Modern company management based on AI: a holistic and forecasting approaches

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ORIGINAL ARTICLE

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Abstract. The article examines the challenges of managing a modern company in increasing dynamics of digital transformation. Moreover, the integration of artificial intelligence (AI) is a key element ensuring company management flexibility, adaptability, and proactivity. The development of a holistic hierarchical economic-mathematical model synthesises strategic planning, operational management, and predictive analytics. The model is based on machine and deep learning algorithms, and considers dynamic interrelationships between internal and external factors influencing the company's activities. The research considers practical aspects of AI implementation in critical business processes, analyses its on companies key performance indicators, 2020-2024. It also studies industry specifics, macro- and microeconomic trends, and socio-cultural aspects. The implementation of AI intensifies decision-making, minimises cognitive biases, optimises time costs, affects the operational processes, increases both the level of customer interaction personalisation and the company's competitiveness. Moreover, the article concerns with AI ethical aspects, development of control and regulatory mechanisms to provide transparency, fairness, and responsible decision-making.

Keywords: digital transformation; artificial intelligence; economic and mathematical modeling; holistic approach; prognostic approach

JEL codes: M15, O33, C63, L86, M21, D81

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Introduction

The modern economic situation is fundamental transformation of the structure of markets, the evolution of consumer preferences, a change in the paradigm of interaction between market participants, and an acceleration of technological progress. In the dynamic environment the concept of digital transformation dominates. It is a fundamental reconfiguration of the company's business models based on the deep integration of digital technologies into all aspects of its activities from strategic planning to operational management [1, 2].

Recently, various approaches to digital transformation have been actively discussed in the scientific literature. There are a lot of researches concerning AI. According to the papers [16-20], AI successful implementation requires technological readiness, corporate culture changes, staff retraining, and revision of business processes. For instance, the study [16] analyses the impact of AI on strategic management; [17] examines the risks associated with labour automation. The authors of [18] propose a model for assessing the digital maturity of companies; [19] studies the role of AI in the formation of competitive advantages. The works [20, 21] consider the ethical aspects of AI, issues of algorithms transparency and responsibility for decisions based on machine learning; [22] discusses methods for integrating AI into value chains; [23] analyses the impact of digital technologies on sustainable business development; [24, 25] focuses on companies adaptation to new technologies; [26] analyses the role of AI in risk management; [27, 28] consider the influence of AI on marketing strategies; [29] explores the role of digital platforms in the transformation of business models; [30] examines the prospects for the development of AI in the conditions of global economic challenges.

Indeed, AI is the key driver of this transformation. It is able to automate routine operational tasks, intelligently analyse vast amounts of data, model future trends, and make informed management decisions in uncertain and dynamically changing business environment. However, the effective implementation of AI requires the expensive software, transformation of the companies structure, the development of digital

culture, and staff retraining to work effectively with new technologies. Therefore, an integrated approach should consider both technological and organisational aspects of AI implementation [3, 6]. This approach absence could result in failure of the expected returns and have negative impact on the company's activities.

Hence, the relevance of the research is provided by the necessity of a systematic analysis of AI impact on company management and the development of practical tools for its effective implementation. Moreover, our research offers a holistic model combining strategic, operational, and analytical dimensions of AI-based management. It allows us to overcome the fragmentation of approaches typical for many modern studies [16, 20, 24].

In this regard, there is an urgent need to develop fundamentally new approaches to managing a modern company. They should be based on the integration of AI at all levels of decision-making and consider the relationship between various factors affecting companies effectiveness. The purpose of the research is to develop and validate a holistic hierarchical economic and mathematical model of company management. The model includes AI-based digital transformation, assessment of AI impact on key performance indicators. The model also considers industry specifics, macro- and microeconomic trends, and socio-cultural aspects.

According the hypothesis of the research, developed holistic management model based on the integration of AI increases the efficiency of a company by optimising business processes, improving the quality of decisions making, increasing the personalisation of customer interaction and adaptability to changing market conditions.

The scientific novelty of the research is as follows:

1. The development of a holistic hierarchical economic and mathematical model to integrate strategic planning, operational management, and forecasting analytics based on AI. The mosel should consider various factors affecting the company's activities.

2. The methodologies for assessing the digital maturity of a company to determine companies' readiness to implement AI and develop an individual digital transformation strategy.

3. The tools for monitoring and assessment AI impact on companies' key performance indicators in terms of the industry specifics and macroeconomic factors.

