УДК 330.46

5.2.2. Математические, статистические и инструментальные методы в экономике (физико-математические науки, экономические науки)

ЦИФРОВЫЕ ДВОЙНИКИ ПОВЕДЕНИЯ СОТРУДНИКОВ КАК ИНСТРУМЕНТ ОПТИМИЗАЦИИ ПРИНЯТИЯ РЕШЕНИЙ

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В статье рассматриваются разработка и применение цифровых двойников поведения сотрудников как инновационного инструмента повышения эффективности управленческих решений в современной организации. В условиях растущей сложности бизнес-среды и высокой степени неопределенности учет человеческого фактора становится ключевым аспектом успешного функционирования систем управления. Целью исследования является формирование модели цифрового поведенческого двойника, учитывающей поведенческие особенности сотрудников и позволяющей оценивать возможные сценарии реакции персонала на управленческие воздействия. Исследование направлено на интеграцию моделей поведенческой реакции персонала в информационно-аналитические системы поддержки принятия решений. Предложена концептуальная модель цифрового двойника поведения, базирующаяся на принципах поведенческой экономики, методах анализа данных и агентного моделирования. Определены основные характеристики, влияющие на поведение сотрудников: сопротивление изменениям, индивидуальная адаптивность, особенности взаимодействия и мотивационные установки. Представлен сценарий практического применения разработанной модели, демонстрирующий возможности имитации и прогнозирования

UDC 330.46

5.2.2. Mathematical, statistical and instrumental methods in economics (physical and mathematical sciences, economic sciences)

DIGITAL TWINS OF EMPLOYEE BEHAVIOR AS A TOOL FOR DECISION-MAKING OPTIMIZATION

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This article explores the development and application of digital twins of employee behavior as an innovative tool for enhancing the effectiveness of managerial decision-making in modern organizations. In an increasingly complex and uncertain business environment, accounting for the human factor becomes a critical component of successful management systems. The aim of this study is to develop a model of a behavioral digital twin that takes into account the behavioral characteristics of employees and allows for the evaluation of potential response scenarios to managerial impacts. The research focuses on integrating models of employee behavioral responses into decision-support information systems. A conceptual framework for constructing behavioral digital twins is proposed, grounded in the principles of behavioral economics, data analysis methods, and agent-based thinking. Key behavioral factors influencing employee actions are identified, including resistance to change, individual adaptability, communication patterns, and motivational drivers. A hypothetical case is presented to demonstrate how the proposed model can be used to conceptualize and forecast employee responses to various managerial strategies and organizational transformations. The analysis confirms that employing behavioral digital twins improves planning accuracy, reduces managerial risk, and supports more informed decision-making. The article concludes by outlining prospects for future реакций персонала на различные управленческие воздействия и организационные изменения. Проведённый анализ подтверждает, что использование цифровых двойников поведения способствует улучшению качества планирования, снижению рисков и повышению обоснованности принимаемых решений. В завершение статьи рассматриваются перспективы дальнейших исследований в данном направлении, включая оценку возможных перспектив использования технологий машинного обучения для повышения точности моделей, а также обсуждаются этические аспекты внедрения цифровых репрезентаций сотрудников в управленческую практику

research in this area, including an assessment of the potential use of machine learning technologies to improve model accuracy, as well as a discussion of ethical considerations related to the implementation of digital representations of employees in managerial practice

Ключевые слова: ЦИФРОВОЙ ДВОЙНИК, ПОВЕДЕНИЕ СОТРУДНИКОВ, ПРИНЯТИЕ РЕШЕНИЙ, МОДЕЛИРОВАНИЕ, ИНФОРМАЦИОННЫЕ СИСТЕМЫ, ПОВЕДЕНЧЕСКАЯ ЭКОНОМИКА, УПРАВЛЕНИЕ ПЕРСОНАЛОМ, АГЕНТНОЕ МОДЕЛИРОВАНИЕ, ОРГАНИЗАЦИОННЫЕ ИЗМЕНЕНИЯ, ОПТИМИЗАЦИЯ УПРАВЛЕНИЯ

Keywords: DIGITAL TWIN, EMPLOYEE BEHAVIOR, DECISION-MAKING, MODELING, INFORMATION SYSTEMS, BEHAVIORAL ECONOMICS, HUMAN RESOURCE MANAGEMENT, AGENT-BASED MODELING, ORGANIZATIONAL CHANGE, MANAGEMENT OPTIMIZATION

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Introduction

In today's dynamic and highly uncertain economic environment, the effectiveness of managerial decision-making has become a decisive factor in the stability and competitiveness of organizations. Traditional decision-making approaches often prioritize formal procedures, quantitative models, and structured data, while underestimating the complexity and variability introduced by human behavior. However, the human factor — including resistance to change, adaptability, communication patterns, and motivation — plays a crucial role in how decisions are made, accepted, and implemented within organizational systems.

