

INNOVATION SCIENCE AND TECHNOLOGY



Scopus || Electronic journal specializing in Scopus

ISSUE 12



Acceptance of papers **December, 2025**



**Acceptance of
papers**

Published monthly



Topics

economics,
technology, social
sciences

ISSN 3060-5229



EDITOR-IN-CHIEF:

Mirzaliev Sanjar Makhmatjon ugli

DEPUTY EDITOR-IN-CHIEF:

Makhmudov Nosir Makhmudovich
DSc., Prof., Academician

DEPUTY EDITOR-IN-CHIEF:

Ochilov Bobur Bakhtiyor ugli – Senior
lecturer at TSUI

THE SCIENTIFIC-POPULAR ELECTRONIC
JOURNAL **"INNOVATION SCIENCE AND
TECHNOLOGY"** HAS BEEN REGISTERED
UNDER THE NUMBER **C-5669633** BY THE
AGENCY FOR INFORMATION AND MASS
COMMUNICATIONS (AOKA) OF THE
REPUBLIC OF UZBEKISTAN, EFFECTIVE
FROM OCTOBER 9, 2024.

CONTACTS

Phone: **+998 50 737 87 88**

Website: <https://ist-journal.uz>

Email: innovationist2025@gmail.com

The scientific electronic journal "Innovation Science and Technology" has been included in the list of scientific publications recommended for the publication of main scientific results of dissertations for the award of PhD and DSc degrees in economics and technical sciences, in accordance with the Resolution No. 370 of the Presidium of the Higher Attestation Commission of the Republic of Uzbekistan, dated May 8, 2025.

Electronic publication, Issue 12. 483 pages.
Approved for publication on December, 2025.

Editorial board:



Sharipov Kongiratbay Avezimbetovich,
Doctor of Technical Sciences (DSc), Professor



Abdurakhmanova Gulnora Kalandarovna, Doctor of
Economic Sciences (DSc), Professor



Cham Tat Huei,
Doctor of Philosophy (PhD), Professor (Malaysia)



Muhammad Imran Sadiq
Doctor of Philosophy in Economics (PhD), Professor,
Malaysia



Ahmed Aziz Ismail
Doctor of Technical Sciences (DSc),
Professor (Egypt)



Lee Chin
Doctor of Philosophy in Economics (PhD), (Malaysia)



Asongu Simplicie
Doctor of Philosophy in Economics (PhD), Cameroon



Rui Dang
Doctor of Chemistry (DSc), Professor, China



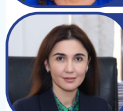
Zahoor Ahmed
Doctor of Philosophy in Economics (PhD), Turkey



Shujaat Abbas
Doctor of Philosophy in Economics (PhD), Russia



Tina A Coffelt
Doctor of Philosophy in Educational Sciences (PhD),
USA



Abdikarimova Dinara Rustamxanovna
Doctor of Economic Sciences (DSc), Professor

Kurbonbekova Mohichehra Turobjonovna
Doctor of Economic Sciences (DSc), Professor

