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MODELS AND METHODS OF ANALYTICAL SUPPORT FOR DECISION-MAKING SYSTEMS IN TRANSFORMATIONAL CHANGE PROCESSES UNDER THE CONDITIONS OF THE DIGITAL AND GREEN ECONOMY

The article substantiates a methodological approach to analytical support for decision-making systems in the context of transformational changes caused by the simultaneous development of the digital and green economy. The relevance of the study is determined by the need to combine technological modernization, environmental responsibility, resource efficiency, and enterprise competitiveness within a single analytical framework. The purpose of the article is to develop an integrated assessment model that makes it possible to evaluate the readiness of enterprises for data-driven digital and green transformation. The proposed approach is based on three analytical blocks: digital maturity, green transformation capacity, and competitiveness of management decisions. The study uses normalization of indicators, weighted aggregation, construction of partial indices, and calculation of an integrated readiness index. Open data sources that can be used for empirical application of the model are systematized, including the State Statistics Service of Ukraine, Eurostat, World Bank Enterprise Surveys, World Development Indicators, and UNIDO Statistics. The article presents a decision matrix that links the level of digital maturity and green maturity with recommended management actions. An illustrative calculation for conditional enterprises demonstrates how the proposed index can classify enterprises into low, medium, and high readiness zones. The practical value of the approach lies in its adaptability to enterprises, sectors, regions, or countries and in its ability to support strategic decisions related to digitalization, sustainability, resource efficiency, and competitive development.

Keywords: digital transformation, green economy, enterprise competitiveness, analytical support, business analytics, management decisions.

Tabl. 3, Fig. 2, Lit. 16.

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МОДЕЛІ ТА МЕТОДИ АНАЛІТИЧНОГО ЗАБЕЗПЕЧЕННЯ СИСТЕМ ПРИЙНЯТТЯ РІШЕНЬ У ПРОЦЕСАХ ТРАНСФОРМАЦІЙНИХ ЗМІН В УМОВАХ ЦИФРОВОЇ ТА "ЗЕЛЕНОЇ" ЕКОНОМІКИ

У статті обґрунтовано методичний підхід до аналітичного забезпечення систем прийняття рішень у контексті трансформаційних змін, зумовлених одночасним розвитком цифрової та зеленої економіки. Актуальність дослідження визначається необхідністю поєднання технологічної модернізації, екологічної відповідальності, ресурсної ефективності та конкурентоспроможності підприємств у межах єдиної аналітичної моделі. Метою статті є розроблення інтегральної моделі оцінювання, яка дає змогу визначати готовність підприємств до цифрової та зеленої трансформації на основі даних. Запропонований підхід ґрунтується на трьох аналітичних блоках: цифровій зрілості, спроможності до зеленої трансформації та конкурентоспроможності управлінських рішень. У дослідженні використано нормалізацію показників, вагове агрегування, побудову часткових індексів та розрахунок інтегрального індексу готовності. Систематизовано відкриті джерела даних, які можуть застосовуватися для емпіричної апробації моделі, зокрема Державну службу статистики України, Eurostat, World Bank Enterprise Surveys, World Development Indicators та UNIDO Statistics. Запропоновано матрицю управлінських рішень, яка пов'язує рівень цифрової зрілості та зеленої трансформації з рекомендованими управлінськими діями. Ілюстративний розрахунок для умовних підприємств демонструє можливість класифікації підприємств за низьким, середнім і високим рівнем готовності. Практичне значення підходу полягає в його адаптивності до підприємств, секторів, регіонів або країн та можливості підтримки стратегічних рішень щодо цифровізації, сталого розвитку, ресурсної ефективності й конкурентного зростання.

Ключові слова: цифрова трансформація, зелена економіка, конкурентоспроможність підприємств, аналітичне забезпечення, бізнес-аналітика, управлінські рішення.

Табл. 3, Рис. 2, Літ. 16.

