European Science Review

2026, No 1–2

PREMIER Publishing

Vienna
2026

European Science Review

Scientific journal

2026, No 1–2

ISSN 2310-5577

Proofreading Kristin Theissen

Cover design Andreas Vogel

Additional design Stephan Friedman

Editorial office Premier Publishing Praha 8
Karlín, Lyčkovo nám. 508/7, PSČ 18600

Email: pub@ppublishing.org

Homepage: ppublishing.org

European Science Review an international, English language, peer-reviewed journal. The journal is published in electronic form.

The decisive criterion for accepting a manuscript for publication is scientific quality. All research articles published in this journal have undergone a rigorous peer review. Based on initial screening by the editors, each paper is anonymized and reviewed by at least two anonymous referees. Recommending the articles for publishing, the reviewers confirm that in their opinion the submitted article contains important or new scientific results.

Premier Publishing s.r.o. is not responsible for the stylistic content of the article. The responsibility for the stylistic content lies on an author of an article.

Instructions for authors

Full instructions for manuscript preparation and submission can be found through the Premier Publishing s.r.o. home page at: http://ppublishing.org

Material disclaimer

The opinions expressed in the conference proceedings do not necessarily reflect those of the Premier Publishing s.r.o., the editor, the editorial board, or the organization to which the authors are affiliated. Premier Publishing s.r.o. is not responsible for the stylistic content of the article. The responsibility for the stylistic content lies on an author of an article.

Included to the open access repositories:

The jurnal has Index Copernicus Value (ICV) 92.08 for 2022.

SJIF 2024 = 6.735 (Scientific Journal Impact Factor Value for 2024).

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 1. Economics and management

DOI:10.29013/ESR-26-1.2-3-9

RISK ANALYSIS IN THE FIELD OF INTERNATIONAL FURNITURE TRADE: HOW TO MINIMIZE LOSSES WHEN INTERACTING WITH CHINA

Bykov Pavel [1]

[1] CEO GETABOX furniture tour (cofounder), China, Foshan

Cite: *Bykov, P. (2026). Risk Analysis in The Field of International Furniture Trade: How to Minimize Losses When Interacting With China. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-3-9

Abstract

The article presents a systematic analysis of the risks faced by companies engaged in the international furniture trade when working with suppliers from China. In addition, the authors evaluate the economic effectiveness of measures aimed at reducing losses. The study revealed that the main causes of damage are related to different shipping times and container downtime, as well as non-compliance of materials and packaging with the requirements of importing countries. In addition, the losses are affected by fluctuations in transportation rates and exchange rates. A quantitative model of expected losses was created based on open data such as reliability of schedules, rate indices, downtime tariffs, and foreign trade statistics for the furniture product group. This made it possible to compare the options before and after the implementation of the proposed measures. Practical recommendations include clarification of the terms of delivery and the responsibilities of the parties in the contract, multi-stage quality control and packaging testing, early booking and downtime management, insurance coverage and settlement coordination. The results showed that the risk-based organization of processes makes it possible to reduce unscheduled costs, stabilize deadlines and increase the predictability of the importer's margin.

Keywords: *international furniture trade, China, supply risks, delivery time, container downtime, quality and packaging, transportation tariffs, currency fluctuations, economic assessment, expected losses.*

Relevance of the study

International furniture trade is characterized by a high degree of uncertainty, and China remains a key manufacturing center and source of supply for many countries. Long chains, which include steps from the production of raw materials and components to assembly, international transportation and domestic distribution, are vulnerable to failures at each stage. Problems can arise at any

of them: from disruptions of the production schedule and fluctuations in quality to congestion of the port infrastructure, container downtime, delays at customs and discrepancies between the planned and actual delivery time. In addition, trade is affected by fluctuations in exchange rates, changes in customs, tariff and non-tariff requirements, as well as stricter standards on material safety and emissions of harmful substances, as well as labeling and packaging requirements.

The risks associated with furniture production increase significantly due to the large size of the products, increased requirements for packaging strength, as well as a large number of visible defects and significant return costs. In addition, vulnerabilities arise when choosing the terms of delivery according to the rules of Incoterms, the distribution of responsibility between the parties, the structure of prepayment and guarantees, as well as when working with contract production under someone else's trademark and individual developments. Experience shows that without systematic risk management, which includes checking the integrity of counterparties, fixing quality indicators and deadlines in the contract, multi-stage inspections, as well as insurance protection of cargo and civil liability, companies face loss of margins, increased inventory and disrupted sales.

