However, in the context of a strategic focus on sustainable development, these parameters are insufficient: there is a need to formalize processes that consider environmental, social and managerial risks. mathematical modeling, which allows you to make decisions based on multivariate analysis, and not just intuitive assessments[19].

One of the key approaches is modeling sustainable development systems considering the quantitative indicators of business, scenario impacts and uncertainty of the external environment. Such models allow you to identify optimal points of influence on the management system, minimize costs while

[17] Global Reporting Initiative. GRI 12: Coal Sector Standard 2023. Amsterdam: GRI, 2023. URL: https://www.globalreporting.org/standards/sector-standards/coal-sector/

[18] Fuller A., Fan Z., Day C. et al. Digital Twin: Enabling Technologies, Challenges and Open Research. *IEEE Access*. 2020. Vol. 8. P. 108952–108971. DOI: https://doi.org/10.1109/ACCESS.2020.2998358

[19] Tiwari A., Turner C., Sackett P. Modelling the Sustainability of Manufacturing Business. *Int. Journal of Production Research*. 2007. Vol. 45(18–19). P. 4025–4046. DOI: https://doi.org/10.1080/00207540701440261

maximizing the impact on sustainability targets reducing the carbon footprint, improving working conditions, and increasing the energy efficiency of computing infrastructure.

The most common approaches to building mathematical models in the context of sustainable management are:

1) multi-criteria evaluation models (AHP, ELECTRE, TOPSIS);
2) simulation modeling of business processes;
3) optimization models of sustainable development;
4) scenario analysis based on the scenarios «Business as Usual», «Green Shift», «Post-Conflict Recovery»;
5) system dynamics with feedback modeling.

Each of the approaches has its own advantages and limitations. For example, the AHP method provides a subjectively weighted assessment of alternatives, which is an advantage in conditions of insufficient historical data, while simulation modeling allows you to build detailed dynamics of system behavior but requires the presence of a complete set of parameters[20].

In the realities of Ukrainian IT business, it is advisable to combine two or three models to justify each management decision. For example, an assessment of the feasibility of switching to green cloud storage can be based on a combination of the TCO (Total Cost of Ownership) model, an assessment of the CO_2 equivalent of energy consumption, and a SWOT analysis involving ESG indicators (Table 2.1)

Table 2.1

Comparative characteristics of decision-making methods in the context of sustainable development

Method	Model type	Scope of application	Advantages	Restriction
AHP	Multi-criteria	Evaluation of sustainability alternatives	Intuitiveness, simplicity	Subjectivity of weights
Simulation Modeling	Stochastic	Modeling IT processes in a variable environment	Flexibility, detail	High requirements for computing resources
Scenario planning	Combined	Building strategies in the face of uncertainty	Variability, qualitative analysis	Complexity of formalization
System dynamics	Causative	Modeling the strategic consequences of decisions	Taking into account feedback	The need for precise functional dependencies

[20] Saaty T. L. Decision making with the analytic hierarchy process. *Int. Journal of Services Sciences*. 2008. Vol. 1(1). P. 83–98. DOI: https://doi.org/10.1504/IJSSCI.2008.017590

The integration of these methods into Decision Support Systems (DSS) makes it possible to automate the selection of the optimal strategy based on the formed script base. Such systems can be implemented both in *Python* and *R* environments using *SimPy*, *PySD*, *AnyLogic* libraries, and in BI systems such as *Power BI* or *Qlik*, which allow you to visualize sustainability scenarios in the format of analytical dashboards.

In the practice of IT enterprises, it is advisable to start by building a matrix of decisions that considers: a set of goals (economic, environmental, social), available resources, time horizons, scenarios for the development of the external environment.

The next step is to build an optimization function, for example:

$$Z = \alpha_1 \cdot E + \alpha_2 \cdot S + \alpha_3 \cdot G - \beta \cdot R \rightarrow max \text{ where}$$

Z – target function.

E, S, G – respectively economic, social, environmental components.

R is the risk of non-fulfillment of indicators.

α_i, β are the weight coefficients determined by experts.

The implementation of mathematical models of sustainable development in IT companies should take place not as a separate project, but as an integral part of the strategic management system. To do this, it is necessary to develop integrated modules that allow you to combine data from different sources (business processes, finance, ESG reports) and formalize the consequences of management decisions. An effective form of implementation is the creation of a system of sustainability indicators adapted to industry specifics, which can be implemented through BI tools.