4. An approach to company management based on ethical principles and ensuring transparency, fairness, and responsibility in decision-making.

Methods

An interdisciplinary approach was used as the methodological basis of the research. It combines the methods of system and cognitive modelling analysis, mathematical and simulation modelling, statistical and big data analysis, and expert assessments. We develop a holistic hierarchical economic and mathematical model to integrate strategic planning, operational management, and AI-based analytics.

Model Description

The proposed holistic hierarchical management model based on the integration of AI is a multi-level adaptive system. It ensures consistency of goals and objectives at each management level in terms of the relationship between internal and external factors affecting company activities.

1. Strategic Level (macro level). At this level, a company establishes long-term development strategy, defines the strategic goals and objectives, analyses the external environment (macroeconomic factors, industry trends, technological changes, socio-cultural aspects), assesses risks and opportunities, allocates resources, etc. AI analyses big data (market, competitor, consumer data, and technology trends), forecasts demand, models company development scenarios, optimises investment decisions, develops marketing strategies, and assesses a company performance. Moreover, key performance indicators (KPIs) are formed. They are used to assess the effectiveness of the company itself and its individual divisions. The relevant aspect is the assessment of a company digital maturity to determine companies' readiness to implement AI and develop an individual digital transformation strategy.

2. Operational Level (meso-level). At this level, the operational management of business processes, control over the implementation of plans and coordination of departments activities are provided. AI automates

routine operational tasks (robotic process automation – RPA), optimises logistics and inventory management (demand forecasting, optimisation of delivery routes, inventory management), manages production processes (forecasting analytics, optimisation of equipment schedules, product quality control). It also controls the marketing campaigns (personalisation of advertising, targeting, effectiveness of advertising campaigns), customer service management (chatbots, automatic customer request analysis systems, personalisation of service), human resource management (personnel search and selection, employee performance assessment, identification of training and development needs), etc.

3. Analytical Level (microlevel). At this level, data on the company's activities is collected, processed, and analysed; patterns and anomalies are identified, risks and opportunities are forecasted, data-driven decision making is supported, the effectiveness of the company and its individual divisions is controlled. AI analyses big data (sales, customer, production process, logistics, financial and transaction data), identifies patterns and trends, forecasts risks and opportunities, and develops recommendations for improving business processes and the company's performance. The analytical level provides feedback between the strategic and operational levels of management to correct the plans and strategies in accordance with changing market conditions and the company's performance. An important element of the analytical level is the use of cognitive modelling methods to analyse consumer behaviour and making effective marketing decisions.

The scientific novelty of the model is in the development of a holistic approach to company management based on the integration of AI at all levels of management in terms of the relationship between various factors affecting the company's performance; using advanced machine and deep learning methods to analyse big data and forecast future trends; considering industry specifics, macro- and microeconomic trends, and socio-cultural aspects in development of a digital transformation strategy; development a system for monitoring and assessing the company's performance based on KPIs; quickly respond to changes in market conditions and adjust plans and strategies; development of an approach to company management based on ethical principles; ensuring transparency, fairness, and responsibility in decision-making; integration of cognitive modelling techniques to analyse consumer behaviour and make effective marketing decisions.

Mathematical description of the model:

1. Strategic planning function (F_S) (1).

$$F_S = argmax\ \{ E[U(X,Y,Z,W,V)|\Theta] - \lambda R(I,\sigma,\rho), \quad (1)$$

where U is a utility function depending on performance indicators: X (revenue growth in terms of both market share and dynamics), Y (cost reduction in terms of the cost of AI implementing and the cost of capital), Z (increased customer satisfaction in terms of loyalty and personalisation), W (social responsibility and ESG factors in terms of environmental, social, and managerial aspects of sustainable development), V (innovation, design and development of new products and services);

R is a risk function depending on investments in AI (I), the level of uncertainty in the external environment (σ), and the level of company digital maturity (p);

λ is the coefficient of risk aversion determined by the company's risk profile, strategic goals, and the level of digital maturity;

Θ – information on the state of the external environment obtained using AI methods (big data analysis, machine learning, deep learning, natural language processing, machine vision);

E [...|Θ] is the mathematical expectation of the utility function provided information about the external environment. The U function could be a a weighted sum of performance indicators in terms of the company's strategic priorities.