Problem statement. The increasing turbulence of the business environment, the spread of digital technologies, and the transition to a green economy are changing the logic of managerial decision-making. In this article, the green economy is understood as an economic development model that improves competitiveness and social welfare while reducing environmental risks, resource intensity, and ecological pressure. Enterprises have to respond simultaneously to technological change, market uncertainty, environmental restrictions, and the growing demand for transparent and data-driven decisions.

The problem is particularly relevant for enterprises operating in transformation conditions, where management decisions must rely on comparable, measurable, and interpretable indicators. Analytical support should not only describe the current state of an enterprise but also help classify its readiness for digital and green transformation and identify appropriate management actions.

The relevance of this problem is amplified by the broader policy context. The European Green Deal and the related Fit for 55 and Industry 5.0 initiatives establish binding

decarbonization, energy efficiency, and reporting requirements that propagate to enterprise-level decision-making across European value chains. The Sustainable Development Goals add a complementary set of social and environmental targets. For Ukraine, the dual transformation agenda is reinforced by the post-war reconstruction trajectory and EU integration commitments, which make digital modernization and green transition not parallel but interconnected priorities at the enterprise, sectoral, and regional levels. In this setting, enterprises and policy-makers need analytical instruments that translate heterogeneous indicators of digital maturity, environmental performance, and competitiveness into actionable management decisions, rather than treating these dimensions in isolation.

Analysis of recent research and publications. Research on digital transformation treats it as an organizational change process rather than only the adoption of individual technologies. The author of [1] conceptualizes digital transformation as a process in which digital technologies trigger strategic responses and changes in value creation, while the authors of [2] distinguish digitization, digitalization, and digital transformation as successive levels of business change. The study [3] shows that digital transformation research in business and management has become multidisciplinary and increasingly connected with strategy, innovation, and organizational capabilities.

A second research stream links digital technologies with sustainability and green transformation. The work [4] emphasizes the sustainability functions of Industry 4.0, including resource efficiency, emission reduction, and business model innovation. The authors of [5] demonstrate that Industry 4.0 technologies differ in their sustainability effects and therefore require differentiated assessment. The study [6] connects digitalization with progress toward the Sustainable Development Goals, and [7] frames digital sustainability as a field where digital innovation supports climate and sustainable development challenges.

A third group of studies focuses on the performance and decision-support effects of analytics. The authors of [8] show that big data analytics capability can improve market performance through disruptive business models, especially under competitive intensity. The study [9] finds that digital transformation can improve financial performance through green technology innovation, while [10] identifies green innovation as a mediating mechanism between digital transformation and ESG performance. The work [11] also shows that digital transformation can affect firm performance through enterprise risk management and strategic decision effectiveness. However, these studies rarely combine digital maturity, green transformation, and competitiveness into one interpretable decision-support index, which defines the methodological gap addressed in this article.

A related stream of work develops composite indicators for digital and industrial readiness. The Digital Economy and Society Index (DESI) tracks digital performance across EU member states along connectivity, human capital, internet use, integration of digital technology, and digital public services. The European Index of Digital Entrepreneurship Systems (EIDES) and Industry 4.0 readiness indices apply weighted aggregation to firm- and country-level capability variables. These instruments confirm the methodological viability of composite measurement, but they are typically scoped either to the digital dimension (DESI, EIDES) or to industrial modernization (Industry 4.0 readiness), without integrating environmental performance and competitiveness in the same framework. The model proposed in this article adopts the composite-index methodology of this stream and extends it by combining digital maturity, green transformation, and competitiveness into a single interpretable index linked to a decision matrix.

Purpose of the article. The purpose of the article is to substantiate a methodological approach to analytical support for decision-making systems in transformational change

processes under the conditions of the digital and green economy. The object of the study is the decision-making process of enterprises under digital and green transformation. The subject of the study is the set of models and methods of analytical support used to assess enterprise readiness for such transformation. The article proposes and illustrates an integrated index that combines digital maturity, green transformation capacity, and competitiveness indicators, and provides a decision matrix for interpreting the results of the assessment.