An example of this approach is demonstrated by *SAP*, which has implemented its own model of the Sustainability Control Tower, which is based on the regular collection and modeling of ESG indicators. The index is built on a scale from 0 to 100 and includes sub-indices related to energy consumption, gender equality, supply chain transparency, etc. Companies that demonstrate indicators above 75 receive priority in public procurement and preferential lending[21].

In domestic conditions, adaptation of such approaches is possible based on open-source tools. For example, with the help of *the KNIME* or *Orange Data Mining* platform, it is possible to automate the construction of models of the risk of losing customers due to environmental or social reputational crisis. analysis[22].

[21] SAP. SAP Sustainability Control Tower. [BM]: SAP, 2023. URL: https://www.sap.com/products/scm/sustainability-control-tower.html

[22] Kotu V., Deshpande B. *Data Science: Concepts and Practice*. Elsevier, 2018. URL: https://shop.elsevier.com/books/data-science/kotu/978-0-12-814761-0

The use of risk analysis as a separate module is especially important in a period of uncertainty caused by the war. The main risks for IT enterprises in this context are infrastructure losses; loss of human capital (evacuation, mobilization); disruption of funding chains; risk of reputational loss due to unethical business practices.

Each of these risks can be evaluated in a formalized model based on the probability – impact matrix, as shown in Table 2.2.

Table 2.2

Risk matrix for an IT company in the context of sustainable development

Risk	Probability	Impact	Cumulative Risk Score (0–1)
Loss of access to data centers	High	High	0,90
Mass relocation of employees	Average	High	0,75
Interruption of partnership agreements	Low	Medium	0,30
Unsatisfactory ESG rating	Average	High	0,70

To reduce aggregate risk, a company can apply a portfolio scenario model – that is, allocate resources between projects with different levels of impact on sustainable development and different levels of risk. Mathematically, this task boils down to optimizing a limited budget under conditions of stochastic uncertainty, which can be solved by Monte Carlo methods, stochastic programming, or modified Lagrange algorithms[23].

An additional aspect is the econometric assessment of the effectiveness of the implemented sustainability models. For example, according to a study *by Harvard Business School*, companies that systematically publish non-financial statements according to GRI standards demonstrate 11–18% higher profitability in the medium term. This is due to increased investor confidence, stable operating activities, and lower regulatory compliance costs[24]. In the case of the IT sector, an important analytical parameter is the relationship between ESG indicators and the volume of external funding. According to the results of a comparative study of startups in Central and Eastern Europe, the presence of sustainable development policies in

[23]Birge J. R., Louveaux F. *Introduction to Stochastic Programming*. Springer, 2011. URL: https://industri.fatek.unpatti.ac.id/wp-content/uploads/2019/03/120-Introduction-to-Stochastic-Programming-John-R.-Birge-Francois-Louveaux-Edisi-2-2011.pdf

[24] Eccles R. G., Ioannou I., Serafeim G. The Impact of Corporate Sustainability on Organizational Processes and Performance. *Management Science*. 2014. Vol. 60(11). P. 2835–2857. DOI: https://doi.org/10.1287/mnsc.2014.1984

companies increases the likelihood of attracting venture capital by 22%, especially in the Cloud Computing and AI sectors[25].

Thus, mathematical modeling in the sustainable management system of an IT company not only supports strategic decision-making, but also increases the transparency, predictability, and financial attractiveness of the company in the global market.

The successful use of mathematical models in the field of sustainable development of IT enterprises requires not only the technical implementation of individual algorithms, but also the integration of this approach into the strategic management cycle. This means a transition from a one-time analysis model to continuous adaptive decision support, where mathematical models are constantly updated based on new data, changes in the external environment and internal goals of the enterprise[26].

The formalization of such a cycle involves the following stages:

1. Identification of target parameters (KPIs, ESG metrics).
2. Construction of a structural model (network of influences, restrictions).
3. Data collection and calibration (from historical sources or projections).
4. Calculation of alternatives (simulation or optimization models).
5. Assessment of the consequences of each scenario.
6. Feedback and adaptation of parameters.

In the practice of strategic management, it is especially important to use scenario analysis, which allows you to consider the unpredictability of factors, in particular in the context of hostilities, changes in regulatory policy, and the availability of investment capital. Typical scenarios that can be modeled in the strategic planning system of an IT company are:

1) Business-as-usual – maintaining the status quo with minimal changes.

2) Green Shift – active reorientation to ESG indicators, reducing the carbon footprint.

3) Crisis Mitigation – adaptation to limited resources, supply chain disruptions.

4) Innovation Leadership – focus on R&D, implementation of Digital Twins and AI to reduce costs.