2. Operational Control function (F_O) (2)

$$F_O = min\ \{ C(A,B,Q,S) + \mu P(E,\delta,\varepsilon)\}, \quad (2)$$

where C is a cost function depending on the level of automation (A), resource efficiency (B), management quality (Q), and speed of adaptation to environmental changes (S);

P is a loss function depending on targets deviations (E), the level of uncertainty in the operating environment (δ), and ethical risks associated with the use of AI (ε);

μ is the coefficient of loss significance; it shows the company's priorities regarding compliance with targets, risk minimisation, and ethical standards;

A is the level of process automation determined by the proportion of automated tasks and the use of AI to optimise operations (robotic process automation, machine vision, natural language processing);

B – resource efficiency calculated as the ratio of results to resources expended (material, financial, labour, energy, environment) in terms of sustainable development;

Q – quality management on the basis of expert assessments and indicators of management processes effectiveness (speed of decision-making, level of coordination, effectiveness of communications, level of motivation of employees);

S is the rate of adaptation to changes in the external environment; it is assessed through the rate of new technologies introduction, change in business processes, and the speed of response to changing customer needs.

3. AI-based analytics function (F_A) (3)

$$F_A=argmin\ \{(1/N)\Sigma[y_i-f(x_i,\theta,\omega,\xi)]^2+\gamma\Omega(\theta)+\eta\Psi(\omega)+\zeta\Xi(\xi)\} \quad (3)$$

where y_i is the actual value of the indicators;

f (x_i, θ, ω, ξ) are forecasting values obtained using ensemble machine learning algorithms and cognitive modelling (the function f depends on the input data x_i, model parameters θ, the weights of the assambly ω, and the parameters of the cognitive model ξ);

Ω(θ) is a regularisation function to prevent overfitting of machine learning models;

Ψ(ω) is a regularisation function providing balance between different models in assembly;

Ξ(ξ) is a regularisation function ensuring the adequacy of the cognitive model and preventing its overfitting based on historical data;

γ is the regularisation coefficient for machine learning models;

n is the regularisation coefficient for the weights of the assembly;

ζ is the regularisation coefficient for the parameters of the cognitive model;

N is the number of observations.

Model Practical Testing

To verify the effectiveness of the pilot testing of a holistic hierarchical management model in the real economy, we conducted a retrospective analysis of the operational data of an anonymous company. Those develops IT tools for medium and large businesses, 2020-2024. To respect trade secrets and confidentiality, we cannot provide a company name, as the disclosure of data analysis can damage its competitive position, provide valuable information to competitors, and negatively affect its market strategy. Nevertheless, company provided data analysed in an aggregated form; it confirms data scientific value.

The research considers the industry specifics, determinants of macro- and microeconomic conditions, and socio-cultural factors.

Initially, we selected this company from 100 typical companies on the innovation market. The company designs and develops IT tools for medium and large businesses. The main selection criteria were as follows: assessment of experience and stability in the market (the minimum period of work in the market is at least 5-10 years); financial stability and positive dynamics of key indicators (revenue, profit); reputation and customer reviews (reliability rating, partner certificates); specialisation (focus on IT-solutions and digital transformation, work with medium and large enterprises, availability of innovative products and services related to AI and automation); business size and scale (number of employees providing integrated processes, geographical coverage, and customer base sufficient to summarise research results); availability and quality of data (availability of data collection systems, data storage and analysis (BI, CRM, ERP systems), the company's willingness to cooperate and provide data for research. compliance with confidentiality and ethics requirements); digital maturity and innovation potential (availability of a digital transformation strategy, the use of AI and modern technologies in business processes, the level of investment in R&D and innovation); willingness to provide data for analysis with respecting all confidentiality requirements. Indeed, this approach

to data anonymisation is widely used in academic research for commercial information [21, 26].

The following performance indicators were considered: revenue growth index (in terms of market share and dynamics); cost reduction index (in terms of the cost of implementing AI and the cost of capital); customer satisfaction index (in terms of loyalty and personalisation); business process automation index (in terms of the complexity of tasks and the level of qualification of personnel); resource efficiency index (in terms of environmental factors and principles of sustainable development); the innovation activity index (in terms of the number of new products and services launched on the market and investments in R&D) [4].

The company under study has been operating in the market for more than 15 years. It has a reputation as a reliable partner offering innovative and effective tools for business process automation, data management, cybersecurity, and digital marketing. The company's digital maturity at the beginning of the study period (2020) was assessed as average one. However, that time it did not use AI, machine learning, and big data. However, the management of the company under study was aware of the need for digital transformation, the expediency of investing in new technologies, and staff training.