The scientific novelty of the study lies in integrating digital maturity, green transformation capacity, and competitiveness of management decisions into a single interpretable readiness index linked to a management decision matrix. The contribution of the study is threefold: (1) it integrates three analytical blocks that are usually examined separately into a single framework; (2) it formalizes an integrated readiness index with transparent normalization and weighting procedures and explicit thresholds for low, medium, and high readiness; (3) it links the index with a decision matrix that translates combinations of digital and green maturity into recommended management actions.

Presentation of the main research material. The methodological basis of the study is an integrated assessment model of analytical support for decision-making in enterprises undergoing simultaneous digital and green transformation. The study applies the method of composite indicators, normalization of stimulators and destimulators, weighted aggregation, comparative analysis, matrix interpretation, and illustrative calculation. The model combines three analytical blocks: digital maturity (understood as the degree to which an enterprise integrates digital technologies into its operational and decision-making processes), green transformation capacity, and competitiveness of management decisions.

The three blocks are not independent but form a system of mutually reinforcing relationships. Digital maturity provides the data infrastructure (ERP, IoT sensors, analytics platforms) that makes resource consumption, emissions, and material flows measurable, which is a precondition for green transformation. Green transformation, in turn, reduces energy and material costs, regulatory exposure, and reputational risk, and thereby releases resources and managerial attention for further capability building. Competitiveness aggregates the resulting productivity, innovation, and market outcomes, and the financial slack it generates feeds back into investment in digital tools and sustainability initiatives. The integrated index captures the cumulative state of this loop at a given point in time, while the decision matrix prescribes which side of the loop is the binding constraint and therefore the priority for management action.

The initial indicators are divided into stimulators and destimulators. For stimulators, where a higher value improves the enterprise's position, normalization is performed as follows:

$$x'_{ij} = \frac{x_{ij} - x_{min,j}}{x_{max,j} - x_{min,j}} \quad (1)$$

For destimulators, where a higher value reflects higher resource pressure or environmental burden, normalization is performed as follows:

$$x'_{ij} = \frac{x_{max,j} - x_{ij}}{x_{max,j} - x_{min,j}}, \quad (2)$$

The partial indices are calculated as weighted sums of normalized indicators:

$$D = \sum_j w_{dj} x'_{dj},\ G = \sum_j w_{gj} x'_{gj},\ C = \sum_j w_{cj} x'_{cj}, \quad (3)$$

where D is the digital maturity index, G is the green transformation index, and C is the competitiveness and decision-support index. In empirical applications, C may include several indicators such as productivity, value added, innovation activity, output dynamics, and employment stability; in the illustrative calculation below, C is represented by an aggregate productivity-based proxy to keep the example transparent. The general integrated index is calculated by the formula:

$$I = w_D \cdot D + w_G \cdot G + w_C \cdot C. \quad (4)$$

The block weights wD, wG, and wC are assumed to be approximately equal in the absence of empirical calibration on a representative dataset. In this article they are set to wD = 0.35, wG = 0.35, wC = 0.30, which gives slight priority to the technological and environmental dimensions while preserving the role of the competitiveness block. In further empirical applications, the weights can be calibrated using expert procedures such as the Delphi method or the Analytic Hierarchy Process (AHP), or estimated from data through entropy-based weighting. A sensitivity check on the illustrative calculation in Table 3 shows that the readiness classification of enterprises A, B, and C is stable when each block weight is varied within +/-0.10 from the baseline values, since the underlying partial indices D, G, and C differ substantially across the three enterprises.

For applied interpretation, the following intervals are proposed: 0.00-0.39 - low readiness; 0.40-0.69 - medium readiness; 0.70-1.00 - high readiness for data-driven digital and green transformation. The recommended indicators and open data sources [12; 13; 14; 15; 16] are summarized in Table 1, which were selected on the basis of three criteria: (i) availability in open statistical databases that allow reproducible calculation; (ii) cross-country and cross-sector comparability of definitions and measurement units; and (iii) direct conceptual relevance to digital maturity, green transformation, or competitiveness of management decisions.