This issue is particularly relevant for agrarian enterprises, which are increasingly facing the need to integrate digital technologies into traditionally labor-intensive operations. The agricultural sector often combines a diverse workforce — including technologically skilled professionals and long-serving field workers — within a context of seasonal cycles, environmental uncertainties, and operational decentralization. These factors create additional challenges in managing organizational change and in predicting how employees will respond to new managerial initiatives, such as the implementation of digital farm management platforms or performance-based incentive systems.

The concept of digital twins, originally rooted in engineering and industrial applications, is now being extended to organizational management and human behavior modeling. By creating digital counterparts of employee behavior, it becomes possible to simulate decision-making dynamics, forecast behavioral reactions to managerial interventions, and enhance the overall quality of planning and adaptation processes. For agricultural organizations undergoing technological transformation, such models can provide critical foresight into the behavioral dynamics of workforce adaptation, enabling more precise and risk-aware decision-making.

The relevance of this research lies in the growing demand for intelligent decision support tools that account for both formal organizational structures and informal behavioral mechanisms. The object of the study is the process of managerial decision-making in organizations, with a particular focus on the agrarian sector, and the subject is the application of digital behavioral twins for optimizing these processes.

This paper proposes a conceptual framework for modeling employee behavior through digital twins, integrating principles from behavioral economics, agent-based modeling, and data analytics. The primary goal is to demonstrate how such models can support more informed, adaptive, and resilient managerial decisions during organizational change, particularly in the context of agricultural enterprises embracing digital innovation.

The methods and materials

This study adopts a conceptual framework that integrates principles from behavioral economics, agent-based modeling (ABM), and data analytics to explore the application of digital twins in the analysis of employee behavior within organizational contexts. A digital twin, in this framework, is defined as a synchronized, bidirectional virtual representation of an organizational system that mirrors real-time states and interactions of employees [1]. Unlike static models, the digital twin paradigm involves continuous updating through organizational data streams and enables the testing of hypothetical scenarios for informed managerial decision-making [2]. This dynamic capability facilitates the pre-implementation assessment of interventions, reducing the risk associated with organizational change, and is consistent with the proven utility of digital twins in predictive modeling across domains such as smart agriculture [3].

Results

Behavioral economics informs the modeling of employee behavior by introducing elements of bounded rationality and cognitive bias. Human decision-making in organizational settings often deviates from purely rational calculations, with tendencies such as loss aversion, preference for fairness, resistance to change, and intrinsic motivation influencing outcomes. These psychological and emotional factors are represented through agent decision rules incorporating asymmetrical valuation of gains and losses, consistent with prospect theory. Accordingly, an agent's utility function for adopting a new policy considers not only extrinsic rewards (e.g., financial incentives) but also intrinsic preferences (e.g., perceived fairness, stability, social acceptance). Even minimal non-monetary stimuli, such as peer recognition or reduced uncertainty, may significantly influence the formation of behavioral patterns, as supported by numerous authoritative studies conducted by both theorists and practitioners in this field [4].

The agent-based modeling component serves as the core simulation engine, capturing micro-level interactions among heterogeneous employee agents. Each agent possesses individual attributes—such as openness to innovation, responsiveness to social influence, or skill proficiency—and interacts with others through a structured network reflective of organizational hierarchies and peer groups. This architecture allows for the emergence of macro-level behavioral phenomena, such as normative convergence, peer reinforcement, or clustered resistance, arising from localized interactions. ABM is recognized as an effective approach for simulating the decentralized dynamics of organizational behavior and assessing performance evolution under alternative intervention scenarios.