Alimardonov Ilkhom Muzrabshokovich
Doctor of Economic Sciences (DSc), Professor

CONTENTS

| | |
|--|-----|
| THE THEORETICAL FOUNDATIONS OF APPLYING TAX INCENTIVES FOR INVESTMENTS DIRECTED TOWARD HUMAN CAPITAL | 14 |
| Quliyev Begimqul Melikovich | |
| ECONOMETRIC MODELS OF CASHLESS SETTLEMENTS AMONG ECONOMIC ENTITIES..... | 21 |
| Ruzimuradov Shukhrat Khusanovich | |
| PROSPECTS FOR THE DEVELOPMENT OF TOURISM BRAND MARKETING IN MODERN CONDITIONS (UAE: DUBAI ON THE EXAMPLE OF A CITY)..... | 26 |
| Ibodova Dilsora Ibodovna | |
| CREDIT DEFAULT SWAPS AS A WAY TO HEDGE AGAINST FORTHCOMING FUTURE UNCERTAINTIES IN THE DEBT MARKET OF UZBEKISTAN | 31 |
| Abduganiev Abdulaziz Alisher o'g'li | |
| SHOULD THE REGULATION OF THE E-COMMERCE MARKET IN THE REPUBLIC OF UZBEKISTAN BE CARRIED OUT BY THE NATIONAL AGENCY FOR PERSPECTIVE PROJECTS OR THE CENTRAL BANK? | 39 |
| Sadikov Aziz Mirsharapovich | |
| MECHANISM FOR IMPLEMENTING ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN THE OPERATIONS OF COMMERCIAL BANKS IN UZBEKISTAN..... | 46 |
| Bakhriddin Berdiyarov | |
| INNOVATIVE APPROACHES OF SMALL BUSINESSES IN THE INDUSTRY AND CONSTRUCTION SECTORS AND THEIR IMPACT ON EMPLOYMENT..... | 53 |
| Ergasheva Nigora Abdigapparovna | |
| AI-BASED NORMALIZATION METHODOLOGY FOR COLLECTING AND PROCESSING KPI INDICATORS..... | 56 |
| Shuhratov Mamurjon Shuhrat o'g'li | |
| REFORMS AND PROSPECTS FOR THE DEVELOPMENT OF THE PARTICIPATORY BUDGETING INITIATIVE IN UZBEKISTAN | 63 |
| Khamidov Khabibullo Hikmatulla ugli | |
| PROBLEMS OF THE INWARD PROCESSING CUSTOMS REGIME AND WAYS TO ELIMINATE THEM..... | 70 |
| Abdullaev Shakhzodbek | |
| FINANCIAL ANALYSIS OF SMALL BUSINESS AND PRIVATE ENTREPRENEURSHIP IN CONSTRUCTION | 74 |
| Musayeva Shoirazimovna | |
| MEASURES TO ENHANCE THE ROLE AND EFFECTIVENESS OF SMALL BUSINESS IN REGIONAL ECONOMIC DEVELOPMENT..... | 80 |
| Ergashev Jamshid Jamoliddinovich | |
| THEORETICAL AND METHODOLOGICAL FOUNDATIONS FOR IMPLEMENTING INNOVATIVE TECHNOLOGIES IN EDUCATION..... | 84 |
| Alijonova Marjonabonu Jaxongir qizi | |
| INDIA'S EXPERIENCE IN ENHANCING PUBLIC WELFARE THROUGH THE DEVELOPMENT OF ENTREPRENEURIAL ACTIVITY | 88 |
| Aripov Oybek Abdullayevich | |
| GREEN STRUCTURAL TRANSFORMATION IN UZBEKISTAN: GREEN FINANCE AND ECO-INNOVATION FOR SUSTAINABLE INDUSTRIAL AND AGRICULTURAL DEVELOPMENT..... | 93 |
| Egamberdiev Khumoyun | |
| AGRICULTURAL MANAGEMENT BASED ON INNOVATIVE TECHNOLOGIES AT THE INTERNATIONAL LEVEL: THE EXAMPLE OF UZBEKISTAN..... | 101 |
| Bustonov Komiljon Kumakovich | |
| ANALYSIS OF THE FINANCIAL CONDITION OF ENTERPRISES: ASSESSMENT OF EQUITY EFFICIENCY | 110 |
| Umurkul Shukhratovich Fayziev | |

| | |
|--|-----|
| IMPROVING THE QUALITY OF ECONOMIC GROWTH THROUGH THE TRANSITION TO THE DIGITAL ECONOMY..... | 118 |
| Mamadaliyev Akmaljon | |
| МЕТОДЫ И МЕХАНИЗМЫ ИССЛЕДОВАНИЯ ПОТРЕБИТЕЛЬСКОГО ПОВЕДЕНИЯ НА ТУРИСТСКОМ РЫНКЕ..... | 124 |
| Нурматова Ситора Шавкатовна | |
| ANALYSIS OF INNOVATION ACTIVITIES..... | 133 |
| Alieva Elnara Ametovna | |
| METHODS AND MECHANISMS FOR STUDYING CONSUMER BEHAVIOR IN THE TOURISM MARKET..... | 139 |
| Nurmatova Sitora Shavkatovna | |
| ALGORITHMS AND METHODS FOR CALCULATING THE AREA OF A GASTRIC ULCER DEFECT USING MODERN MATHEMATICAL TECHNIQUES..... | 145 |
| Yusupov Ibrohimbek XXX, Abdusamatova Munira Sultonbek qizi | |
| UTILIZATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN ENTERPRISE MARKETING ACTIVITIES..... | 151 |
| Sadikov Shohrux Shukhratovich | |
| ENSURING THE FINANCIAL SUSTAINABILITY OF HIGHER EDUCATION INSTITUTIONS: STRATEGIC DIRECTIONS, GLOBAL TRENDS, AND POLICY IMPLICATIONS..... | 156 |
| Inomiddin Imomov | |
| THEORETICAL FOUNDATIONS OF THE STRUCTURE OF THE NATIONAL ECONOMY..... | 161 |
| Bustonov Mansurjon Mardonakulovich | |
| IMPORTANT CHARACTERISTICS OF THE DEVELOPMENT OF E-COMMERCE SERVICES..... | 169 |
| Jurakulov Shohruh Bahtiyorovich | |
| AGRICULTURE PROMOTION AND DEVELOPMENT IN MOUNTAIN AND MOUNTAIN REGIONS..... | 173 |
| Abdulxayeva Gulshan Maxmudovna | |
| IMPROVING MECHANISMS FOR ENHANCING ECONOMIC EFFICIENCY IN SERVICE ENTERPRISES..... | 178 |
| Seytimbetov Kabul Serimbetovich | |
| INTEGRATION OF INTELLIGENT CONTROL IN DRYING SYSTEMS: PROCESS OPTIMIZATION THROUGH SENSORS, ARTIFICIAL INTELLIGENCE, AND MODULAR DRYING..... | 184 |
| Yangiboyeva Raxbaroy Mashrabboy qizi | |
| THEORETICAL MODELS AND CONCEPTS OF ECONOMIC DEVELOPMENT IN THE ENERGY SECTOR..... | 190 |
| Nigmatullaeva Gulchekhra Nurullaevna | |
| STATISTICAL ANALYSIS OF REGIONAL ECONOMIC POTENTIAL (A CASE STUDY OF NAMANGAN REGION)..... | 196 |
| Tursinbayev Azizbek Nabijon o'g'li, Sirojiddinov Kamoliddin Ikromiddinovich | |
| DIRECTIONS FOR DEVELOPING INVESTMENT AND EXPORT IN REMOTE SERVICE ENTERPRISES..... | 203 |
| Uzakov Ortik Shaymardanovich | |
| SPECIFIC FEATURES OF ENTREPRENEURSHIP IN INCREASING THE INCOME OF THE POPULATION IN THE REGION..... | 207 |
| Kuldasheva Maftuna Musurmon kizi | |
| KEY FACTORS OF ATTRACTING INVESTMENT THROUGH SUBSIDIES AND INVESTMENTS TO INCREASE AGRICULTURAL CROP PRODUCTION IN UZBEKISTAN..... | 211 |
| Mamatkulova Nadira Makkamovna | |
| RAQAMLI MARKETING VA INNOVATSION TEXNOLOGIYALAR ASOSIDA EKOTIZIM SAMARADORLIGINI OSHIRISH USULLARI..... | 216 |
| Sobirov Azizbek Avazbekovich | |
| WAYS TO IMPROVE THE STATISTICAL ASSESSMENT OF FRUIT AND VEGETABLE PRODUCTION PROCESSES AND EXPORT POTENTIAL IN THE REPUBLIC OF UZBEKISTAN..... | 223 |
| Anorboeva Bakhtijamol Daniyar kizi | |