Each of these scenarios can be formalized in the form of vectors of parameters that are substituted into the corresponding models – econometric, stochastic or agent-based. For example, the "Green shift" scenario involves a change in the company's energy policy (reorientation to suppliers with a low

[25] Gromek M. ESG strategies and early-stage investment: Evidence from CEE. *Journal of Private Equity*. 2022. Vol. 25(2). P. 17–28. DOI: https://doi.org/10.3905/jpe.2022.1.150

[26] Gromek M. ESG strategies and early-stage investment: Evidence from CEE. *Journal of Private Equity*. 2022. Vol. 25(2). P. 17–28. DOI: https://doi.org/10.3905/jpe.2022.1.150

carbon footprint), which leads to a redistribution of operating costs, a change in the risk profile and an increase in the ESG rating[27].

An important condition for effective model implementation is the provision of a digital infrastructure for processing large amounts of data and supporting real-time modeling. This requires the presence of the following components: a centralized data warehouse (Data Lake, Data Warehouse), modular BI systems (for example, Microsoft Fabric, Tableau Server), a computing platform for simulations and model training (for example, AWS SageMaker), an internal think tank, or a sustainability stakeholder committee[28].

In addition, organizational readiness to use models plays a special role. This involves:

1) the availability of competencies among managers and analysts;
2) formalized decision-making processes using modeling;
3) support from business owners or external investors;
4) regulatory consolidation of the obligation to analyze ESG risks.

Empirical studies prove that IT companies that have built model and analytical tools into the corporate governance structure demonstrate better resilience in crisis conditions and higher investment attractiveness. For example, according to a study by *PwC*, about 68% of investors in 2023 said that they prefer companies with transparent sustainable governance mechanisms, which are confirmed by quantitative models[4].

Concluding the analysis, it is advisable to summarize the methodological aspects of building a solution support system for the sustainable development of IT enterprises in the form of the following principles[29]:

1. The model should be adaptive – with the possibility of operational restructuring for changing conditions.
2. Model indicators must be verifiable – come from verified data sources.
3. Modeling results must be interpretable and appropriate for managerial decision-making.
4. The model should be integrated – implemented in the structure of strategic management.
5. Decisions should be evaluated considering ESG impact, not just financial performance.

It is this formulation of the task – as a multi-factor optimization process with dynamic updates, expert validation and strategic consolidation – that

[27] Van der Heijden K. Scenarios: The Art of Strategic Conversation. Wiley, 2005 https://www.amazon.com/Scenarios-Conversation-Kees-van-Heijden/dp/0470023686

[28] Gartner. Gartner Strategic Data and Analytics Predictions Through 2028. [B.M.]: Gartner, Inc., 2023. URL: https://www.globalreporting.org/standards/

[29] PwC. Global Investor Survey: Sustainability in Decision-Making. 2023. URL: https://www.pwc.com/gx/en/services/esg/global-investor-survey-2023.html

allows IT companies to ensure systemic sustainable development against the backdrop of global challenges, while maintaining competitiveness, adaptability and transparency.

3. Integration of analytical approaches into the strategic management of sustainable development of IT enterprises

The integration of analytical approaches into the strategic management system of IT enterprises is a critical factor in their ability to sustainably develop in a complex and turbulent environment. A digital company today operates as an open-dynamic system, making decisions based on proactive data analysis, risk forecasting, and considering long-term socio-environmental impacts.

A key challenge for IT companies in this context is the need to synthesize several types of analytics – descriptive, diagnostic, predictive and normative. This approach is in line with the concept of Sustainable Management Analytics, within which each management action is accompanied by a model assessment of its impact on economic, environmental and social outcomes[30].

The integration of models takes place mainly in the format of Business Intelligence platforms, which allow not only to visualize metrics, but also to connect them with real management goals. Modern solutions (Power BI, Tableau, Qlik Sense) already contain ESG metrics support modules that can be adapted for the IT sector through the development of specific KPIs. Typical examples of such KPIs are:

1) Carbon Intensity per Gigabyte (CIG) – specific emission level per 1 GB of data.

2) Diversity Index in DevOps.

3) Open-Source Ethics Ratio (OSER) is a share of open source created by a company[31].

