A Scientific and Methodological Approach to Identifying and Solving Current Problems in the Context of Digital Economic Transformation

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Abstract

The article presents a comprehensive methodology for identifying and solving scientific and practical problems that possess commercialization potential. The methodology is based on a systems approach and consists of eleven interrelated stages — from analyzing prerequisites to assessing economic efficiency. Particular attention is paid to the scientific validity of each stage and their applicability in the context of digital transformation of modern enterprises. The proposed approach minimizes risks during the implementation of innovative solutions and ensures their alignment with real market needs.

1 Introduction

In the era of the Fourth Industrial Revolution and the accelerating digital transformation of the economy, methodologies that allow for the systematic identification and solution of practically significant problems with commercial potential are of particular importance. Modern enterprises face the need to optimize processes under conditions of growing competition and digitalization.

According to research by the McKinsey Global Institute, up to 60% of employees' working time in traditional organizations is spent on coordination and auxiliary processes not related to their core competencies [1]. This creates significant potential for optimization and automation.

The proposed methodology is based on the principles of systems analysis, control theory, and the economics of innovation, which ensures both scientific validity and practical applicability.

2 Methodological Foundation

2.1 Prerequisites for Problem Identification

A scientific approach to identifying prerequisites involves a comprehensive analysis of technological, economic, and social trends. The key sources of prerequisites are:

- **Technological gaps** — mismatches between existing and potentially achievable technological capabilities. Such gaps are identified through comparative analysis of technological roadmaps and patent research. Quantitative assessment of these gaps makes it possible to determine priority directions for investment in research and development. Monitoring technological trends helps forecast points of innovation breakthroughs.
- **Economic imbalances** — suboptimal distribution of resources within production systems. The analysis of economic imbalances includes the study of resource utilization efficiency and the identification of bottlenecks in production chains. Methods of functional-cost analysis and factor productivity assessment are applied. The revealed imbalances form the basis for formulating specific optimization problems.
- **Socio-organizational contradictions** — conflicts between traditional organizational structures and the requirements of the digital economy. Research into these contradictions requires the analysis of organizational culture, communication flows, and decision-making structures. Special attention is paid to discrepancies between formal and informal processes in organizations. Resolving such contradictions creates opportunities for organizational innovation.

Methods for identifying prerequisites include big data analysis, expert surveys, patent landscape studies, and technological forecasting.

2.2 Problem Formulation

The scientific formulation of a problem must meet the criteria of measurability, reproducibility, and verifiability. Methods of formalization and structuring include:

- **Decomposition of complex systems into elementary components.** Decomposition reduces cognitive complexity and reveals key relationships between system elements. Hierarchical analysis and connection diagrams are used. Each component must have clear boundaries and defined interaction interfaces.
- **Causal modeling.** Causal modeling is based on system dynamics and graph theory. Such models identify direct and feedback relationships within a system and determine leverage points for control actions. Model validation is carried out through comparison with empirical data and expert evaluation.

- **Formalization of constraints and optimality criteria.** Constraint formalization includes defining resource, time, technological, and regulatory limits of the project. Optimality criteria are formulated as objective functions to be maximized or minimized. Special attention is paid to balancing conflicting requirements and finding compromise solutions.

2.3 Expected Result

The definition of the expected result is based on the principles of Management by Objectives (MBO) and the Theory of Constraints (TOC). The result must be:

- **Specific and measurable.** Specificity is achieved through quantitative indicators and clear qualitative characteristics. Measurability is ensured by developing a system of metrics and KPIs reflecting all essential aspects of the result. For each indicator, data collection methods and verification procedures are established.
- **Achievable within the defined timeframe.** Achievability is determined through the analysis of available resources and technological possibilities. The implementation timeline is set according to task complexity and required depth of elaboration. A step-by-step plan with milestones is developed.
- **Relevant to the identified prerequisites.** Relevance is ensured through traceability between the identified prerequisites and the formulated results. The consistency of the result with the initially identified problems and needs is assessed. The potential impact of the result on resolving the original contradictions is evaluated.
- **Scalable and sustainable.** Scalability implies the possibility of extending the result to related areas and increasing its coverage. Sustainability is achieved through mechanisms that support and develop the result after project completion. Replication potential and adaptability to changing conditions are evaluated.