| | |
|---|-----|
| THE IMPACT OF DEGRADATION ON THE OPERATIONAL CHARACTERISTICS OF PHOTOVOLTAIC MODULES UNDER SHARPLY CONTINENTAL CLIMATIC CONDITIONS | 229 |
| Qurbanov Yunus Murtaza o'g'li | |
| INTEGRATED NEW MEDIA OPERATION MODEL FOR INTELLIGENT TALENT ASSESSMENT PLATFORMS: THE PATH OF QR CODE ACTIVATION AND CONTENT-DRIVEN ENGAGEMENT..... | 235 |
| Wang Biao | |
| METHODOLOGICAL FOUNDATIONS FOR SHAPING THE CREATIVE ACTIVITY OF YOUNGER PUPILS IN SOLVING MATHEMATICAL PROBLEMS | 239 |
| Dzhurakulova Adolat Khalmuratovna | |
| SOLIDWORKS-BASED MODELING OF AN AIR-BLOWING SYSTEM TO ENSURE HIGH-QUALITY FIBER REMOVAL FROM SAW TEETH | 247 |
| Mirzakarimov Mirsharoffiddin Mirzaabdurahimovich | |
| THEORETICAL STUDY OF TEMPERATURE AND THERMAL PHENOMENA IN MECHANICAL CUTTING OF WHITE CAST IRON..... | 256 |
| Allanazarov Akmal Abdulxaqovich | |
| THEORETICAL AND METHODOLOGICAL FOUNDATIONS OF SUSTAINABLE DEVELOPMENT OF THE REGIONAL ECONOMY | 262 |
| Turdiyev Ulug'bek Qayumovich | |
| THE INTERRELATIONSHIP BETWEEN MIGRATION AND THE INDUSTRIAL ECONOMY | 266 |
| Khusanbek Begmatov | |
| THE IMPACT OF ESG PRINCIPLES ON THE HOTEL INDUSTRY | 271 |
| Khusenova Mekhrangiz | |
| CURRENT STATUS OF INDUSTRIAL PRODUCTION AND SERVICES MARKET IN KASHKADARYA REGION..... | 276 |
| Norov Murodjon Makhmudovich | |
| DEVELOPMENT OF AN ARTIFICIAL INTELLIGENCE-BASED CYBERSECURITY SYSTEM FOR THE AUTOMATIC DETECTION OF FAKE FINANCIAL RECEIPTS, PHISHING URLS, AND MALICIOUS APK FILES | 284 |
| Shermatov Axlidin Sharobiddin o'g'li | |
| WAYS TO INCREASE REVENUES IN COMMERCIAL BANK OPERATIONS | 287 |
| Ostonaqulova Gulchehraxon Muhammadyoqub qizi | |
| РОЛЬ СВОБОДНЫХ ЭКОНОМИЧЕСКИХ ЗОН В РЕГИОНАЛЬНОМ РАЗВИТИИ И ЗАРУБЕЖНЫЙ ОПЫТ..... | 301 |
| Файзиева Ширин Шодмоновна | |
| RAQAMLI IQTISODIYOTGA O'TISH SHAROITIDA IQTISODIY O'SISH OMILLARINING TA'SIRINI BAHOLASH METODOLOGIYASI..... | 307 |
| Bustonov Mansurjon Mardonakulovich | |
| FINTECH TRENDS: NEW TOOLS FOR ATTRACTING FINANCING IN THE CONTEXT OF DIGITAL TRANSFORMATION | 313 |
| Madjitova Lolakhon Lazizovna | |
| CHALLENGES AND PROSPECTS FOR THE DEVELOPMENT OF E-COMMERCE IN UZBEKISTAN..... | 317 |
| Toshpulatov Akhror Tukhtamurod ugli | |
| STRATEGIC DETERMINANTS OF FOREIGN DIRECT INVESTMENT IN UZBEKISTAN | 326 |
| Rustamov Foziljon | |
| TYPES AND MEANS OF ADVERTISING IN THE FIELD OF TOURISM | 335 |
| Bahriyeva Zarina Nasimovna | |
| INTELLECTUALIZATION OF TECHNICAL MEANS FOR CONTROLLING TECHNOLOGICAL REFINING PROCESSES..... | 340 |
| Ruziyev Umidjon Abdimajitovich | |
| NECESSITY OF ENSURING AND INCREASING THE COMPETITIVENESS OF PLACEMENT MEANS | 349 |
| Sherkulov Dilshod Jurakulovich | |
| YASHIL IQTISODIYOT VA MOLIYAVIY INKLYUZIYANING O'ZARO BOG'LIQLIK NAZARIYALARI..... | 354 |
| Adashaliyev Baxtiyorjon Valisher o'g'li | |