Under these conditions, a scientifically based risk analysis and an economically verified set of measures to reduce them (from the choice of delivery terms and payment scheme to standardization of quality, packaging engineering and digital control of cargo movement) becomes an essential element of importers' competitiveness.

The purpose of the study

The purpose of this study is to identify and assess the main risks associated with importing furniture from China, as well as to propose cost-effective ways to minimize them based on open data.

Materials and research methods

Information base: we have at our disposal the official statistics of foreign trade in the furniture product group. We also have public indexes of container shipping rates, indicators of reliability of shipping line schedules, and open tariffs for downtime and storage. In addition, we carefully study the regulations of importing countries regarding the safety of materials, labeling and packaging, as well as contractual documentation and quality inspection protocols.

Risk analysis methods: risk register and "probability – impact" matrix, scenario analysis ("basic" and "intense"), modeling of expected losses from events such as "delay", "downtime", "damage", "rise in price", sensitivity analysis, comparison of "before" and "after" options, taking into account the costs of implementing measures, performance monitoring based on key indicators.

The results of the study

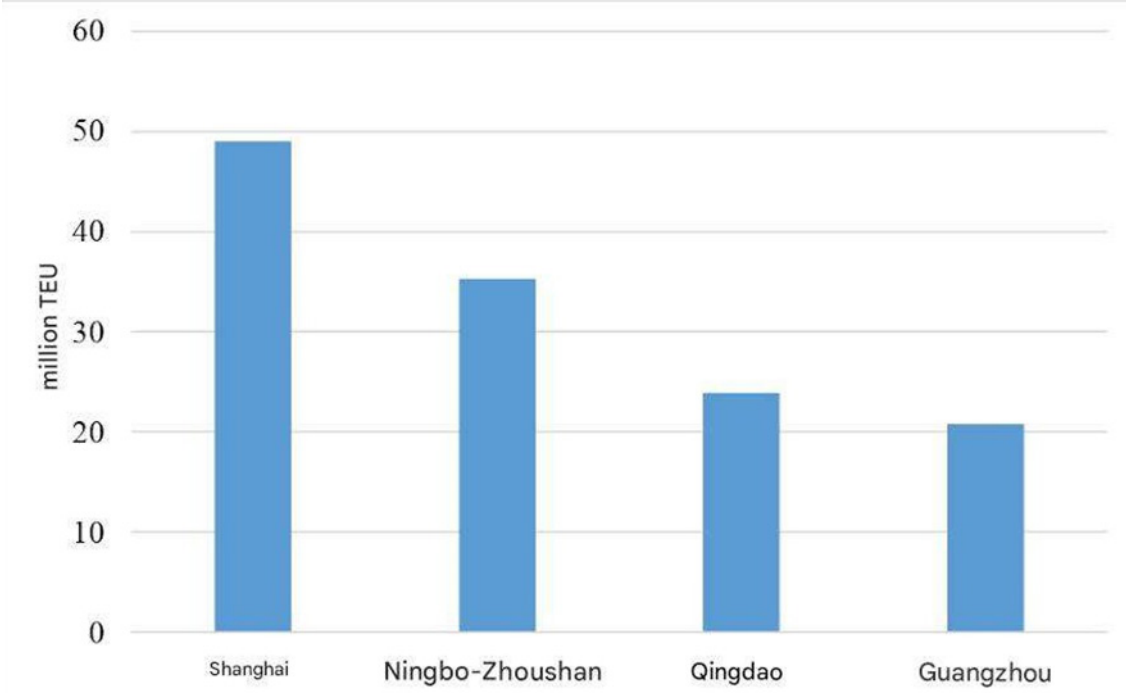
Risk management in the furniture trade is based on standard methods aimed at identifying, assessing and accounting for possible uncertainties at all stages – from the conclusion of contracts to after-sales service. The methodology is based on the international standard ISO 31000. He defines risk as "the impact of uncertainty on the achievement of goals." The standard establishes the principles of integrating risk management into organizational processes, consistency, consideration of the human factor and continuous improvement (ISO 31000 – Wikipedia).