Table 1. Recommended indicators and open data sources for calculating the integrated index

Block	Indicator	Open data source	Analytical use
D	Basic digital intensity, ERP, AI, IoT, e-commerce, ICT security	State Statistics Service of Ukraine; Eurostat	Assessment of enterprise digital maturity
D/G	Use of ICT systems to reduce energy consumption and material use	State Statistics Service of Ukraine; Eurostat	Link between digital tools and environmental effects
G	Energy intensity, renewable energy share, CO_2 emissions	World Bank WDI	Assessment of green transformation capacity
C	Value added, employment, output, productivity by industry	UNIDO Statistics; World Bank Enterprise Surveys	Measurement of competitiveness and performance
C	Sales, employment, innovation activity, business constraints	World Bank Enterprise Surveys	Firm-level decision-support variables
I	Integrated index of analytical support for transformation decisions	Author's calculation based on normalized open data	Classification of enterprises, sectors, or countries by readiness level

Source: compiled by the authors based on open statistical databases and the reviewed literature.

The appropriate management action for each combination of digital and green maturity levels is formalized in the decision matrix (Table 2), with a visual representation provided in Figure 1. The matrix is constructed as a 2x2 combinatorial scheme over the digital and green maturity dimensions and follows the logic of Industry 4.0 sustainability research [4; 5], in which digital and environmental capabilities accumulate along distinct but interdependent trajectories. Each cell prescribes the management action that closes the binding capability gap: enterprises weak in both dimensions need basic data and energy infrastructure, single-leading enterprises need to extend their advanced capability to the lagging dimension, and dual-leading enterprises move toward predictive analytics and sustainable innovation strategies.

Table 2. Decision matrix for interpreting digital and green transformation readiness

Digital maturity	Green maturity	Recommended management decision
Low	Low	Basic modernization of data collection, energy accounting, and operational control
High	Low	Ecologization of digitally supported business processes and energy management
Low	High	Digitalization of sustainability management and integration of green indicators into dashboards
High	High	Innovation leadership strategy based on predictive analytics and sustainable competitiveness

Source: developed by the authors.

An illustrative numerical calculation for three conditional enterprises is presented in Table 3. The three enterprises are deliberately constructed to represent contrasting starting positions along the digital and green dimensions: a leader (A), a balanced mid-range case (B), and a lagging enterprise (C). For each enterprise, the table reports the normalized values of the underlying indicators, the partial indices D, G, and C calculated according to formula (3), and the integrated readiness index I obtained from formula (4) with the baseline block weights. The same three cases are mapped onto the digital-green readiness matrix in Figure 1, which provides a visual representation of their relative positions and shows how the partial indices translate into the corresponding cells of the decision matrix in Table 2.