Table 3.1

Examples of ESG-Oriented KPIs for IT Companies

Indicator	Formula or data source	Target value
Carbon Intensity per Gigabyte	CO_2 (tons)/Data Traffic (GB)	< 0,01
Accessibility for people with disabilities	% of interfaces compliant with WCAG 2.1	≥ 90%
Gender Balance in IT departments	% of women among developers	≥ 40%
GDPR/CCPA compliance	% of projects that have a compliance check	100%

[30] Bughin J., Chui M., Manyika J. Ten IT-enabled business trends for the decade ahead // McKinsey Quarterly. 2013. № 4. Pp. 56–69 (in Russian). URL: https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/ten-it-enabled-business-trends-for-the-decade-ahead

[31] World Economic Forum. Measuring Stakeholder Capitalism: Towards Common Metrics and Consistent Reporting of Sustainable Value Creation. Geneva: World Economic Forum, 2020. URL: https://www.weforum.org/stakeholder-capitalism/our-metrics/

The integration of such indicators into strategic management maps involves not only control but also forecasting their dynamics using modeling.

For example, based on data on energy consumption by a data center, it is possible to predict changes in the carbon footprint when scaling the service according to three scenarios: basic, intensive, and optimized. The results obtained can form the basis of a scenario budget that considers not only costs, but also ESG loads. The implementation of such an approach in practice requires the creation of analytical control circuits based on modularity. It is advisable to distinguish the following functional components:

1) Data sourcing – data collection from internal and external sources (ERP, CRM, API, standardized ESG reports).

2) Analytics engine – mathematical models for assessing scenarios, risks, and development options.

3) Strategic management interface: decision cockpit (dashboards, reports, scenario models).

4) Governance module – control of compliance with standards (GRI, SASB, ISO 14001).

Such analytical systems should not be isolated but deeply embedded in the OKR (Objectives and Key Results) or Balanced Scorecard (BSC) cycle, which allows establishing cause-and-effect relationships between management actions and sustainable results.

In the practice of companies working in the field of SaaS or cloud computing, there is an active transfer of strategic models to the level of DataOps – continuous analytics that allows you to update forecasts and automate the response of the management system to detect deviations. This allows you to ensure stability at the level of operational processes in a dynamic environment.

Effective management of the sustainable development of an IT enterprise requires not only monitoring current performance but also designing the future state of the company in conditions of uncertainty. In this context, the integration of scenario analysis with business intelligence data makes it possible to build strategic resilience through verified development alternatives.

Building strategic scenarios in the field of IT management involves identifying the main drivers of change (technological innovations, access to finance, personnel mobility, regulatory policy, geopolitical stability) and their combination in a multidimensional space. Each scenario is formalized as a vector of input parameters into the corresponding optimization or simulation model, which allows you to compare the consequences of management strategies in terms of economic performance and ESG effects[32].

[32] Börjeson L., Höjer M., Dreborg K. H., Ekvall T., Finnveden G. Scenario types and techniques: Towards a user's guide. *Futures*. 2006. Vol. 38(7). P. 723–739. DOI: https://doi.org/10.1016/j.futures.2005.12.002

In practice, it is advisable for IT companies to use a combined approach, which includes: a structured expert assessment of the probabilities of scenario development; modeling in a system of dynamical equations or logistic functions with constraints; assessment of multi-criteria effectiveness of scenarios using the methods of ELECTRE, PROMETHEE, MAUT.

The integration of such analysis into the strategic management environment allows you to reduce dependence on the subjective judgment of managers and form decisions with a reasonable level of trust. As evidenced by the experience of companies that have implemented this model, not only financial performance, but also the stability of the corporate structure in crisis conditions increases.

Scenario analysis is of particular importance for Ukrainian IT companies during the war and reconstruction. It is important to consider additional parameters here: the risk of physical destruction of assets; restrictions on logistics and cyberattacks; loss or displacement of human capital; instability of the currency environment.

In conditions of instability, the strategic planning model should include scenarios of «Partial Relocation», «Digital Decentralization», «National Recovery Priority», etc. Each of them must have not only financial calculations, but also ESG justification, particularly the impact on local communities, digital inclusion, carbon neutrality, and resistance to cyber threats.

The experience of *Grammarly*, *MacPaw*, *Genesis* and other Ukrainian representatives of the IT market shows the effectiveness of step-by-step adaptation of strategic models in the post-crisis environment. They demonstrate a combination of:

1) internal ESG control (at the level of HR, procurement, R&D);
2) decentralization of server infrastructure;
3) automation of decision-making processes using BI panels and object models.

An important task is to institutionalize such approaches through internal regulations, compliance policies, and public non-financial reporting. For example, according to GRI standards 302, 305, 401 and 414, an IT company must annually publish:

1) energy consumption of data centers;
2) the number of incidents of violation of ethical conduct;
3) policies for the accessibility of digital services for vulnerable groups.

