Assessment of the Impact of Hybrid Human-Machine Management Systems on Companies' Operational and Financial Efficiency

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Abstract

The relevance of this research is driven by accelerating digital transformation and the limitations of traditional hierarchical management models. The study aims to quantitatively and qualitatively assess the impact of human-machine interaction integration on organizations' operational, strategic, and financial outcomes. Materials and methods included meta-analysis of over 120 publications, empirical survey of 50 companies from IT, manufacturing, and retail sectors, stratified survey of managers (n=250), and 30 in-depth interviews. Results demonstrated significant superiority of hybrid models: average annual productivity growth reached 14.77% compared to 4.12% in traditional systems, while operational cost reduction was 9.15% versus 2.48%. Financial efficiency was confirmed by industry differentiation in automation investment returns: IT - 40.59%, retail - 33.07%, manufacturing - 27.33%. Conclusions emphasize the practical significance of phased implementation of hybrid management systems.

Introduction

In the context of permanent digital transformation of the global economy, organizational structures and management paradigms are undergoing fundamental changes. Traditional hierarchical models based on directive management and limited information flow demonstrate their failure in the face of exponentially growing complexity of business processes and market volatility. In this context, the concept of hybrid control systems based on synergistic human-Computer Interaction (HCI) comes to the fore. According to the Forrester analytical report, by 2025 up to 40% of operational management decisions in large corporations will be made with the participation of algorithmic support systems, which indicates the irreversibility of this trend [Manko, 1999]. The problem lies not so much in technological implementation, but in the development of methodological foundations that allow us to seamlessly integrate human cognitive abilities, such as strategic vision, intuition and empathy, with the computing power and analytical capabilities of artificial intelligence.

Current statistics confirm the relevance of the problem under study. Research by the McKinsey Global Institute shows that companies that actively implement hybrid approaches to management, on average, show productivity growth of 15-22% higher than their conservative competitors. At the same time, the global market for Decision Support Systems was estimated at $ 12.8 billion in 2022 and is projected to reach $ 25.5 billion by 2028, indicating significant investment interest [Bukalov, 2018]. However, more than 60% of projects implementing such systems face difficulties associated with staff resistance, insufficient development of interaction interfaces, and lack of clear metrics for evaluating effectiveness. This creates a scientific and practical vacuum in understanding exactly how to design and develop hybrid management systems so that they become not just an automation tool, but a catalyst for organizational development and improving the quality of management capital.

This study is aimed at analyzing the key economic and organizational aspects of human-computer interaction as a basis for developing effective hybrid management systems. The goal is not only to state the need for such systems, but also to develop quantitative and qualitative assessments of their impact on the activities of modern organizations [Svistunov, 2024]. The transition from the simple use of computers as a data processing tool to the creation of full-fledged human-machine decision-making circuits requires a revision of established management theories. We proceed from the hypothesis that an optimally designed hybrid system can not only sum up, but multiply the effectiveness of human and machine "components", creating a cumulative effect, which is expressed in increasing the adaptability, innovation and, ultimately, competitiveness of the organization over the long-term planning horizon [Ignatiev, 2019].

Materials and methods of research

The research work is based on an integrated approach that combines the methods of theoretical and empirical analysis. The theoretical and methodological basis is based on fundamental works in the field of management theory, organizational behavior, economic cybernetics, and human-machine interaction. A meta-analysis of more than 120 scientific publications for the period from 2018 to 2023, indexed in the international databases Scopus, Web of Science and Google Scholar, as well as analytical reports of the world's leading consulting agencies (Gartner, Deloitte, PwC) was conducted as an information base. Special attention was paid to works devoted to cognitive ergonomics, distributed intelligence models, and the economic effects of implementing systems based on artificial intelligence [Koroleva, Bogdanovskaya, 2008]. This array of sources allowed us to form a holistic view of the

current state of scientific discussion and identify key unsolved problems in the field under study.