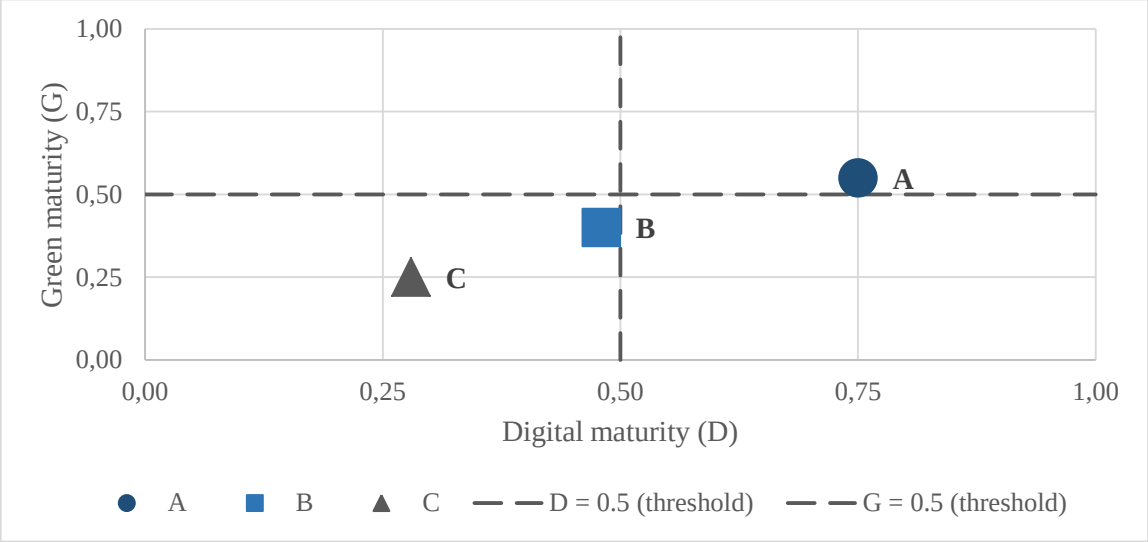

Figure 1. Digital-green readiness matrix of conditional enterprises

Table 3. Illustrative calculation of the integrated index for conditional enterprises

Enterprise	D1 ERP	D2 AI/IoT	G1 Energy ICT	G2 Material ICT	C1 Prod.	D/G/C	I
A	0.85	0.80	0.65	0.60	0.80	0.83 / 0.63 / 0.80	0.75
B	0.55	0.40	0.45	0.35	0.60	0.48 / 0.40 / 0.60	0.49
C	0.30	0.25	0.20	0.30	0.35	0.28 / 0.25 / 0.35	0.29

Source: calculated by the authors for illustrative purposes using conditional data.
Note. Equal weights are used inside each analytical block; block weights are wD = 0.35, wG = 0.35, wC = 0.30. In this illustrative example, C1 Prod. is used as an aggregate proxy for the competitiveness block; in empirical testing, the C block should be expanded according to the indicators listed in Table 1.

The calculation shows that Enterprise A has a high level of readiness for digital and green transformation, Enterprise B has a medium level, and Enterprise C remains in the low-readiness zone.

A closer look at the partial indices identifies the binding capability gap for each enterprise and the corresponding cell of the decision matrix (Table 2). Enterprise A combines high digital maturity (D = 0.83) with high competitiveness (C = 0.80), but the green block (G = 0.63) lags slightly. The binding gap is in environmental performance, and the appropriate actions follow the dual-leading cell of Table 2: deploy predictive analytics for energy and material flows, integrate green KPIs into existing dashboards, and pursue sustainable innovation strategies that monetize the digital and competitive lead. Enterprise B is balanced but uniformly mid-range (D = 0.48, G = 0.40, C = 0.60); no single dimension dominates, which places it close to the centre of the matrix and points to incremental, parallel actions: extending ERP to environmental data, structured energy management, and targeted productivity improvements rather than a single transformative initiative. Enterprise C is low across all three blocks (D = 0.28, G = 0.25, C = 0.35); the binding gap is the absence of basic data and resource-accounting infrastructure, and the matrix prescribes foundational modernization - introducing systematic data collection, energy accounting, and operational control - before any advanced analytics or sustainability initiative can produce a measurable effect. The corresponding index values are illustrated in Figure 2.