China's production and logistics infrastructure is concentrated around large industrial centers and seaports, which determines the regularity and predictability of furniture supplies. According to the statistics of foreign trade operations for the group of 94, China occupies a leading position in the export of furniture and related products. The concentration of cargo flows around several port agglomerations makes the timing and cost of deliveries dependent on the capacity of these hubs. In 2023, the port of Shanghai handled about 49 million standard containers (twenty-foot equivalents, TEU), retaining the first place in the world. The port of Ningbo-Zhoushan reported 35.3 million TEU for the same year, which indicates the reliability of the eastern corridor for the export of finished products (Shanghai remains world's top container port by TEUs).

To clearly demonstrate the scale and structure of container traffic along China's main sea routes, let's turn to comparable data

for 2023. Comparing ports allows us to link furniture shipment planning to their actual capacity and assess the likelihood of seasonal terminal congestion. The figure below shows the container turnover volumes of China's largest ports.

Figure 1. *Container turnover of Chinese ports in 2023 (million TEU)*
(Shanghai remains world's top container port by TEUs)



For the production of wooden furniture in China, it is important to comply with national requirements for the content of formaldehyde and take into account the requirements of importing countries. The basic restrictions are set out in the mandatory GB 18580–2017 standard "Materials for interior decoration – limits for the release of formaldehyde from wood slabs and products made from them." In 2026, it will be replaced by a new version – GB 18580–2025. There is also a classification standard GB/T 39600–2021, which divides products into classes E1, E0 and ENF depending on the level of formaldehyde release. For export shipments of furniture, it is important to specify the required class, test method and laboratory protocols in the specifications. Failure to comply with these conditions can lead to delays, additional inspections, and even denial of market access (GB 18580–2017 Indoor decorating and refurbishing materials).

To the specifics of working with Chinese suppliers, we can add problems related to the efficiency of ports and land logistics. The Port Efficiency Index shows that differences in the processing speed of ships and containers at large hubs directly affect the variability of the actual delivery time and the amount of downtime. For furniture loads, which are usually sensitive to shock and humidity, even minor delays can increase the risk of damage. This requires additional measures, such as strengthening packaging, testing transport strength standards, installing impact and humidity sensors, expanding insurance coverage, and choosing routes with more predictable handling.

In transactions with Chinese factories and traders, it is important to pay special attention to the terms of delivery and payment methods. In China, documentary letters of credit and other non-cash forms of payments are widely used, which allow you to synchronize payments with the submission of transportation and inspection documents. For furniture importers, this means that they must take into account transportation and insurance controls, the availability of consolidation sites, shipping schedules, and the capacity of the selected port to ensure timely delivery of their goods.

In order to quantify the risks associated with international furniture trade, it is necessary to take into account both verifiable market data and the factors described in regulatory documents. These factors affect the timing, cost, and safety of cargo. The key inputs for the simulation are the reliability of shipping line schedules, freight rate dynamics, and downtime at transport network nodes, currency volatility, and regulatory requirements of countries where furniture is imported.

In order to assess time risks in monetary terms, in practice, the expected value of losses is used. It is calculated as the product of the probability of occurrence of an event and the amount of damage, which can be measured in days of delay or in the currency of the contract. Officially published freight rate indexes are used as the initial data for the assessment. For example, as of June 20, 2024, the composite global container transportation index was $5,117 per forty-foot container, which is significantly higher than the average pre-crisis values. On November 6, 2025, the spot rate for the Shanghai-Rotterdam route was estimated at $1,962 per forty-foot container. At the same time, the aggregated index of container freight on the same day was 1550.7 points. For furniture shipments, where transportation costs take up a significant part of the cost due to large dimensions and complex packaging, such changes directly affect the increase in cost and the risk of lower margins (Global Market Update).

The next stage of identifying problems is related to limitations in the operation of the logistics infrastructure. The World Bank's report on the Logistics Efficiency Index 2023 presents indicators of "downtime" in ports and "delivery time" between ports calculated based on extensive data. An analysis of more than 2.5 million observations shows that it is the duration and spread of downtime in network nodes that lead to "long tails" of actual deadlines, which increases the likelihood of shipments falling out of the planned supply window. This is especially important for furniture, as an increase in travel time increases the risk of damage due to additional overload and exposure to external factors, as well as increases the likelihood of additional costs due to container downtime at terminals. These indicators serve as the basis for scenario calculations: "base", "busy season" and "unfavorable" scenarios. As part of these calculations, the upper quantiles and the corresponding time and budget reserves are allocated (Trade Logistics in the Global Economy).