| | |
|---|-----|
| THE IMPORTANCE OF THE AUDIT OF LEASING OPERATIONS ON FARMS OF THE REPUBLIC OF UZBEKISTAN | 359 |
| Tursunov Ulugbek Sativoldievich | |
| METHODOLOGY DEVELOPMENT RETAIL MARKETING AND TRADING SYSTEM..... | 365 |
| Makhmatkulov Golibjon Kholmuminovich | |
| NECESSITY OF ENSURING AND INCREASING THE COMPETITIVENESS OF PLACEMENT MEANS | 369 |
| Sherkulov Dilshod Jurakulovich | |
| ENVIRONMENTAL FISCAL POLICY AS A DRIVER OF GREEN GROWTH AND EMPLOYMENT IN CENTRAL ASIA: EMPIRICAL EVIDENCE | 374 |
| Rakhmatova Zilola Yurevna | |
| ON THE ISSUE OF CALCULATING THE POWER REQUIRED TO HEAT THE EDGES OF THE PIPE BILLET TO THE WELDING TEMPERATURE..... | 379 |
| Zairkulov Elyor Yoqubjon o'g'li | |
| STATISTICAL ASSESSMENT OF REGIONAL ELECTRICITY GENERATION VOLUMES..... | 385 |
| Doliev Shokhabbos Kulmurat ugli | |
| ANALYSIS OF ICT APPLICATION IN UZBEKISTAN'S TOURISM BASED ON EMPIRICAL RESEARCH..... | 389 |
| Nazarov Khusanbek Avazbek ogli | |
| METHODOLOGY FOR FORECASTING AND ANALYZING MANAGEMENT ACCOUNTING INDICATORS AT AN ENTERPRISE..... | 395 |
| Minutdinova Liliya Tagirovna | |
| WELLNESS TOURISM AS AN ESSENTIAL COMPONENT OF HEALTH TOURISM..... | 402 |
| Tashtayeva Saida Kahharovna | |
| THE EXPERIENCE OF GERMANY IN DEVELOPING SMALL AND MEDIUM ENTERPRISES..... | 409 |
| Annaklichev Saxi Saparmuxamedovich | |
| ANALYSIS OF THE APPLICATION OF THE INTERNATIONAL STANDARD ON AUDITING "ANALYTICAL PROCEDURES" IN NATIONAL AUDIT ACTIVITIES | 416 |
| Tajekeev Ziyatdin Kobeyzinovich | |
| ORGANIZATIONAL AND ECONOMIC FOUNDATIONS OF GREEN ENTERPRISE DEVELOPMENT IN ENSURING REGIONAL ENVIRONMENTAL SAFETY | 421 |
| Khamidillo Odilov | |
| A REALIST-POSITIVIST FRAMEWORK FOR ANALYSING MERGERS AND ACQUISITIONS UNDER ECONOMIC POLICY UNCERTAINTY | 429 |
| Zakhidov Azizbek Rustamovich | |
| DEVELOPING MATHEMATICAL MODELS TO SIMULATE THE DYNAMIC BEHAVIOR OF SEPARATION PROCESSES, CONSIDERING THE IMPACT OF EXTERNAL FACTORS | 436 |
| Abdulleva Kamola Rustamovna | |
| THEORETICAL FOUNDATIONS OF IMPLEMENTING DIGITAL TECHNOLOGIES IN THE TRANSFORMATION OF BANKS..... | 445 |
| Umarova Malika Baxtiyarovna | |
| ON THE ISSUE OF RESEARCH AND DEVELOPMENT OF A SLAG-FORMING BASE FOR ELECTRODE COATINGS FOR WEAR-RESISTANT SURFACING..... | 451 |
| Sadikov Jaxongir Nasidjanovich | |
| MODELING OF HEAT FLOWS IN GAS-FIRED CHAMBER FURNACES..... | 456 |
| Rajabov Azamat Toirovich | |
| DEVELOPMENT OF A MIMO MODEL OF AZEOTROPIC DISTILLATION | 462 |
| Shamsutdinova Vinera Khafizovna | |
| THEORETICAL FOUNDATIONS OF THE INTERACTION OF A COTTON TUFT WITH A SCREW CONVEYOR AND A MESH SURFACE..... | 468 |
| Matyaqubova Jumagul Bakhtiyarovna | |
| FORECASTING LIQUIDITY AND SOLVENCY INDICATORS BASED ON ARTIFICIAL INTELLIGENCE | 473 |
| Zaynutdinov Ismoil Samariddin o'g'li | |
| MODELS FOR PREDICTING THE MANAGEMENT OF COMPLEX TECHNOLOGICAL PROCESSES AND PRODUCTIONS | 477 |
| Gulyamov Shukhrat Mannapovich | |