Results

The results of the implementation of the AI model are shown in a retrospective analysis (Table 1).

Table 1 – Dynamics of performance indicators of the company under study in AI-based digital transformation

Indicator	2020	2021	2022	2023	2024
Revenue Growth Index	1.05	1.08	1.12	1.18	1.25
Cost Reduction index	0.98	0.95	0.92	0.88	0.83
Customer Satisfaction Index	1.02	1.04	1.07	1.11	1.16
Business Process Automation Index	0.35	0.48	0.62	0.77	0.92
Resource Efficiency Index	1.01	1.03	1.06	1.09	1.13
AI and Revenue Correlation Coefficient	0.00	0.25	0.52	0.78	0.95
AI and Costs Correlation Coefficient	0.00	-0.28	-0.55	-0.81	-0.97
Share of Automated Tasks	0.20	0.35	0.50	0.65	0.80
Demand Forecasting Index	0.85	0.90	0.95	1.00	1.05
Logistics Optimisation Index	0.90	0.93	0.96	0.99	1.02
Operational Risk Reduction Index	0.95	0.92	0.89	0.86	0.83
Marketing Effectiveness Index	1.03	1.06	1.09	1.12	1.15
Innovation Activity Index	0.97	1.01	1.05	1.10	1.16
Digital Maturity Index	0.40	0.55	0.70	0.85	0.95
AI Ethical Responsibility Index	0.75	0.80	0.85	0.90	0.95

Source: Author

According to data analysis, targeted implementation of AI within the framework of a holistic hierarchical management model has a significant positive impact on key company performance indicators. However, the effectiveness of AI implementation depends on the level of digital maturity of the company, industry specifics, macro- and microeconomic trends, and socio-cultural aspects. The revenue growth index increased by 19%, 2020-2024. It shows an increase in the company's competitiveness and market share. The revenue growth was achieved through the introduction of AI into marketing, sales, and customer service processes. It personalises offers, improves customer service, and increases customer loyalty. The cost reduction index decreased by 15%. It shows the optimisation of operational processes by automating routine tasks, increases resource efficiency, and reduces inventory management and logistics costs. The introduction of AI into production processes increases productivity, reduces waste, and optimises the use of energy resources. The customer satisfaction index increased by 14%. It shows an improvement in the quality of products and services, an increase in the

level of personalisation of service, and prompt response to customer requests. The introduction of chatbots and automatic analysis systems for customer requests has significantly improved the quality of customer service and increased their loyalty.

The growth of the business process automation index is particularly relevant as it increased by 57%, 2020-2024. This is due to the introduction of AI into various areas of the company's activities, including manufacturing, logistics, marketing, customer service, and human resource management. The resource efficiency index also shows positive dynamics. It indicates the optimisation of the use of material, financial, labour, energy, and environmental resources. The company actively implements the principles of sustainable development and uses AI to monitor and manage environmental risks. The innovation activity index increased by 16%. It shows an increase in the number of new products and services introduced to the market and the efficiency of investments in R&D.

The positive dynamics of these indicators is supported by a significant increase in the correlation coefficients between the introduction of AI and changes in revenue (an increase to 0.95) and costs (a decrease to -0.97). It shows a strong causal relationship between these factors. Increasing the share of automated tasks (up to 80% by 2024) has reduced operational risks, improved demand forecasting accuracy, and optimised business processes. However, the introduction of AI into marketing activities has increased their effectiveness by 12% (an increase in the marketing effectiveness index from 1.03 to 1.15). It shows an increased return on investment in marketing and brand awareness. An increase both in the company's digital maturity level (an increase in the digital maturity index from 0.40 to 0.95) and ain the level of ethical responsibility when using AI (an increase in the AI ethical responsibility index from 0.75 to 0.95) is relevant factor of the model effectiveness.

Generally, the company under study demonstrates a gradual steady systematic growth of the integrated AI-based performance indicator as part of the implementation of a holistic hierarchical management model from 1.01 in 2020 to 1.19 in 2024. Indeed, an annual increase is 3-5%. Figure 1 shows this trend in the form of an ascending chart, emphasising the steady positive dynamics without significant fluctuations.