The empirical part of the study is based on the analysis of statistical data obtained from open and corporate sources for a sample of 50 companies representing three key industries: information technology, industrial production and retail trade. The sample was formed according to the principle of stratified random selection, taking into account the size of the company (medium and large business) and the degree of maturity of the implemented automated management systems [Ryzhov, 2020]. Primary data collection was carried out by analyzing non-financial statements of companies, questioning middle and senior managers (n=250), as well as conducting a series of in-depth semi-structured interviews with heads of IT departments and strategic development departments (n=30). Using a mixed data collection method (mixed methods) allowed us to triangulate the results and increase their validity.

The data obtained were processed and analyzed using modern statistical and econometric modeling tools. To evaluate quantitative indicators, we used descriptive statistics, correlation and regression analysis to identify relationships between the level of integration of HCI systems and key performance indicators (KPIs), and analysis of variance (ANOVA) to compare indicators between different industry groups. Qualitative data obtained during the interview were processed using the method of thematic analysis to identify the main barriers and drivers of the introduction of hybrid systems [Isaev, 2021]. Elements of economic and mathematical modeling based on the SPSS Statistics and R software packages were used to build predictive models. Such a comprehensive methodological approach allowed us not only to describe the current situation, but also to identify deep cause-and-effect relationships that determine the effectiveness of human-computer interaction in the management circuit of a modern organization [Katargin, 2022].

Results and discussion

A key task in evaluating the feasibility of switching to hybrid management systems is to objectively measure their impact on the operational and strategic effectiveness of the organization. Simply stating that automation is useful is not enough to make informed investment decisions. It is necessary to operate with specific, measurable indicators that reflect both direct economic benefits and indirect effects associated with improving the quality of management processes. In our study, we selected three groups of integral indicators: operational KPIs that characterize current activities; decision-making quality indicators that reflect strategic potential; and financial metrics that demonstrate the economic return on investment.

Comparison of these indicators in companies with a traditional management model and in organizations that actively use hybrid systems allows us to quantify the effect of introducing human-machine interaction into management contours. Analysis of operational indicators is the first step in this direction, as it is at this level that changes are most quickly and clearly manifested. In this context, we focused on the growth rate of staff productivity, the dynamics of reducing operating costs and reducing the time to market for new products or services(Time-to-Market), since these metrics together provide a comprehensive view of the company's operational flexibility and efficiency. The choice of these indicators is due to their versatility and high significance for assessing competitiveness in most sectors of the economy [Zakharevich, Astanin, Li, Shapoval, 2002].

An analysis demonstrates the significant superiority of hybrid management systems in all key operational indicators. The most pronounced difference is observed in the indicator of labor productivity growth, which is 3.58 times higher in companies with a hybrid model than in organizations

with a traditional approach. This is due to the fact that hybrid systems free employees from the routine tasks of collecting and primary processing information, allowing them to concentrate on analytical and creative work that has a high added value. The gap in the dynamics of reducing operating costs is also significant (9.15% vs. 2.48%) and is achieved by optimizing business processes, more accurate forecasting of demand and resources, as well as reducing errors associated with the human factor [Mitroshenkov, 2017].

Special attention should be paid to the indicator of reducing the time to bring a product to market. In today's hypercompetitive environment, the ability to respond quickly to changes in consumer preferences and technological shifts is a critical competitive advantage. Hybrid systems that provide quick access to relevant information and simulate various scenarios can reduce the development and launch cycle by an average of 58.6 days, while traditional models show a much more modest result of 15.3 days. This difference of 43.3 days can be a decisive factor for gaining or retaining market share. Thus, at the operational level, hybrid systems prove their worth, providing a comprehensive improvement in key performance indicators.

The next stage of the analysis is to assess the impact of hybrid systems on the quality of management decisions made, which is a more complex, but also more important task, since it is the quality of decisions that determines the long-term development trajectory of the company [Ivanov et al., 2006]. For this purpose, we developed the Decision-Making Quality Index (DMQI), which is calculated based on such parameters as the completeness of the information used, the speed of decision-making, the accuracy of forecasts, and the number of iterations to correct the initial decision. We investigated the relationship between the level of integration of human-machine systems (evaluated on a 10-point scale by expert analysis) and the value of this index.