The design of such reports not only satisfies regulatory requirements, but also becomes a source of data for modeling, as it allows you to form historical series, calculate derived sustainability indicators and use them as part of DSS (decision support systems).[33]

[33] Global Reporting Initiative (2023). GRI 12: Coal sector standard 2023. URL: https://www.globalreporting.org/standards/sector-standards/coal-sector/

At the strategic level, a special role is played by the transformation of organizational culture, which should support the model approach to management. This means that:

1) management recognizes analytical results as the basis for decisions;

2) ANALYTICAL functions are not limited to the IT/BI department but are integrated into all levels of management;

3) corporate goals are aligned with model estimates through KPIs and OKRs.

According to *the MIT Sloan Management Review*, organizations that have created such conditions achieve sustainability results 30 to 40% faster by reducing the level of "internal resistance" and better assimilation of innovative practices[34].

The integration of analytical and model approaches into strategic management requires not only internal changes in the organizational culture of an IT company, but also external institutional support, which forms a favorable environment for sustainable development. In this context, the key role is played by regulatory initiatives of the state, financial and regulatory mechanisms, donor programs, as well as reporting standards, which become part of the mandatory audit of the activities of technology companies[35].

In Ukraine and at the international level, the requirement for non-financial reporting containing data on the impact of business on the environment, social aspects and corporate governance system is increasing. For IT companies, this creates both challenges (the need to collect, verify and structure data) and new opportunities – for example, the opportunity to increase trust from venture investors, foreign partners, participation in international tenders[36].

One of the forms of institutional support is state programs to compensate for energy costs, preferential lending to environmental projects, and preferences for companies operating in accordance with ESG principles. In 2023, the European Bank for Reconstruction and Development (EBRD) proposed a joint initiative with Ukrainian IT clusters to develop energy-efficient data centers, which became the basis for modeling investment projects within the framework of public-private partnerships.

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[34] Kane G. C., Palmer D., Nguyen Phillips A., Kiron D., Buckley N. Strategy, Not Technology, Drives Digital Transformation // MIT Sloan Management Review. 2015. № 1. URL: https://sloanreview.mit.edu/projects/strategy-drives-digital-transformation

[35] European Parliament and Council. Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting. Brussels: Official Journal of the European Union, 2022. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32022L2464

[36] Pucker K. P. Overselling Sustainability Reporting // Harvard Business Review. 2021. № 3. Pp. 134–141. URL: https://hbr.org/2021/05/overselling-sustainability-reporting (in Russian)

From the point of view of economic effect, the introduction of analytical models of sustainable development management has both direct and indirect advantages.

Direct effects include cost optimization (reduction of energy consumption, rationalization of infrastructure), improvement of forecasting of revenues and demand, increase in labor productivity through automation of analytics.

Indirect effects are growth of corporate reputation, improvement of ESG ratings (which affects the cost of capital), increased confidence among customers and investors, reduction of risks of regulatory sanctions or reputational crises.

These advantages are confirmed by numerous cases in the IT field. For example, companies that have implemented internal models for assessing the ESG performance of projects at the stage of preliminary analysis (for example, SAP, Salesforce, Atlassian) demonstrate an increase in the profitability ratio by 8-15% within two years by reducing losses from inefficient investments and improving the long-term sustainability of projects[37].

Given these factors, it is advisable to build an integrated strategic planning structure that allows for full coherence between the company's mission, analytical conclusions and operational actions. The structure should consist of the following levels:

Level 1. Vision and strategic goals (considering the SDGs, ESG policies, reputational benchmarks).

Level 2. Analytical assessment (data collection, KPI analysis, formation of scenario models).

Level 3. Strategic session (discussion of modeling results and adoption of development scenarios).

Level 4. Programming of solutions (selection of implementation tools, appointment of responsible persons).

Level 5. Control and feedback (monitoring, model validation, adaptation of strategies).

It is important that such a structure should not be rigidly hierarchical. On the contrary, in conditions of turbulence, hybrid planning is advisable, which combines elements of agile methodologies (sprints, real-time impact assessment) with long-term scenarios built based on DSS models and ESG analytics.

This approach provides:

1) resistance to external shocks;
2) flexibility in responding to new factors;

[37] Khan M., Serafeim G., Yoon A. Corporate Sustainability: First Evidence on Materiality. *The Accounting Review*. 2016. Vol. 91(6). P. 1697–1724. DOI: https://doi.org/10.2308/accr-51383

3) internal coherence between the analytical apparatus and the system of goals;

4) strategic transparency to external stakeholders.