2.4 Formal Methods for Achieving Results

This stage involves selecting and adapting mathematical, algorithmic, and methodological approaches. Depending on the problem type, the following may be used:

- **Mathematical programming and optimization methods.** Linear, nonlinear, and integer programming are applied to find optimal solutions under limited resources. Multi-criteria optimization methods account for conflicting requirements. Modern heuristic algorithms enable solving high-dimensional and complex problems.
- **Machine learning and artificial intelligence algorithms.** Algorithm choice depends on data characteristics and problem type—classification, regression, clustering, or forecasting. Deep learning is applied to unstructured data and complex patterns. Intelligent systems automate decision-making processes.

- **Statistical and data analysis methods.** Statistical analysis includes hypothesis testing, variance analysis, and confidence interval estimation. Data analysis covers exploratory analysis, anomaly detection, and time-series analysis. Visualization supports interpretation and identification of hidden relationships.

- **Simulation modeling and Monte Carlo methods.** Simulation modeling allows studying complex system behavior under different scenarios without real implementation risks. Monte Carlo methods estimate uncertainties and conduct sensitivity analysis. Agent-based modeling is used for systems with distributed intelligence.

2.5 Development Tools for Achieving Results

The scientific approach to development applies engineering principles and software engineering methods:

- **Modular architecture and single responsibility principle.** Modular architecture ensures low coupling and independent component development. Each module must perform a single, well-defined task, simplifying testing, debugging, and maintenance.

- **Design patterns and anti-patterns.** Applying proven design patterns improves architectural quality and reduces the likelihood of errors. Knowledge of anti-patterns helps avoid common design mistakes. Documenting architectural decisions facilitates future system evolution.

- **Test-driven development (TDD).** TDD involves writing tests before implementation, leading to more thoughtful design. Continuous testing detects regressions early and maintains code quality. Automated testing reduces verification time.

- **Principles of continuous integration and delivery (CI/CD).** Continuous integration ensures regular merging of changes from different developers. Continuous delivery automates deployment and reduces release risks. This accelerates the feedback loop and improves development reliability.

2.6 Scalability and Project Support

The theoretical basis for ensuring scalability includes:

- **Theory of complex systems and emergence.** Studying emergent properties helps forecast system behavior during scaling. Complex systems analysis identifies critical growth points and limitations. Managing emergence is a key factor in successful scaling.

- **Fractal organization principles.** Fractal organization provides structural self-similarity at different scales. This simplifies the management of complex distributed systems and reduces cognitive load. Fractal principles support the creation of stable and adaptive architectures.

- **Horizontal and vertical scaling methods.** Horizontal scaling adds new nodes to the system, improving fault tolerance. Vertical scaling increases the capacity of existing nodes. The scaling strategy is chosen according to architectural constraints and performance requirements.

- **Approaches to fault tolerance.** Fault tolerance is achieved through redundancy of critical components and automatic recovery mechanisms. Methods of graceful degradation maintain functionality under partial failures. Monitoring and proactive detection reduce the risk of catastrophic failures.

2.7 Data Preparation

Scientific methods for working with data include:

- **Data preprocessing and cleaning.** Preprocessing includes normalization, standardization, and transformation of data into a suitable analytical form. Cleaning removes noise, outliers, and missing values. The quality of preprocessing directly affects analytical accuracy.

- **Feature construction and selection.** Feature construction transforms raw data into informative attributes that enhance model performance. Feature selection eliminates multicollinearity and reduces dimensionality. These techniques significantly improve machine learning efficiency.

- **Overfitting prevention and representativeness assurance.** Regularization, cross-validation, and early stopping prevent overfitting. Representativeness is ensured by stratification and distribution checks. Class balancing and data augmentation enhance generalization ability.

- **Data quality assurance principles.** Data quality is evaluated in terms of accuracy, completeness, consistency, and timeliness. Monitoring and control processes are implemented at all data processing stages. Data quality metrics serve as KPIs for evaluating data management maturity.

2.8 Virtual Modeling and Testing

The use of digital twin methods enables:

- **Reducing implementation risks.** Virtual testing reveals issues before real deployment, saving time and resources. Modeling critical scenarios assesses system resilience under extreme conditions. Iterative hypothesis validation accelerates decision-making.