MODELS FOR PREDICTING THE MANAGEMENT OF COMPLEX TECHNOLOGICAL PROCESSES AND PRODUCTIONS

Gulyamov Shukhrat Mannapovich

Tashkent State Technical University

Professor, Department of Automation of Production Processes

Doctor of Technical Sciences

ORCID: 0009-0001-0693-3990

Abstract: Issues of linear and nonlinear modeling of complex technological processes and production in improved (advanced) control systems are considered. The development of the Advanced Process Control APC-control is considered. The application of forecasting algorithms based on artificial neural networks is briefly described.

Key words: improved and APC-controlled predictive models of neural networks, complex chemical-technological processes and production.

Annotatsiya: Takomillashgan (ilg'or) boshqarish tizimlarida murakkab texnologik jarayonlar va ishlab chiqarishlarni chiziqli va nochiziqli modellashtirish masalalari ko'rib chiqilgan. Takomillashgan APC-boshqaruvining rivojlanishi yoritilgan. Sun'iy neyron tarmoqlar asosida bashoratlash algoritmlarining qo'llanilishi qisqacha bayon etilgan.

Kalit so'zlar: murakkab kimyoviy-texnologik jarayonlar va ishlab chiqarishlarni bashorat qiluvchi neyron tarmoqlar, takomillashtirilgan modellar, APC-boshqarish.

Аннотация: Рассматриваются вопросы линейного и нелинейного моделирование сложных технологических процессов и производств в системах усовершенствованного (продвинутого) управления. Рассмотрено развитие совершенного Advanced Process Control APC-управления. Кратко изложена применение алгоритмов прогнозирования на основе искусственных нейронных сетей.

Ключевые слова: усовершенствованной и APC-управления прогнозирующие модели нейронные сети сложные химико-технологические процессы и производства.

INTRODUCTION

Depending on the model of forecasting control used, linear forecasting models are divided into two main classes. Linear forecasting model and nonlinear forecasting model. The difference between them is not very large, but from the point of view of calculations and theory, linear forecasting models, a very important function of nonlinear forecasting models, as well as the theory of linear control and the theory of nonlinear control are analyzed.

Linear forecasting models appeared first, and forecasting management applications are based on a linear model.

Nonlinear forecasting models represent the control of nonlinear objects using an MPU algorithm that takes into account the nonlinearity of the object. Nonlinear forecasting models are similar to linear forecasting models, and the characteristics of the management system are the same. Consequently, it is possible to determine the set of optimal control values by minimizing objective criteria; the distance horizon strategy has been implemented.

Options for using nonlinear forecasting models:

- in processes that are significantly nonlinear and often subject to significant noise (for example, pH control);
- in processes where the working space frequently changes and covers a relatively wide area of nonlinear process dynamics.

REVIEW OF LITERATURE ON THE SUBJECT

Introduction to the theory of nonlinear forecasting models is discussed in the work of Findersen et al. [1]. The mathematical formulation of nonlinear predictive models is shown, the main principles and features of predictive control systems are presented, and their main advantages and disadvantages are highlighted. A number of theoretical and computational aspects of nonlinear forecasting models are discussed in the work of Allgover et al. These authors also emphasize the practical application of nonlinear forecasting algorithms and the need for reliable and fast real-time identification and optimization methods.

Camacho [2], Grune [3] in their scientific works are devoted to models of nonlinear forecasting. Li [4] considers the development of forecasting management systems over the past thirteen years, and in the first decade after the announcement of MPU, forecasting management became widespread and accepted in industry, especially in oil refineries and chemical plants. In the second decade, significant theoretical achievements were made, including the development and interpretation of space models, the determination and proof of the criteria for the stability of predictive control systems. In the third decade, the main focus was on designing and developing algorithms for so-called fast MPUs.