The risks associated with compliance with the requirements of the countries of import for the safety of materials, labeling and packaging can lead to delays and refusals in the release of goods. International phytosanitary standard No. 15 applies to wooden containers and cushioning materials. In some countries, it has become mandatory for imports from third countries. Violations of labeling or processing may result in delays and additional inspections. To assess this risk in monetary terms, it is necessary to take into account the expected cumulative losses. This amount includes fees for downtime, additional control services, possible recycling or repackaging, as well as penalties that may be imposed on counterparties due to delivery time violations.

Transportation strength testing and packaging engineering are used to reduce the risk of damage during transportation. Research in the field of dynamic impacts during falls and impacts has shown that optimizing packaging in conditions that simulate real logistics statistically reduces the amount of damage and, consequently, the expected damage per unit of production. This is especially true for cabinet furniture and wood-based products that are sensitive to impact and moisture. In practical calculations, importers establish the permissible proportion of defects and damages during acceptance, link it to the inspection plan, and test methods. This allows us to predict the residual risk of marriage for each batch (Measurement and Analysis of the Shock and Drop Levels Experienced by Small and Medium Packages in the Korean Parcel Delivery System).

Currency risk should be considered separately, as payments for furniture and transportation are often made in US dollars, while costs are calculated in Yuan. According to official statistics, time series of the exchange rate between the Yuan and the US dollar are available on an annual and monthly basis. This allows you to model scenarios of

strengthening and weakening of the buyer's national currency and assess how sensitive the margin is to exchange rate changes. In our applied model, currency risk is taken into account as the distribution of monthly exchange rate changes. This allows you to estimate the expected reassessment of the purchase over a selected time horizon, for example, within 3–6 months between the signing of the contract and the payment of the main batch.

Table 1 shows the tools that help to purposefully reduce these risks when working with suppliers from China.

Table 1. *Tools for minimizing losses when working with China*

The tool	Point	What kind of risk reduces	Effect metric
Choosing the basis according to the rules of Incoterms	Fixes the moment of transfer of risks and the area of responsibility	Deadlines, downtime, cost overruns	The proportion of deliveries completed on time; the proportion of orders for which there were no overruns.
Shipment calendar and early booking	Synchronization with the power of ports and lines	Delays, downtime	Average waiting time; percentage of advance bookings.
Quality inspection before and before shipment	Early detection of inconsistencies	Quality inconsistencies, refunds	The percentage of defective goods upon acceptance; the number of complaints.
Laboratory testing of materials	Confirmation of compliance with regulations	Delays in release, non-conformity of materials	The percentage of parties that received complete protocol packages.
Reinforced packaging and strength testing	Overload and vibration protection	Damage in transit	The share of damages; the average amount of payments for insured events.
Cargo insurance with extended coverage	Financial compensation for unforeseen losses	Damages, losses, force majeure	The proportion of reimbursed cases; the settlement period.
Demurrage and cub management	Preventing container downtime charges	Downtime, increased cost of transportation	Downtime payments per container; percentage of shipments without downtime.
Currency hedging	Limiting the impact of the exchange rate	Re-evaluation of the purchase	Price deviation due to the exchange rate; share of hedged volumes.

A source: author's development

Currently, based on the current market situation, the main financial losses in furniture shipments from China are due to delays in scheduled delivery, container downtime (fines and lost profits), as well as due to the variability of freight rates. On average, the most "recoupable" are early booking and time reserve in the contract (risk reduction of 46.2% of delays), demurrage/cub management measures (direct impact on public tariff payments), as well as negotiation/contractual instruments for rates (index/corridor binding). The use of reinforced packaging and extended insurance coverage can further reduce the expected damage costs, which is especially important for oversized furniture. The magnitude of this effect depends on your complaint history and routes, and it can be

estimated using the "before/after" method, taking into account the cost of implementing these measures. The final set of activities and their cost-effectiveness should be regularly reviewed, taking into account changes in the rate indices and statistics on schedules and downtime.

Table 2 provides a matrix that links each type of risk to a specific instrument and provides an easy way to verify the results.

Table 2. *The short matrix "risk tool – how to check the effect"*

Risk	The tool	How to capture the effect
Deadlines are disrupted	Early booking, reservation according to the terms in the contract	Proportion of deliveries on time, average delay (in days).
Container downtime	Agreed «free days», documents ready, quick pick-up	Downtime payments per container, the proportion of batches without downtime.
Quality mismatch	Inspections at three stages, linking payments to certificates	The percentage of defects on acceptance, the number of complaints per thousand products.
Damage in transit	Reinforced packaging, strength testing, sensors	The share of damages, the amount of insurance payments per batch.
Increase in the cost of transportation	Contractual bid corridors, route selection	Deviation of the actual bid from the budget.
Currency revaluation	Coordination of the settlement currency, fixing the exchange rate	Deviation of the purchase price at the exchange rate.