- **Optimizing system parameters.** Sensitivity analysis identifies influential parameters. Optimization methods determine optimal parameter values for given criteria. Visualization clarifies trade-offs between settings.
- **Testing boundary conditions and critical scenarios.** Boundary value testing identifies operational limits. Modeling critical scenarios evaluates robustness under extreme loads and failures. Analysis of edge cases prevents unexpected behavior in real operation.
- **Assessing system stability.** Stability assessment analyzes the system's ability to maintain functionality under varying inputs and uncertainty. Long-term testing identifies potential degradation issues.

Mathematical foundations include system dynamics and agent-based modeling.

2.9 Forecasting Potential Negative Outcomes

Risk analysis and catastrophe theory methods are used:

- **FMEA (Failure Mode and Effects Analysis).** FMEA systematically identifies potential failures and assesses their severity and probability. Preventive and detection measures are defined for each failure. Risk prioritization focuses resources on the most critical areas.
- **Scenario development and analysis.** Developing pessimistic, optimistic, and realistic scenarios helps assess possible outcome ranges. Branching scenario analysis accounts for interrelated event chains. Scenario probability assessment is based on historical data and expert evaluation.
- **System stability assessment methods.** System stability is evaluated by its ability to absorb disturbances and restore functionality. Single points of failure are analyzed, and redundancy mechanisms are introduced. Stability testing includes stress testing and chaos engineering.

2.10 Implementation Proposal

Scientific approaches to change management include:

- **AARIS model (Awareness, Acceptance, Readiness, Implementation, Sustainment).** Awareness of the need for change is formed through analysis of the current state and demonstration of transformation benefits. Acceptance is achieved by involving stakeholders and fostering positive attitudes toward change. Readiness is ensured through training, competence development, and resource provision. Implementation includes practical introduction of new processes and technologies. Sustainment is achieved through motivation systems, monitoring, and continuous improvement, ensuring the long-term stability of changes.

- **Phased implementation and pilot testing.** Phased implementation reduces risks through gradual functionality expansion. Pilot testing in a limited scope validates processes and identifies issues. Iterative adaptation ensures responsiveness to feedback and changing conditions.
- **Methods for managing resistance to change.** Sources of resistance are identified through stakeholder and interest analysis. Communication strategies clarify benefits and reduce uncertainty. Involving opinion leaders and building a "coalition of the willing" accelerates adaptation.
- **Assessing organizational readiness.** Readiness assessment includes evaluation of technological, process, and cultural maturity. Readiness indices are developed across different dimensions. Improvement plans are implemented prior to large-scale rollout.

2.11 Expected Economic Effect

Methods for evaluating economic efficiency include:

- **ROI (Return on Investment) and NPV (Net Present Value).** ROI measures return on invested capital as a percentage. NPV accounts for the time value of money and shows the absolute investment efficiency. Break-even analysis identifies the payback point.
- **Sensitivity and break-even analysis.** Sensitivity analysis identifies key factors influencing results. Determining the break-even point shows the minimum implementation volume for payback. Scenario analysis evaluates economic stability under external changes.
- **Total Cost of Ownership (TCO) assessment.** Total cost of ownership includes all expenses throughout the full life cycle of the solution—from implementation to decommissioning. Both direct and indirect costs, as well as operating expenses, are considered. Comparing TCO across alternatives helps select the most economically effective option.
- **Methods for evaluating intangible benefits.** Intangible benefits are measured through improvements in customer and employee satisfaction. Enhancement of reputation and brand image is evaluated using media activity metrics and perception surveys. Growth in organizational capabilities is regarded as a strategic asset.

3 Relevance and Practical Significance

The proposed methodology is especially relevant under the following conditions:

- Accelerating digital transformation of traditional industries
- Increasing complexity and interconnection of business processes
- The need for rapid adaptation to changing market environments
- Growing demands for resource efficiency

The scientific novelty of the approach lies in integrating systems analysis, project management, and innovation economics into a unified methodological framework.

4 Conclusion

The proposed methodology offers a systematic, scientifically grounded approach to solving current challenges of digital transformation. Its comprehensive structure, covering all stages—from problem identification to economic efficiency evaluation—ensures practical value for both researchers and practitioners.

Further research may focus on developing specialized software tools to support this methodology and adapting it to various industries.

References

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