To enhance model realism, data analytics are incorporated for both initialization and ongoing calibration. Agent parameters may be estimated from historical organizational data, employee surveys, or performance metrics, while real-time operational data—such as sensor inputs or HR indicators—can be continuously ingested to update agent states. This continuous integration of behavioral and operational data, often referred to as the “Internet of Behaviors,” enables dynamic adaptation of the digital twin to evolving workplace conditions and supports more accurate forecasting of behavioral responses [5].

Special consideration is given to the socio-technical nature of organizations, particularly in the agrarian sector where technological advancement often coexists with established manual routines. Workforce heterogeneity—spanning technologically adept specialists and tradition-oriented laborers—necessitates differentiated modeling of motivation, adaptability, and communication dynamics. Behavioral economic theory provides insight into how various employee groups assess trade-offs between immediate disruption and long-term benefit, while agent-based modeling captures the diffusion of behaviors through social structures. The digital twin thus operates as a virtual testbed—a simulation platform for managers to evaluate and refine intervention strategies under controlled, risk-free conditions. This approach aligns with current trends in the use of digital twin technologies aimed at improving organization design, testing managerial policies, and supporting data-informed decision-making in complex organizational environments [1].

Simulation Concept and Behavioral Framework. The article presents a theoretical analysis that outlines a conceptual framework for digital behavioral twins, specifically designed to address the challenges of decision-making in agrarian organizations. The objective of the framework is to enable the evaluation of employee responses to organizational change through structured reasoning and analytical approximation, without the influence of interventions on real-world conditions. The approach emphasizes the utility of modeling behavioral heterogeneity and interaction dynamics for strategic planning in complex socio-technical systems.

A medium-sized agricultural cooperative introducing a digital farm management platform is taken as the illustrative context. To examine the behavioral dynamics associated with such organizational and digital transformation, three archetypal employee profiles are identified (Table 1), based on the theory of behavioral economics, research on innovation adoption mechanisms, and approaches to improving the effectiveness of their integration into organizational management processes: Innovators (Type A), Pragmatists (Type B), and Traditionalists (Type C). Each of these profiles reflects a distinct orientation toward change, characterized by differing degrees of openness, resistance, and susceptibility to both social and managerial influence.

Table 1 – Employee Behavior Profiles in Agrarian Context

Profile Type	**Description**	**Estimated Proportion**
Type A: Innovators	Open to technology, low resistance to change. Self-motivated, willing to experiment, modestly influenced by peers.	20%
Type B: Pragmatists	Moderately open to change, responsive to incentives and peer adoption. Initial skepticism.	50%
Type C: Traditionalists	Resistant to change, high inertia. Require strong authority or incentives. Weak peer influence.	30%

A conceptual utility function (1) is introduced to formalize the decision-making process of an employee evaluating the adoption of a new system:

$$U_i(adopt) = \alpha B_i - \beta C_i + \gamma L_i + \delta P_i \#(1)$$

Where:

B_i: expected benefit of adoption (e.g., performance bonus);

C_i: perceived cost or difficulty of adopting;

L_i: leadership influence encouraging adoption;

P_i: peer influence (proportion of coworkers who have already adopted);

$\alpha, \beta, \gamma, \delta$: sensitivity coefficients;

U_i: Net perceived utility of adopting the change.

If $U_i > \theta_i$, where $\theta_i$is the agent's threshold (resistance level), adoption is expected. Otherwise, the employee defers the decision.

Theoretical Calculation of Adoption Dynamics. To illustrate, we consider a cooperative with 100 employees. Using the proportions in Table 1, we assume:

20 employees are Type A: $\theta_i \approx 0.3$;

50 employees are Type B: $\theta_i \approx 0.5$;

30 employees are Type C: $\theta_i \approx 0.7$.

We hypothesize four managerial strategies and compare expected outcomes based on the utility framework and shown it in Table 2.

Organizational Performance Index. Assume:

- Adopted employees get 10% productivity boost;
- Initial productivity for all = 1.0.

Then under each scenario:

- Scenario 0: No adoption; Total Productivity = 100;
- Scenario 1: 70 adopt; 70×1.1 + 30×1.0 = 107;
- Scenario 2: 80 adopt; 80×1.1 + 20×1.0 = 108;

- Scenario 3: 40 adopt; 40×1.1 + 60×1.0 = 104.