A source: author's development

In practice, it all comes down to a few simple steps: supplier verification, a thorough contract, and early logistics planning. First, you need to make sure that the supplier has all the necessary documents: registration, confirmation of capacity, samples and test reports. Then important details are included in the contract: the basis of delivery, the time of transfer of risks, requirements for goods and packaging, the inspection plan and the calculation procedure that will be linked to the documents.

Quality control is carried out in stages: from checking reference samples and sampling during the production process to the final inspection before shipment with mandatory recording of the results. The packaging is designed taking into account the route and is tested for resistance to drops, vibrations and humidity. Special sensors are used to protect sensitive products.

Shipments are planned, taking into account seasonal peaks. Time is reserved for this, the necessary documents are prepared before the arrival of the cargo, and containers are quickly picked up to avoid charges for their downtime. If necessary, routes and lines are diversified, and as the volume of shipments increases, mixed shipments are transformed into full-container shipments.

Insurance coverage is selected depending on the route and packaging, payments are made in stages, and an agreed settlement currency or exchange rate fixing offsets currency fluctuations. Regular analysis of delays, downtime, defects, damages, and budget deviations allows for timely adjustments to requirements and schedules, which helps to stabilize deadlines and minimize losses.

Conclusions

Thus, the main losses in the international furniture trade are related to the unpredictability of shipping times and container downtime, as well as inconsistencies in quality and legislation. In addition, prices and exchange rates are affected by changes in rates and exchange rates. Risks are increasing in the Chinese market due to the high concentration of production and dependence on large ports, as well as strict requirements for materials, packaging and documents. The sustainabili-

ty of supplies is ensured by a comprehensive risk management system at all stages – from contract conclusion and quality control to shipment planning and insurance protection.

Quantitative assessment based on open indicators allows you to calculate expected delays, downtime payments, sensitivity to changes in rates and exchange rates, the proportion of defects and damages. Early booking and time reserve, downtime management, linking payments to inspection reports and documents, enhanced packaging and correct insurance coverage, provide the greatest economic effect.

The limitations are related to the variability of the external environment and differences in approaches that are used in ports and among carriers. The data needs to be clarified for specific routes and assortment. In the future, it is planned to examine the impact of packaging engineering in more detail, typify contractual solutions, and expand scenario analysis based on seasonal factors and alternative routes. In general, a systematic risk-based approach to working with China makes it possible to stabilize delivery times, minimize unscheduled costs, and increase margin predictability.

References

GB 18580–2017 Indoor decorating and refurbishing materials – Limit of formaldehyde emission of wood-based panels and finishing products (English Version) – Code of China [Electronic resource]. – Access mode: https://www.codeofchina.com/standard/GB18580–2017.html.

Global Market Update [Electronic resource]. – Access mode: https://www.pentagonfreight.com/wp-content/uploads/2024/08/2024-Q2-Market-Report.pdf.

ISO 31000 – Wikipedia [Electronic resource]. – Access mode: https://en.wikipedia.org/wiki/ISO_31000.

Measurement and Analysis of the Shock and Drop Levels Experienced by Small and Medium Packages in the Korean Parcel Delivery System

[Electronic resource]. – Access mode: https://pdfs.semanticscholar.org/2339/c8917baf2caa08a90c5efe53bb973cdfa57f.pdf.

Shanghai remains world's top container port by TEUs [Electronic resource]. – Access mode: https://english.shanghai.gov.cn/en-Latest-WhatsNew/20240103/ fb3f56e6285a4f92bb5259c397cb5b1e.html.