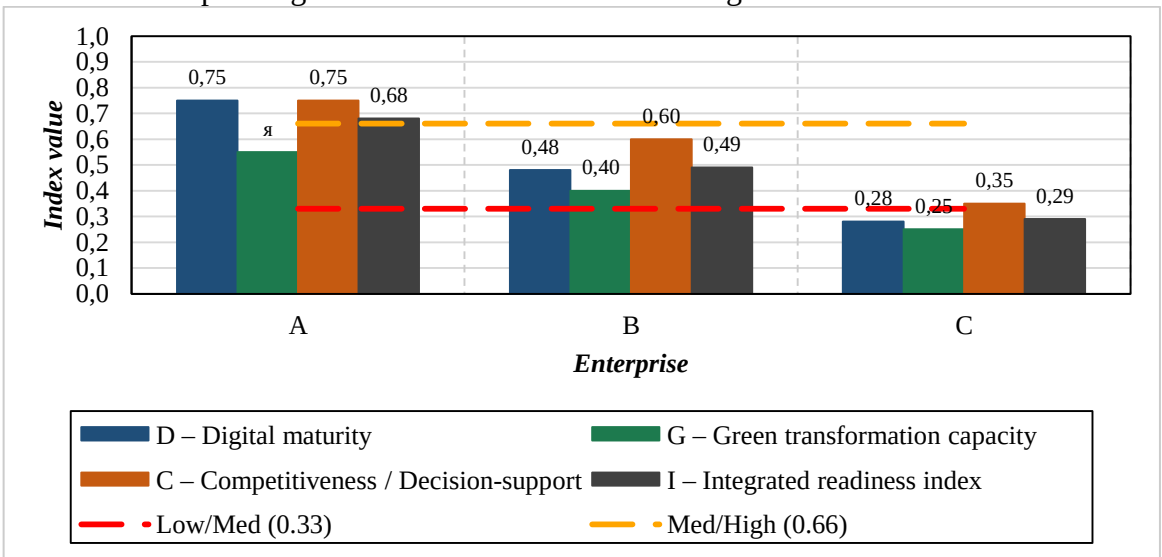

Figure 2. Integrated readiness index of conditional enterprises

Implementation roadmap. The proposed approach can be applied at the enterprise level through the following sequence of steps. First, data collection: assemble the indicators listed in Table 1 from internal records (ERP, energy and resource accounting) and from open data sources (State Statistics Service of Ukraine, Eurostat, World Bank, UNIDO) for the chosen reference period and benchmarking sample. Second, normalization: apply formulas (1) and (2) to convert raw indicators into a zero-to-one scale, treating each indicator as a stimulator or destimulator according to its economic interpretation. Third, aggregation: compute the partial indices D, G, C using formula (3) and the integrated index I using formula (4) with the baseline weights or weights calibrated through Delphi, AHP, or entropy procedures. Fourth, classification and interpretation: assign the enterprise to the low, medium, or high readiness zone, identify the binding capability gap from the partial indices, and read the matching cell of the decision matrix (Table 2) to derive recommended management actions. Fifth, monitoring: recompute the index on a regular cycle (annual or semi-annual), track movement of partial indices and the integrated value over time, and use the trajectory to evaluate the effect of implemented actions and adjust the strategy.

Conclusions. The proposed approach indicates that analytical support for decision-making in transformational change processes should be based on an integrated view of enterprise development. In the conditions of the digital and green economy, the quality of management decisions depends not only on financial indicators but also on the ability of an enterprise to use digital technologies, reduce resource pressure, and maintain competitiveness.

The proposed methodological approach combines three analytical blocks: digital maturity (D), green transformation capacity (G), and competitiveness of management decisions (C). The use of normalization procedures and weighted aggregation makes it possible to compare heterogeneous indicators and transform them into partial indices and the general integrated readiness index I with explicit low, medium, and high readiness thresholds.

The decision matrix developed in the article provides a practical interpretation of the results. It allows enterprises with different combinations of digital and green maturity to identify appropriate management actions, ranging from basic modernization of data collection and resource accounting to predictive analytics and sustainable innovation strategies.

The illustrative calculation demonstrates that the proposed index can be used to classify enterprises according to their readiness for digital and green transformation. The model can be adapted for enterprise-level, sectoral, regional, or cross-country analysis, provided that comparable open data are available.

Theoretical contribution. The article integrates three streams of research - digital transformation, green transformation, and analytics-based competitiveness - into a single decision-support framework, formalizes an integrated readiness index with explicit normalization, weighting, and threshold rules, and connects the index with a decision matrix that maps combinations of digital and green maturity to management actions.

Practical implications. The proposed approach provides managers and analysts with a transparent and reproducible tool for benchmarking enterprises against open data sources, identifying the binding capability gap (digital, green, or competitiveness), and selecting management actions consistent with the readiness zone of the enterprise. The same logic can be applied at the sectoral, regional, or cross-country level for monitoring dual transformation progress.