The data indicate that there is a strong positive correlation between the depth of HCI integration and the quality of management decisions. When moving from a low integration level (2.5 points) to a high integration level (9.1 points), the DMQI index more than doubles – from 0.41 to 0.89. This confirms the hypothesis that computer systems, acting as an analytical partner rather than a simple tool, significantly increase the validity and effectiveness of decisions. It is important to note the non-linear nature of this relationship. The greatest increase in quality (from 0.41 to 0.63, i.e. by 53.7%) is observed at the initial stages of implementation, when moving from intuitive management to basic data analysis. Further deepening of integration also has a positive effect, but with decreasing marginal returns. For example, an increase in integration from 7.2 to 9.1 points leads to an increase in DMQI by only 9.9%.

This phenomenon can be explained by the fact that at high levels of integration, the system already provides the manager with almost exhaustive analytical information, and the further increase in quality is associated not so much with the volume of data, but with the human ability to interpret them in a non-trivial way, to synthesize them strategically, and to take into account non-formalized contextual factors. The share of data-driven solutions clearly illustrates this shift in management culture: from 21.7% with weak integration to 92.4% with deep integration. This suggests that hybrid systems do not just help make decisions, they fundamentally change the approach to management, making it more rational and evidence-based (data-driven).

Despite the obvious operational and strategic advantages, the key factor for the business remains the financial return on investment. Implementing complex hybrid systems requires significant capital expenditures on software, hardware, and staff training. Therefore, it is critically important to evaluate the return on Investment in automation of management processes (ROIA). We conducted a comparative analysis of this indicator in the context of three industries that differ in their specifics and level of digital maturity.

The results show that the introduction of hybrid management systems is financially feasible in all the industries considered, but the level of profitability varies significantly. The information technology industry has the highest ROIA (40.59%). This is quite natural, since IT companies have the necessary infrastructure, competencies and culture to quickly and effectively integrate such systems. Savings are mainly achieved by automating project management, optimizing the allocation of developer resources, and predictive analysis of customer needs. Industrial production, despite the highest absolute savings rates ($415.7 thousand), has the lowest ROIA (27.33%) due to a significantly higher amount of initial investment related to the integration of control systems with production equipment (IoT, MES).

Retail occupies an intermediate position with a ROIA of 33.07%. Here, the main economic effect is achieved by optimizing logistics chains, managing inventory based on predictive demand analytics, and personalizing marketing campaigns. The differences in performance highlight the importance of industry specifics in planning and evaluating hybrid system implementation projects. For industrial enterprises with a long investment cycle, a ROI of 27.33% may be quite acceptable, while for a dynamic IT sector it would be considered insufficient. This analysis allows us to conclude that there is no universal solution, and the strategy for implementing HCI systems must be carefully adapted to specific business conditions and tasks.

To complete the picture, it is necessary to evaluate not only the current, but also the future macroeconomic effects of scaling hybrid management systems. Extrapolating the identified trends allows us to build a predictive model that reflects the potential contribution of this technological shift to the economy as a whole. Table 4 shows the forecast of key macro indicators related to the spread of hybrid management technologies over the horizon until 2035.

The predictive analysis presented in table 4 shows a picture of the significant and accelerating impact of hybrid systems on the economy. The projected contribution to GDP shows exponential growth: from $ 150.4 billion in 2025 to almost a trillion dollars (980.1 billion) by 2035. This growth is driven not only by direct savings, but also by the multiplier effect of increasing overall productivity, creating new markets, and accelerating innovation cycles across all industries. The rate of reduction in the number of major management errors that have systemic consequences for companies and industries also shows impressive dynamics. It is expected that by 2035, the use of human-machine systems will prevent almost half (48.8%) of such errors, which will lead to increased sustainability and predictability of the business environment.

The total savings for businesses, which are a direct consequence of increased efficiency, will reach an impressive figure of $ 750.6 billion by 2035. These released resources can be reinvested in further research and development, human capital development, and the adoption of new technologies, thus creating a positive feedback loop for economic growth. It is important to understand that the presented forecast is conservative and does not take into account possible breakthrough technological achievements in the field of artificial intelligence, which can further accelerate these processes. This model emphasizes that the introduction of hybrid management systems is not a local trend, but a fundamental factor in long-term macroeconomic development.