In recent years, distributed and hierarchical systems with nonlinear forecasting models have received significant development. They are suitable for managing complex technological facilities and even entire factories. Various hierarchical structures with MPU are presented in the scientific works of Brdys et al. [5], Falcone et al. [6]. A review of various decentralized, distributed, and hierarchical system architectures used in MPU systems is presented in Skattolini's scientific work [7].

It is cited in Lee's article [8], which examines the basic requirements for modeling, as well as modeling and identification methods for nonlinear forecasting models; Pearson [9] discussed the selection of suitable structures for the nonlinear model. In it, the author describes some of the main classes of nonlinear structures.

In his work, Waller [10] divides the models used in nonlinear forecasting models into 3 groups. In the first group, models are based on fundamental connections, in the second group, models are based on empirical data, and the third type of model represents a combination of the first two and is called hybrid. Due to the complexity of nonlinear objects, it is impossible to develop methods for their direct detection by expanding linear methods. Alternatively, the regulator of nonlinear forecasting models can be derived from a model based on fundamental relationships. The main advantage of these models is that they are valid worldwide, and therefore, they can be extrapolated to jobs that are not represented in the data set used for model modeling.

In the case of empirical nonlinear models, choosing a suitable model structure is a decision that needs to be made. As a main drawback, it should be noted that the applicability of these models is limited and depends on the input/output data used in their development. Currently, the following models are mainly used for nonlinear forecasting models:

- Walter's model;
- Hammerstein models;
- models based on fuzzy logic;
- combined models.

Neural networks, neuro-fuzzy models, fuzzy logic, and hybrid universal approximators are well-known and are therefore widely used for modeling and detecting nonlinear objects. For forecasting management purposes, they are used separately and in combination with Hammerstein and Wiener models. An example of this is Voltaire's neuro-fuzzy model presented in Todorov's scientific work [11]. The model is integrated into a controller with nonlinear forecasting, used to control the cooling-drying process. Most of Hammerstein's model uses usage reports in combination with soft computing methods.

Aboni et al. [12] propose a similar block structure that implements nonlinear statics using fuzzy logic in their research. For this, they describe the behavior of the system in a mode determined by the zero-order Takagi-Sugeno uncertainty model.

In their scientific work, Ngia et al. [13] constructed the Hammerstein model as a combination of a hidden layer and a direct-propagation neural network with a linear impulse characteristic. In practice, determining the parameters of the pulse characteristic is difficult due to their large number. By combining the properties of fuzzy logic and neural networks, Zhia et al. [14] propose Hammerstein's neuro-fuzzy model. For this, the authors evaluate the nonlinear element using the Takagi-Sugeno neuro-fuzzy model based on the radial basis neural network (RBNN), and the linear part has the form of an autoregression model.

Hachino et al. in their scientific work [15] use RBNN as a nonlinear static part, and the neural network structure (the number of Gaussian functions, their width, and center) is created using genetic algorithms.

Viner models are used for the purposes of nonlinear forecasting models, and this includes the selection of reversible static nonlinearities, as well as a complex identification process.

Aboni [16] proposes a forecasting algorithm consisting of a linear-impulse characteristic Viner model and a zero-order Takagi-Sugeno uncertainty model.

The Wiener model described by Ajar [17] represents a sliding average autoregression model and RBNN (Rules Based Neural Networks) represents a set of neural networks, the parametric identification of which is carried out by the least squares method. Laurenchuk [18] presented a computationally efficient predictive controller based on the Viner neuron model.

The idea of neural networks is borrowed from biological neural networks, and they similarly possess the following properties:

- the possibility of training with or without an operator;
- high reliability. If one or more neurons fail, the neural network continues to function effectively.
- high processing speed.

These properties lead to the widespread use of neural networks in control systems. They are used for designing, modeling, and identifying neural controllers and are known as universal approximators. Neural networks are suitable for modeling nonlinear, multidimensional static and dynamic systems using the black box method. Norgaard [19] in his scientific work describes the construction of nonlinear models of various structures (NNFIR, NNARX, NNARMAX) using neural networks. In predictive management, the accuracy of the model, that is, the minimum error between the initial process and the model, is important. The accuracy of neural network modeling depends not on the type of neural network, but on its structure (the number of hidden layers). Usually, a larger number of hidden layers and neurons in them leads to more accurate modeling, but there is no unified methodology for determining their structure.

RESEARCH METHODOLOGY

The study employs a mixed methodological approach based on the collection of secondary data from scientific publications, industrial reports, and technical documentation, as well as primary process data obtained from monitoring systems. The analysis is conducted using comparative evaluation, mathematical modeling, and predictive simulation techniques to assess management effectiveness under different operational scenarios.