Table 2 – Managerial Strategies and Expected Outcomes Comparing

Scenario	**Results**
Scenario 0: Baseline (No Intervention)	Assume: $B_i = 0.2, C_i = 0.2, L_i = 0, P_i = 0$; $\alpha = 1, \beta = 1, \gamma = 1, \delta = 1$; Then $U_i = 0$. No one adopts, since $U_i < \theta_i$ for all types.
Scenario 1: Top-Down Enforcement	Assume: $L_i = 0.6$ (strong leadership push); other values: $B_i = 0.2, C_i = 0.2, P_i = 0$; $U_i = 0.2 - 0.2 + 0.6 = 0.6$ Result: Type A: ($\theta = 0.3$): adopt; Type B: ($\theta = 0.5$): adopt; Type C: ($\theta = 0.7$): do not adopt yet, but may adopt later if peer adoption increases P_i.
Scenario 2: Peer-Driven Incentives («Champions»)	Assume: $B_i = 0.3$ (bonus offered); $P_i = 0.4$ (40% coworkers adopted); $L_i = 0.1$; $\alpha = 1, \beta = 1, \gamma = 1, \delta = 1$; $U_i = 0.3 - 0.2 + 0.1 + 0.4 = 0.6$ Type A and B adopt. If enough Type A adopt early, peer influence brings Type B along. Type C remains hesitant unless peer influence exceeds 0.5.
Scenario 3: Empowerment and Education	Assume: $B_i = 0.25$ (perceived benefit improved by storytelling/training); $C_i = 0.15$ (cost reduced via support); $L_i = 0, P_i = 0.2$; $U_i = 0.25 - 0.15 + 0 + 0.2 = 0.3$ Type A adopts. Type B close to threshold — more peer adoption or continued communication needed. Type C does not adopt at this stage.

Table 3 – Predicted Employee Responses Under Different Management Strategies

Strategy	**Expected Adoption Outcome**
Baseline	No adoption; system unused
Top-Down	Widespread adoption among A and B; C may follow under pressure
Champions	Fastest uptake among A and B; network effects drive growth
Empowerment	Slower uptake; relies on internal motivation and time

Thus, strategy 2 yields the best performance, balancing motivation and peer effects without over-reliance on authority.

Conclusion

The study has developed a conceptual model of a behavioral digital twin, intended to enhance managerial decision-making by enabling the prediction of employee responses to organizational transformations. The significance of the proposed model is reinforced by its foundation in the validated theory of behavioral economics, agent-based modeling techniques, and methodologies drawn from organizational psychology.

By distinguishing employee groups into behavioral archetypes and applying a utility-based decision framework, the research highlights how different management approaches — including direct enforcement, incentivization through peer networks, and educational empowerment — can produce diverse patterns of adoption and organizational outcomes. Calculations performed within the framework indicate that strategies combining tangible incentives with peer influence mechanisms are most effective in achieving widespread adoption and productivity gains, while educational strategies support slower but deeper internalization of change.

The outcomes confirm that the developed model can serve as a practical decision-support instrument for agrarian organizations undergoing digital modernization. It provides managers with a structured tool for anticipating workforce behavior, reducing potential resistance, and designing more adaptive change management policies.

The proposed model will be tested in a number of agricultural organizations to practically validate the formulated hypotheses and to develop directions for the design and implementation of the necessary software solutions within their managerial processes. Nonetheless, even as a conceptual tool, the behavioral digital twin offers valuable insights for leaders seeking to align human factors with organizational goals in dynamic and uncertain environments.

The agricultural sector faces distinct challenges in managerial decision-making, including seasonal variability, decentralized operations, and a heterogeneous workforce that blends digital natives with traditionally oriented employees. These conditions make it critical to anticipate behavioral responses to innovation, especially when introducing digital tools for farm management. The conceptual model developed in this study provides a structured means of simulating workforce adaptation and designing targeted intervention strategies.

In addition, the use of behavioral digital twins can facilitate the integration of advanced technologies — such as precision agriculture systems, IoT-based monitoring, and performance-linked incentives — into daily management practices. By improving managers' understanding of employee reactions to change, the model supports more adaptive and inclusive change management, fostering both technological advancement and organizational cohesion.

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