The systematic integration of analytical and model tools into the strategic management of IT enterprises allows solving several critical tasks: ensuring strategic sustainability, balancing goals, increasing the efficiency of resource use, reducing risks and strengthening reputational capitalization. Instead of a reactive management model based on operational KPIs, the company is moving to a predictive scenario mode, where each decision is considered as the result of modeling long-term impacts.

Empirical studies of companies that have implemented such approaches indicate a significant increase in adaptive ability and innovation potential. Thus, *Atlassian* implemented a strategic management system based on its own BI module integrated with ESG panels, which reduced the loss of time for managerial decision-making by 30% and reduced the carbon footprint by 18% per year[38].

It is important that the implementation of such practices does not require a large budget or external funding – a significant part of the analytical infrastructure can be created on the basis of open-source software (R, Python, KNIME), combined with BI services on a freemium basis or with the help of internal teams. This is especially true for small and medium-sized IT companies in Ukraine, which often operate in a highly competitive environment, but have limited resources for complex IT integrations[39].

Based on the analysis of the practices presented in global and Ukrainian cases, it is advisable to identify 5 key principles that an IT company should consider when integrating analytical approaches into strategic management of sustainable development:

1. Consistency is the formation of a unified logic for collecting, processing, interpreting, and using data at the level of business processes, strategies, and corporate reporting.

2. Modularity is the construction of the architecture of an analytical system as a set of interrelated components that can be changed or scaled in accordance with the development of the company.

3. Impact orientation – measuring not only the results, but also the effects of actions on the ecosystem, users, employees, and external partners.

[38] Atlassian ESG Report and Decision Analytics. 2023. URL: https://www.atlassian.com/sustainability

[39] Raji I. D., Gebru T., Mitchell M. Actionable auditing: Investigating the impact of public machine learning models // FAccT. 2020. P. 49–58. DOI: https://doi.org/10.1145/3351095.3372873

4. Flexibility and adaptability – the use of scenario analysis, uncertainty models and dynamic recalculation of strategic indicators.

5. Responsibility and transparency – implementation of ethical principles in analytical processes, openness of reporting and building trust based on verified data.

Methodological recommendations for Ukrainian IT companies operating in an unstable environment are of relevance. They should take into account: the need for regional diversification of resources (computing, personnel, infrastructure); building a minimum viable analytical infrastructure (even at the level of Google Sheets + API); orientation to external funding indicators (grants, international ratings, innovation competitions); use of ethical standards of project management (e.g. IT4Good, Digital Responsibility Goals); Creating coalitions or partnerships to share data, practices, and tools between cluster companies.

As a result, the integration of analytical approaches not only improves the quality of management decisions, but also forms a new culture of strategic management, where sustainable development is not a declaration, but a measurable process that is constantly adapted and improved. This allows IT enterprises to act not only as subjects of digital transformation, but also as drivers of social change, sustainable growth and institutional modernization of the Ukrainian economy.

4. System integration of sustainable development models into the management practice of IT enterprises

The analysis carried out in the previous sections confirmed that ensuring the sustainable development of IT enterprises in the conditions of high dynamics of the external environment is possible only if a strategic approach is combined with flexible analytics and modeling mechanisms. At the same time, the key advantage of the IT sector is the technological ability not only to process large amounts of data, but also to quickly apply analytical tools in management processes.

The systematic implementation of sustainable transformation models requires enterprises to realize their role in the digital economy ecosystem, supported by the quantification of solutions and a long-term vision of strategic development.

The formation of a sustainable governance system at the enterprise level requires not only structuring goals in accordance with the SDGs and ESG indicators, but also the use of mathematical models to justify decisions. The integration of business intelligence with models of multi-criteria analysis, scenario planning, risk management, and optimization ensures the reliability

of management strategies and increases the company's resilience to external threats. Such integration can be considered as a multi-level system covering:

1) Operational level: monitoring of key ESG indicators and their interpretation through BI panels.

2) Tactical level: comparison of solution options based on AHP, ELECTRE, TOPSIS models.

3) Strategic level: construction of development scenarios and their evaluation through optimization and simulation models.

4) Corporate level: consolidation of the model approach in policies, institutional documents, reporting.

In this context, the concept of system integration arises, which implies the unity of three circuits: analytical, managerial and normative. The combination of these contours allows you to create not just a decision-making system, but an institutionally built adaptation architecture that ensures both the internal sustainability of the enterprise and its ecosystem responsibility.

A special role is played by a sequential combination of input data (internal KPIs, external indicators, public databases); analytical core (mathematical models, expert systems, DSS platforms); solution interface (dashboards, automated recommendations, scenario simulators); validation mechanisms (model audit, forecast accuracy assessment, external verification).