ANALYSIS AND RESULTS

The management of complex technological processes and industrial production systems represents one of the most challenging tasks in modern engineering and applied economics. Such systems are characterized by high dimensionality, nonlinear dynamics, strong interdependencies among variables, uncertainty in external conditions, and strict requirements for efficiency, safety, and reliability. Under these conditions, traditional reactive control approaches become insufficient, making predictive management models a critical element of contemporary industrial systems.

Predictive management models are based on the idea of anticipating future system behavior and making control decisions proactively rather than reactively. These models rely on mathematical, statistical, and computational methods to forecast system states over a specified time horizon and to determine optimal control actions that minimize deviations from desired performance criteria. In complex technological processes, prediction is not merely an auxiliary tool but a central component of decision-making.

One of the fundamental challenges in predicting complex technological systems lies in their nonlinear nature. Many industrial processes—such as chemical reactions, metallurgical operations, energy production systems, and advanced manufacturing lines—exhibit nonlinear relationships between inputs and outputs. Linear models, while computationally simple and analytically convenient, often fail to capture the true dynamics of such systems, especially under varying operating conditions. As a result, nonlinear predictive models have gained increasing attention in both research and industrial practice.

Model-based predictive control (MPC) has become one of the most widely applied frameworks for managing complex technological processes. The core idea of MPC is to use an explicit model of the process to predict future system behavior over a finite prediction horizon. At each control step, an optimization problem is solved to determine the control sequence that minimizes a predefined objective function, subject to system constraints. Only the first control action is implemented, after which the process is repeated using updated measurements. This receding horizon strategy allows MPC to adapt to disturbances and model uncertainties in real time.

In complex production systems, predictive models must account not only for process dynamics but also for operational constraints. These constraints may include physical limitations of equipment, safety thresholds, environmental regulations, and economic considerations such as energy costs or resource availability. A key advantage of predictive management models is their ability to explicitly incorporate such constraints into the optimization framework, ensuring feasible and safe system operation.

Another important aspect of predictive management is the treatment of uncertainty. Complex technological processes are often subject to random disturbances, measurement noise, and incomplete information. Uncertainty may arise from raw material variability, environmental fluctuations, equipment degradation, or human factors. Advanced predictive models address uncertainty through stochastic modeling, robust optimization, or adaptive mechanisms that continuously update model parameters based on observed data. These approaches enhance the resilience of control systems and reduce the risk of performance degradation under unforeseen conditions.

The increasing availability of high-frequency industrial data has significantly influenced the development of predictive management models. Modern production systems are equipped with numerous sensors, monitoring devices, and digital platforms that generate large volumes of data in real time. This has enabled the integration of data-driven methods, such as machine learning and artificial intelligence, into predictive control frameworks. Unlike traditional physics-based models, data-driven models learn system behavior directly from historical and real-time data, allowing them to capture complex patterns that may be difficult to represent analytically.

Hybrid predictive models, which combine first-principles modeling with data-driven techniques, have emerged as a particularly promising approach. In such models, fundamental physical laws provide structural consistency, while machine learning components compensate for modeling errors and unmodeled dynamics. This combination improves prediction accuracy and enhances the robustness of management decisions in complex technological environments.

In production systems with multiple interconnected units, predictive management becomes a multi-level and multi-objective problem. Decisions made at one stage of the production chain can have significant downstream effects, influencing product quality, throughput, and resource consumption. Predictive models enable coordinated control across different process stages by considering the system as an integrated whole rather than a set of isolated subsystems. This holistic perspective is essential for optimizing overall system performance rather than local objectives.

From an economic perspective, predictive management models play a crucial role in improving production efficiency and competitiveness. By anticipating future demand, equipment conditions, and process deviations, enterprises can reduce downtime, minimize waste, optimize energy consumption, and improve product quality. Predictive models support strategic planning by enabling scenario analysis and what-if simulations, allowing managers to evaluate the impact of alternative operational strategies before implementing them in practice.

In recent years, the concept of digital twins has further expanded the capabilities of predictive management. A digital twin is a virtual representation of a physical process or production system that continuously synchronizes with real-world data. Predictive models embedded within digital twins allow for real-time forecasting, virtual experimentation, and proactive decision-making. This approach significantly enhances the transparency and controllability of complex technological systems.

Despite their advantages, predictive management models face several practical challenges. Model development and validation require substantial expertise, high-quality data, and computational resources. Inaccurate models can lead to suboptimal or even unsafe control decisions. Moreover, the integration of predictive models into existing industrial infrastructures often involves organizational and technical barriers, including resistance to change, lack of skilled personnel, and cybersecurity concerns.

Another limitation is the trade-off between model complexity and computational efficiency. Highly detailed models may provide accurate predictions but can be computationally intensive, limiting their applicability in real-time control. Conversely, simplified models may be faster but less accurate. Effective predictive management requires a careful balance between these factors, ensuring that models are both reliable and practical for real-world implementation.