Limitations. The proposed calculation is illustrative and uses conditional enterprises A, B, and C rather than primary enterprise-level observations. The model does not test causal relationships and does not validate indicator weights on real datasets. The proposed weights and threshold intervals may need recalibration for other sectors, regions, countries, and data environments. Empirical application also depends on the quality, completeness, and

timeliness of open data, and on the cross-country comparability of indicator definitions, which is not always guaranteed across the State Statistics Service of Ukraine, Eurostat, World Bank, and UNIDO sources.

Further research should focus on empirical testing of the proposed model using real statistical datasets, refinement of weighting procedures, and integration of the index into digital dashboards for strategic management and monitoring of sustainable competitiveness.

REFERENCES

1. Vial, G. (2019). Understanding digital transformation: A review and a research agenda. The Journal of Strategic Information Systems, 28(2), 118-144. https://doi.org/10.1016/j.jsis.2019.01.003

2. Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. Journal of Business Research, 122, 889-901. https://doi.org/10.1016/j.jbusres.2019.09.022

3. Kraus, S., Durst, S., Ferreira, J. J., Veiga, P., Kailer, N., & Weinmann, A. (2022). Digital transformation in business and management research: An overview of the current status quo. International Journal of Information Management, 63, 102466. https://doi.org/10.1016/j.ijinfomgt.2021.102466

4. Ghobakhloo, M. (2020). Industry 4.0, digitization, and opportunities for sustainability. Journal of Cleaner Production, 252, 119869. https://doi.org/10.1016/j.jclepro.2019.119869

5. Bai, C., Dallasega, P., Orzes, G., & Sarkis, J. (2020). Industry 4.0 technologies assessment: A sustainability perspective. International Journal of Production Economics, 229, 107776. https://doi.org/10.1016/j.ijpe.2020.107776

6. Mondejar, M. E., Avtar, R., Baños Diaz, H. L., Dubey, R. K., Esteban, J., Gómez-Morales, A., Hallam, B., Mbungu, N. T., Okolo, C. C., Prasad, K. A., She, Q., & Garcia-Segura, S. (2021). Digitalization to achieve sustainable development goals: Steps towards a Smart Green Planet. Science of the Total Environment, 794, 148539. https://doi.org/10.1016/j.scitotenv.2021.148539

7. George, G., Merrill, R. K., & Schillebeeckx, S. J. D. (2021). Digital sustainability and entrepreneurship: How digital innovations are helping tackle climate change and sustainable development. Entrepreneurship Theory and Practice, 45(5), 999-1027. https://doi.org/10.1177/1042258719899425

8. Olabode, O. E., Boso, N., Hultman, M., & Leonidou, C. N. (2022). Big data analytics capability and market performance: The roles of disruptive business models and competitive intensity. Journal of Business Research, 139, 1218-1230. https://doi.org/10.1016/j.jbusres.2021.10.042

9. Ren, Y., & Li, B. (2023). Digital transformation, green technology innovation and enterprise financial performance: Empirical evidence from the textual analysis of the annual reports of listed renewable energy enterprises in China. Sustainability, 15(1), 712. https://doi.org/10.3390/su15010712

10. Wu, S., & Li, Y. (2023). A study on the impact of digital transformation on corporate ESG performance: The mediating role of green innovation. Sustainability, 15(8), 6568. https://doi.org/10.3390/su15086568

11. Xu, N., Lv, W., & Wang, J. (2024). The impact of digital transformation on firm performance: A perspective from enterprise risk management. Eurasian Business Review, 14, 369-400. https://doi.org/10.1007/s40821-024-00264-9

12. State Statistics Service of Ukraine. (n.d.). Use of information and communication technologies at enterprises. https://stat.gov.ua/en/datasets/use-information-and-communication-technologies-enterprises

13. Eurostat. (n.d.). Digital economy and society statistics: ICT usage in enterprises. https://ec.europa.eu/eurostat/web/digital-economy-and-society/information-data

14. World Bank. (n.d.). World Development Indicators. https://databank.worldbank.org/source/world-development-indicators

15. World Bank. (n.d.). Enterprise Surveys data. https://www.enterprisesurveys.org/en/data

16. UNIDO. (n.d.). UNIDO Statistics Portal. https://stat.unido.org/

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