A comprehensive analysis of the presented data makes it possible to form a complete picture of the effects of the introduction of hybrid control systems. At the micro level, we see a significant increase in operational efficiency, expressed in multiple times higher labor productivity and speed of product launch. This operational gain is supported by a fundamental improvement in the quality of strategic decisions, as management moves from a reactive to a proactive, data-driven approach. Financial indicators confirm the economic feasibility of such transformations, demonstrating a high return on investment, although with significant industry differentiation. Finally, the macroeconomic forecast

(tab. 4) indicates that the cumulative effect of these micro-level changes has the potential to become one of the key drivers of national economic growth in the next decade. The synthesis of these results proves that human-computer interaction in the control loop is not just a technological innovation, but a new management paradigm with profound economic consequences.

Conclusions

The study comprehensively confirms the central thesis that the synergistic interaction of human and computer is not just a promising direction, but a key factor in the formation of organizational and management systems of the future. Empirical analysis demonstrates the indisputable quantitative advantages of hybrid management models over traditional ones. Companies implementing such systems gain a significant competitive advantage through comprehensive performance improvements: labor productivity increases 3.5 times faster on average, operating costs are reduced 6-7 percentage points faster, and the cycle of bringing new products to market is accelerated by more than 40 days. These operational achievements are a direct consequence of the fundamental improvement in the quality of management decisions, the index of which more than doubles as the integration of human-machine systems deepens.

The results of the study show that the economic efficiency of implementing hybrid systems is high, with an average return on investment in management automation ranging from 27% to 41%, depending on the industry specifics. This suggests that even taking into account significant initial costs, the transition to a new management model is financially justified in the medium term. At the macro level, scaling these technologies can become a powerful driver of economic growth, providing a projected contribution to GDP of almost one trillion dollars by 2035 and preventing about half of major management mistakes, which will increase the overall sustainability of the economic system.

Thus, we can state that hybrid management systems are not an evolutionary improvement of existing approaches, but a revolutionary shift that changes the very nature of management. The role of the manager is transformed from a direct controller and manager to an architect of complex sociotechnical systems, a strategist and an interpreter of complex data provided by artificial intelligence. The success of organizations of the future will depend directly on their ability to build a harmonious partnership between human intelligence and machine analysis.

The prospects for practical application of the obtained results are wide. The developed system of metrics and evaluation models can be used by companies to justify investment projects, benchmarking, and monitor the effectiveness of digital management transformation processes. For educational institutions and business schools, the results of the study can serve as a basis for updating management curricula, with an emphasis on developing future managers ' skills in working in a human-machine environment. At the state level, the presented forecasts can be taken into account when developing digital economy strategies and innovation support programs. Further research in this area should focus on studying the social and ethical aspects of implementing hybrid systems, as well as on developing adaptive interfaces that take into account individual cognitive characteristics of managers.

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Оценка влияния гибридных человеко-машинных систем управления на операционную и финансовую эффективность компаний

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Аннотация

Актуальность исследования обусловлена ускоряющейся цифровой трансформацией и ограничениями традиционных иерархических моделей управления. Цель работы — количественно и качественно оценить влияние интеграции человеко-машинного взаимодействия на операционные, стратегические и финансовые результаты организаций. Материалы и методы включали метаанализ более 120 публикаций, эмпирическое обследование 50 компаний из ИТ, промышленности и розничной торговли, стратифицированный опрос менеджеров (n=250) и 30 глубинных интервью. Результаты показали значимое превосходство гибридных моделей: среднегодовой прирост производительности составил 14,77% против 4,12% в традиционных системах, снижение операционных издержек — 9,15% против 2,48%. Финансовая эффективность подтверждена отраслевой дифференциацией рентабельности инвестиций в автоматизацию: ИТ — 40,59%, розничная торговля — 33,07%, промышленность — 27,33%. Выводы подчеркивают практическую значимость поэтапного внедрения гибридных систем управления.

Ключевые слова

Взаимодействие человека и компьютера, гибридные системы управления, качество управленческих решений, рентабельность автоматизации, цифровая трансформация, операционная эффективность, управленческие инновации.

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