The future development of predictive management models is closely linked to advances in digitalization, artificial intelligence, and industrial automation. As computational power increases and data analytics techniques evolve, predictive models are expected to become more adaptive, autonomous, and scalable. The integration of predictive management with smart manufacturing systems and Industry 4.0 concepts will further enhance the ability of enterprises to manage complex technological processes under dynamic and uncertain conditions.

CONCLUSIONS AND SUGGESTIONS

The analysis presented in this paper demonstrates that predictive control based on linear and nonlinear models plays a key role in the effective management of complex technological processes and industrial productions. While linear predictive models historically formed the foundation of Advanced Process Control (APC) systems and remain widely applied due to their mathematical simplicity and computational efficiency, their applicability is limited when dealing with strongly nonlinear, time-varying, and noise-affected processes.

List of used literature:

1. Findersen, R. and F. Allgöwer (2002). An Introduction to Nonlinear Model Predictive Control. 21-st Benelux Meeting on Systems and Control, Veldhoven. pp. 119-141.
2. Camacho, E. F. and C. Bordons (2007). Nonlinear Model Predictive Control: An Introductory Review. Assessment and Future Directions of Nonlinear Model Predictive Control, Lecture Notes in Control and Information Sciences, Vol. 358, pp. 1-16.
3. Gambier, A. (2008). MPC and PID Control Based On Multi-Objective Optimization, American Control Conference, Westlin Seattle, Washington, USA, June 11-13, pp. 4727-4732.
4. Li, X., Z. Chen and Z. Yuan, (2002). Simple recurrent neural network-based adaptive predictive control for nonlinear systems. Asian Journal of Control, Vol. 4, No. 2, pp. 231-239.
5. F. Ben Aicha, F. Bouani and M. Ksouri (2013). A multivariable multiobjective predictive controller. Int. J. of Applied Mathematics and Computer Science, 23(1), pp. 35-45.
6. Ramiro S. Barbosa, J.A.T. Machado, Isabel M. Ferreira (2004). Tuning of PID controllers based on Bode's ideal transfer function, Nonlinear Dynamics 38 (1/4). pp. 305–321.
7. Abonyi, J., Á. Bódizs, L. Nagy and F. Szeifert (1999). Predictor Corrector Controller using Wiener Fuzzy Convolution Model. Hungarian Journal of Industrial Chemistry, Vol. 27, Issue 3, pp. 227-233.
8. Ngia, K.S.H. and J. Sjobert (1998). Nonlinear acoustic echo cancellation using a Hammerstein model. Acoustics, Speech, and Signal Processing, ICASSP'98. Proceedings of the 1998 IEEE International Conference, Vol. 2, pp. 1229-1232.
9. Jia, L., M. Chiu, S. S. Ge (2004). Neuro-fuzzy system based identification method for Hammerstein processes. Control Conference, 5th Asian, Vol. 1, pp.104 - 111.
10. Lawrynczuk, M. (2009). Neural Networks in Model Predictive Control. Intelligent Systems for Knowledge Management, Studies in Computational Intelligence, Vol. 252, pp. 31-63.
11. Y. L. Huang, H. H. Lou, J. P. Gong, and E. F. Thomas (2000), "Fuzzy model predictive control," IEEE Trans.FuzzySyst., vol. 8, pp. 665-678.
12. Azhar, A. S. S. and H. N. Al-Duwaish (2002). Identification of Wiener Model Using Radial Basis Functions Newral Networks, J.R. Dorronsoro (Ed.): ICANN 2002, LNCS 2415, pp. 344–350.

Proofreader: Zokir ALIBEKOV

Layout and Designer: Oloviddin Sobir ugli

2025. № 12

© When materials are reproduced, the INNOVATION SCIENCE AND TECHNOLOGY journal must be cited as the source. Authors are responsible for the accuracy of the information in materials and advertisements published in the journal. Editorial opinions may not always align with those of the authors. Submitted materials will not be returned to the editorial office.

To publish articles in this journal, you may submit articles, advertisements, stories, and other creative materials through the following links. Materials and advertisements are published on a paid basis.

You may subscribe to the journal at any time using the following details. Once subscribed, please send a screenshot or photo of your payment confirmation to our Telegram page @iqtisodiyot_77. Based on this, we will send the latest issue of the journal to your address each month.

“The journal “INNOVATION SCIENCE AND TECHNOLOGY” has been registered by the Agency for Information and Mass Communications under the Administration of the President of the Republic of Uzbekistan from 09.10.2024 under the registration number №390637. License number: C-5669633. PNFL: 30407832680027

Our address: Tashkent city, Yunusobod district, 19th block,
House 17.



Acceptance of articles

Published every
monthly



Directions

Social, economic, political,
technological, scientific



Scopus || Scientific electronic journal specializing in Scopus

CERTIFICATE NUMBER: №390637

**ORDER NUMBER ACCORDING TO
THE LICENSE REGISTER: C-5669633**

CONTACT:



Contact us
+998 50 737 87 88



Telegram channel
t.me/scopus_IST2100



Journal official website
<https://ist-journal.uz/index.php/IST>