Trade Logistics in the Global Economy [Electronic resource]. – Access mode: https://lpi.worldbank.org/sites/default/files/2023–04/LPI_2023_report_with_layout.pdf.

submitted 12.02.2026;
accepted for publication 26.02.2026;
published 28.02.2026

Contact: pavel-sina2014@yandex.ru

DOI:10.29013/ESR-26-1.2-10-14

INTELLECTUAL PROPERTY IN THE CYBERSECURITY STRUCTURE OF A GEORGIAN PUBLIC COMPANY. REGIMES, PRACTICES AND STRATEGIES FOR PROTECTING INTELLECTUAL PROPERTY FROM CYBER THREATS (Part 2)

Chiladze George Bidzinovich [1]

[1] J.S.D., D.B.A., Prof., University of Georgia, NASA-Georgia

Cite: Chiladze, G.B. (2026). Intellectual Property in the Cybersecurity Structure of a Georgian Public Company. Regimes, Practices and Strategies for Protecting Intellectual Property from Cyber Threats (Part 2). European Science Review 2026, No 1–2. https://doi.org/10.29013/ESR-26-1.2-10-14

Abstract

Each level of intellectual property protection from cyber threats may have its own legal regime of protection, which should ensure the necessary protection of the interests of the intellectual property owner. The article discusses the widespread threats and risks of intellectual property in the field of cybersecurity in Georgian public companies. It is important that in today's digital world, Georgian state-owned companies timely develop the best strategies for protecting intellectual property in the field of cybersecurity, taking into account relevant international practice.

Keywords: *cyber threat, intellectual property, intellectual property protection, public company*

Introduction

Special regimes for the protection of intellectual property from cyber threats include: establishing a regime for state secrets, as well as official or commercial secrets, which are based on the relevant provisions of the law (for example, the Law of Georgia "On State Secrets"). The protection of other relevant information is also provided for by the current normative acts, on the basis of which secret information, commercial information, as well as information technologies, competition, etc. are protected. (Law on State Secrets, 2025).

The protection of information containing state, official or commercial secrets (which reflects data on the protected results of intellectual activity) in a special legal regime is also provided for by the relevant articles of the Civil Code of Georgia. Protected objects containing information constituting state secrets may include: computer programs and databases; secret inventions and industrial designs; topologies of integrated circuits, etc.

As for the protection of production secrets (know-how), it is usually based on the introduction of a confidentiality regime, including a commercial secret regime. A spe-

cial legal regime for the protection of personal data is established by the Law of Georgia on Personal Data Protection and acts of the Government of Georgia concerning the requirements for the protection of personal data when processing them in information systems and the composition and content of organizational and technical measures to ensure the security of personal data when processing them in information systems (Law on Personal Data Protection, 2025).

Main text

1. Common threats and risks of intellectual property in the field of cybersecurity in Georgian public companies

The Georgian government has approved the third National Cybersecurity Strategy for 2021–2024 and its Action Plan. The current strategy focuses on two main groups of threats. These are: cyberwar, information warfare, cyberespionage, cyberattacks directed by state actors, and cybercrime, including attacks against critical infrastructures.

As stated in the document, the goal of information warfare is unauthorized access to information existed in private and public critical infrastructures of Georgia. In addition, the entities implementing critical information systems and services do not have an "appropriate level of information and cybersecurity assurance." Therefore, it is important to increase the quality of security and protection. As for cybercrime, the document lists phishing, ransomware, defacement, DDoS, and mail spoofing as the most common forms of attacks against critical infrastructures. According to the strategy, along with critical state sectors and public companies, commercial entities are increasingly becoming targets of attacks. (National Cybersecurity Strategy for 2021–2024, 2021).

Unfortunately, the document does not mention intellectual property in the field of cybersecurity at all, which, in my opinion, is a clear flaw. In addition, it does not discuss the violations common in this field – their classification is not provided.

However, for Georgian public companies, intellectual property in the field of cybersecurity refers to valuable and confidential information. It is created, stored and / or transferred by an organization or individual in the digital realm, which may include trade secrets, patents, trademarks, designs, software code, data, etc. Intellectual property in the field of cybersecurity often becomes a target of attackers when relevant persons try to steal, copy, modify or destroy it in order to gain profit or cause harm to the original owner.

It is important to discuss some common threats and risks related to intellectual property in the field of cybersecurity, which, unfortunately, are not reflected at all in the National Cybersecurity Strategy of Georgia, to indicate about how these threats and risks can affect the security, reputation and confidentiality of a public company owning intellectual property. It is also important to discuss best practices for protecting and monitoring intellectual property in the field of cybersecurity.