This approach allows the enterprise to adapt to changes in the environment not at the level of reactive response, but at the level of active formation of a sustainable strategy, where each decision is considered in terms of its systemic impact and delayed consequences[40].

In general, the system integration model can be reproduced in the form of a strategic cycle, where each stage is accompanied by appropriate models and indicators:

1) Context diagnostics – PESTEL, SWOT + ESG screening.
2) Formalization of goals – OKR, SR, BSC.
3) Modeling of alternatives – multi-criteria analysis.
4) Predicting consequences – simulation/scenario modeling.
5) Decision-making – DSS module.
6) Validation and feedback – reporting, auditing, model adjustments.

The practical implementation of the analytical and model solutions described is already being carried out in several global and regional IT companies that have implemented systematic logic of managerial decision-making with a focus on sustainable development. Such companies demonstrate not only high efficiency of internal processes, but also

[40] Iansiti M., Lakhani K. R. Competing in the Age of AI: Strategy and Leadership When Algorithms and Networks Run the World. Harvard Business Review Press, 2020. https://www.hbs.edu/faculty/Pages/item.aspx?num=56633

consistency in the implementation of strategies aimed at minimizing ESG risks and increasing management transparency.

One of the typical examples is *Salesforce*, which implemented a centralized system for assessing the impact of each strategic project through a set of internal ESG performance indices. These indices are used as mandatory parameters in evaluating investment decisions, and the results of modeling are used as initial variables for the strategic map. The decision to finance or scale a project is determined by a combined assessment of ROI and ESG Impact Factor, calculated using weighting factors approved by the company's sustainability committee.

In the Ukrainian context, a promising example is the application of a component-based approach to sustainability analytics in mid-level companies – in particular, in IT companies specializing in web development, fintech solutions or AI products. These companies often do not have centralized analytical departments, but they implement integrated dashboards that combine:

1) operational KPIs;
2) customer activity metrics;
3) power consumption of server infrastructure;
4) indicators of employee satisfaction (eNPS, diversity balance);
5) ESG internal audit tools.

A typical tool for such integration is the Sustainability Composite Index, which is calculated as a weighted average of scores in three areas (economic, environmental and social), each of which receives a point score on a scale of 0 – 1. This index can be used as a justification for strategic choices – for example, when choosing a new partner, prioritizing projects or deciding to attract external funding.

Table 4.1

Example of the structure of the Sustainability Composite Index (SCI) calculation

Criterion	**Indicator**	**Meaning**	**Weight**	**Mark**
Economic sustainability	EBITDA/ Total Cost	0,20	0,4	0,08
Environmental sustainability	Kg CO_2 per 1 customer	0,04	0,3	0,09
Social sustainability	Inclusion Index (GDI)	0,7	0,3	0,21
SCI Cumulative Score				**0,38**

The introduction of such tools makes it possible not only to compare alternatives, but also to formalize strategic discussions within the company,

transferring them from the plane of intuition to the plane of the model. As a result, management decisions become reproducible, transparent and standardized – which improves the quality of strategic planning, especially in times of crisis or expansion.

Institutionalization of the model approach to sustainable development involves its consolidation in:

1) corporate charter (through ESG clauses);

2) internal policies and procedures (e.g.«ESG Screening Policy for Vendor Selection»);

3) regular reports to stakeholders (annual non-financial reporting according to GRI or SASB standards);

4) structure of governing bodies (ESG committee, analytical unit with the status of a competence center).

Scaling such models to the level of clusters, associations or industrial parks (for example, *Lviv IT Cluster*, *Diia. City*) creates an opportunity for data exchange, joint training, benchmarking, and standardization of indicators. This is especially important in the Ukrainian realities, where a significant part of small IT companies is outside the formalized practices of reporting and strategic planning[41].

Thus, summing up, we can conclude that the systematic integration of sustainable development models into management practice is not just a technological task. This is a strategic shift to a decision-making model that combines data accuracy, model adaptability, and stakeholder-based management. Only in this configuration can an IT company be not only technologically successful, but also responsible to society and the environment.

Based on the analysis, it can be concluded that the integration of sustainable development models into the management practice of IT enterprises should be considered not as a one-time analytical project, but as a long-term process of forming a new type of management culture, which is based on the values of responsible growth, strategic predictability and systemic adaptability. Sustainable development, under such conditions, turns into an internal regulator of decision-making logic, supported by formal justification tools.