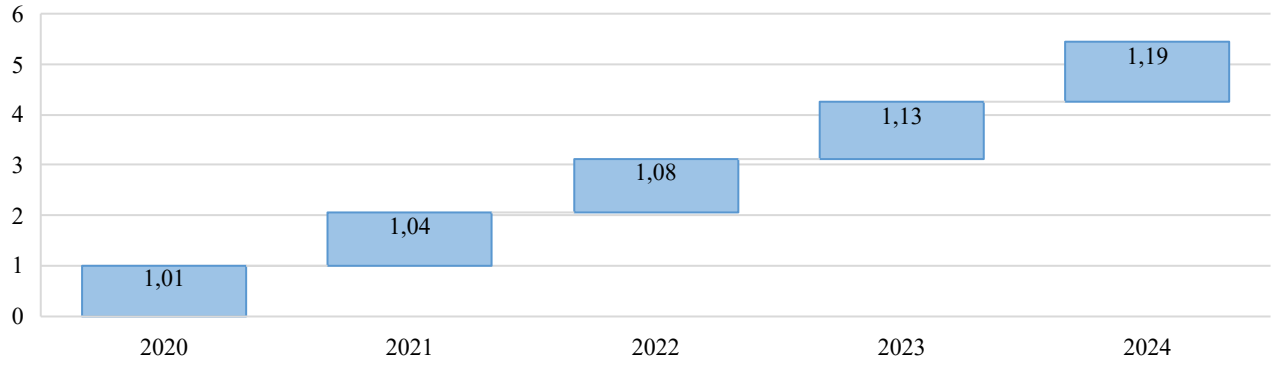

Figure 1. Dynamics of AI based integrated efficiency indicator

Source: Author

In general, the data show an increase in the effectiveness of AI technologies during the study period. It might indicate progress in their implementation and optimisation.

Conclusions

The results obtained confirm the main hypothesis of the study concerning with AI significant positive impact on the effectiveness of company management in the context of digital transformation. The developed holistic hierarchical economic and mathematical model integrates strategic planning, operational management, and AI-based analytics. It provides an integrated approach to management and increases its effectiveness. However, the effectiveness of AI implementation depends on many factors, including the level of digital maturity of a company, industry specifics, macro- and microeconomic trends, and socio-cultural aspects [6].

The results are consistent with the results of other studies [3, 5, 9, 12, 13]. AI introduction can optimise costs, improve the quality of products and services, increase productivity, the level of personalisation of services, and adaptability to changing market conditions. However, AI introduction requires significant investments in technology, infrastructure, staff training, and business process changes [6]. Moreover, advanced development of AI ethical aspects, its control and regulatory mechanisms ensure transparency, fairness, and responsibility in decision-making [7, 8, 15].

The major contribution of this research is the development of a holistic company management model based on the integration of AI. It considers the relationship between various factors affecting the company's performance and ensures its adaptability, flexibility, and proactivity. The model helps to manage resources more efficiently, optimise business processes, improve the quality of decision-making, increase the level of personalisation of customer interaction and company competitiveness.

AI is a key factor in improving the management efficiency of a modern company in digital transformation. The developed holistic hierarchical economic and mathematical model integrates strategic planning, operational management, and AI-based analytics. It provides an integrated approach to management and increases its effectiveness. The results of the retrospective analysis confirm the positive impact of AI on the key performance indicators of the company. However, the effectiveness of AI introduction depends on the level of company digital maturity, industry specifics, macro- and microeconomic trends, and socio-cultural aspects.

Nevertheless, the research limitations should be taken into account when interpreting the results. Firstly, the analysis was based on a single company data. It limits generalising the conclusions to other industries and business models. Secondly, the retrospective analysis does not correspond to assessment of AI implementation in a rapidly changing technological environment. Thirdly, some socio-cultural and ethical aspects of AI require additional qualitative research. Finally, the limited time horizon (2020-2024) does not consider possible structural changes in the economy affecting the effectiveness of AI in the future. These limitations ensure the prospects for further research, including cross-industry comparative analyses, the development of dynamic models of companies' adaptation to technological innovations, etc. [24, 29, 30].

The research results can be used to develop a digital transformation strategy, introduce AI into business processes, assess the effectiveness of investments in AI, and develop ethical principles. Further research might study complex management models in terms of the specifics of various industries and companies, or development the methods for assessing and managing risks associated with the use of AI. [9, 10, 11, 14]. Therefore, it is necessary to develop tools for staff training and AI professional development, protect against discrimination and bias in AI based decision-making.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

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