It is worth highlighting 5 methodological approaches that form the conceptual basis for managing the sustainable development of an IT company:

[41] IT Ukraine Association. Digital Tiger: The Power of Ukrainian IT – 2023. Kyiv: IT Ukraine Association, 2023. URL: https://itukraine.org.ua/en/digital-tiger-the-power-of-ukrainian-it-2023

1. Integration of ESG metrics into KPIs and OKRs – through the creation of a system of sustainability indicators relevant to the industry (energy consumption per unit of data, gender balance in technical teams, the share of "green" suppliers, etc.).

2. The use of DSS models based on scenario modeling and multi-criteria analysis - to evaluate strategic alternatives under conditions of uncertainty.

3. Institutionalization of the model approach – through the consolidation of procedures for analyzing the impact of decisions in corporate documentation (ESG-screening, model validation).

4. System integration of BI tools – which allow you to visualize the dynamics of sustainable indicators and form an information basis for decision-making.

5. Organizational readiness for sustainable transformations - through staff training, the formation of cross-functional ESG committees and the stimulation of internal initiative in sustainable practices.

These approaches can and should be adapted to the conditions of Ukraine, where the digital industry has undergone significant changes because of war, relocation, labor market instability, and infrastructure risks. At the same time, it is in this environment that model-analytical management makes it possible to maintain business stability, minimize reputational risks and increase competitiveness in the global market.

Thus, because of the generalization of theoretical and applied provisions in this work, it is substantiated that the systematic integration of analytics and modeling in the strategies of IT companies is not only relevant, but also methodologically and organizationally possible. In the next, final section, generalized conclusions and practical recommendations will be presented, which are based on the results of the analysis.

CONCLUSIONS

Within the framework of the study, it was proved that effective strategic management of IT enterprises in the context of global economic transformations, social risks and environmental challenges requires a new methodological framework, which is based on the integration of business intelligence, digital monitoring and mathematical modeling. Enterprises of the digital economy should act not only as providers of technological solutions, but also as institutionally mature actors capable of combining innovation with strategic responsibility.

Sustainability in the IT sector is not limited to regulatory declarations or compliance policies – it requires analytical soundness and operational feasibility. The main tool for such implementation is the construction of an internal strategic management system that combines a) ESG indicators; b)

digital business intelligence systems; c) formalized mathematical models. In conditions of uncertainty and multifactorial constraints, such a system allows you to maintain strategic controllability, risk adaptability, and transparency to external stakeholders.

The paper shows that the combination of methods of multi-criteria analysis (AHP, TOPSIS), scenario modeling, simulation approach and Data-driven analytics provides not only an increase in the efficiency of decisions but also allows for their formal validation in the face of changes in external parameters. It is highlighted that DSS (Decision Support Systems) systems acquire the highest strategic value, which include internal ESG ratings, analytical dashboards, social impact metrics, and functions for automatically updating strategies using models.

Based on the analysis of Ukrainian IT companies, international cases and open data, the principles of system integration were formulated: structured, adaptability, interoperability and responsibility. It is recommended to implement a system of sustainability indices, a verified ESG reporting structure, sustainability risk assessment models, as well as adaptive scenarios for responding to external destabilizing factors in companies.

Particular attention is paid to the prospects for Ukrainian enterprises – particularly the importance of forming a local infrastructure for decision support, the development of open analytical libraries, building partnership models of cluster coordination and intersectoral exchange of analytical resources is emphasized.

Thus, the study confirmed the feasibility and effectiveness of integrating analytical and model approaches into the strategic management of sustainable development of IT enterprises. This opens ample opportunities not only to optimize business processes, but also to increase the resilience of Ukraine's digital economy during the period of recovery and long-term growth.

SUMMARY

The paper considers the problem of integrating business analytics and mathematical modeling into the system of strategic management of sustainable development of IT enterprises. The emphasis is on the need to combine environmental, social and economic goals under martial law, post-crisis transformation and global challenges of the digital economy. A methodological approach is proposed, which involves the use of decision support systems (DSS), multi-criteria analysis, simulation modeling and ESG metrics. Examples of integrating models into the internal business processes of companies are given, through the construction of dashboards, sustainability indices and risk response scenarios. The potential for the implementation of such systems in the Ukrainian IT sector has been assessed. The study proves

the feasibility of moving from intuitive to model-analytical decision-making. Practical recommendations for company executives, regulators and educational institutions are summarized. The results obtained are of interest to scientists, management specialists, analysts and policymakers of sustainable development. The developed approach can be adapted to the specifics of other industries where digital transformation is combined with sustainability strategies.

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