2. Practices and strategies for protecting intellectual property in the field of cybersecurity in public companies

It is important that state-owned companies properly understand the intellectual property values from the very beginning, in particular, the importance of their intellectual property in the field of cybersecurity and the potential impact of this property on the organization. With a correct understanding of the value, it will be possible to prioritize protection and allocate appropriate resources. It is also necessary to establish reliable controls over the organization's intellectual property in order to limit unauthorized access to it as much as possible. This includes state-owned companies: a) implementing strong authentication mechanisms, b) managing access based on roles, and c) regularly auditing it to ensure compliance. A state-owned company should ensure a secure network infrastructure – implement reliable network security measures to protect the organization's intellectual property. This should include firewalls, intrusion detection systems, and encryption protocols to protect data both during transmission and storage. At the same time, it is necessary to regularly update and improve security systems and software, including with the latest security patches, the regular use of which helps to

eliminate the causes of vulnerability and reduces the risk of unauthorized access or data leakage. (Strategies to Protect Your IP Effectively, 2024).

A separate issue is the implementation of necessary controls and timely detection of anomalies. It is important to implement advanced monitoring and anomaly detection systems to identify any unusual activity or potential violations. It is necessary to use intrusion detection and breach prevention systems, security-critical information and event management tools to proactively detect threats and respond to them.

It is important to implement secure data storage practices, including: encryption, access control, and regular creation of backups. This ensures the confidentiality, integrity and availability of the company's intellectual property, even in the event of a hacker attack or system failure. Comprehensive, effective cybersecurity incident response plans need to be developed. To test the effectiveness of the current plan, it should include defining of roles and responsibilities, establishing communication channels and conducting regular exercises. Regular audits and reviews should be conducted to identify any gaps or vulnerabilities in the company's cybersecurity practices. This includes penetration testing, vulnerability assessments and compliance audits to ensure compliance with industry standards and regulations. It is also necessary to address the issue of training employees to inform them of the importance of intellectual property in cybersecurity and their role in protecting it; In order to raise awareness, it is necessary to conduct regular trainings on potential threats, phishing attacks and social engineering methods. Finally, the company needs to be informed about the latest trends, threats and best practices in cybersecurity. It is recommended to participate in forums and conferences held within the field. It is also important to use sources of information about threats so that the company has advance information about new risks and can take proactive measures. Protecting a company's intellectual property in the area of cybersecurity requires a multifaceted, differentiated approach. By implementing these best practices and strategies, a state-owned company can improve the security of its valuable assets and reduce potential risks. (Cyber-Security Breaches, 2025).

Conclusions

1) Types of intellectual property rights violations in cyberspace, using electronic and digital means, may include: a) illegal access to information containing commercial secrets (know-how), official or state secrets, their unauthorized receipt and disclosure, including actions with prior intent ("hacking attacks"); b) unauthorized intervention in databases, creation and use of computer software to change or block information in databases with aim to replace it with other digital information (data); c) dissemination of false (inaccurate) information about a natural or legal person on the Internet, or other violation of the right to privacy, or damage to business reputation; d) violation of these rights in cyberspace, in works protected by copyright and related rights; e) illegal use of a trademark, the name of a legal entity and other means of individualization, including the illegal use of designations in domain names or in the content of web pages; f) intentional illegal use of means of individualization (commercial designation, company name, trademark, geographical indication) with the aim of causing direct or indirect harm to the copyright holder. It should be noted that the protection of intellectual property from cyber threats is usually ensured not only in relation to copyright holders with different legal statuses, but is also divided according to the levels of protection.

2) Georgia's Third National Strategy and its Action Plan focus on the following groups of threats: cyberwar, information warfare, cyberespionage, state-led cyberattacks, and cybercrime, including attacks against critical infrastructures. The goal of information warfare is unauthorized access to information in Georgia's private and public critical infrastructures. In addition, entities implementing critical information systems and services do not have "an appropriate level of information and cyber security." Therefore, it is important to improve the quality of security and protection. As for cybercrime, the document lists phishing, ransomware, defacement, DDoS, and mail spoofing as the most common forms of attacks against

critical infrastructure. Unfortunately, the document does not address intellectual property in the field of cybersecurity at all, which is a clear shortcoming. In addition, it does not discuss the violations common in this field and it does not provide a classification. Intellectual property in the field of cybersecurity is often targeted by attackers, when certain parties attempt to steal, copy, modify, or destroy it for profit or to cause harm to the original owner. It is important to discuss some of the common threats and risks related to intellectual property in the field of cybersecurity, which, unfortunately, are not reflected at all in the National Cybersecurity Strategy of Georgia, to indicate/explain as how they can affect the security, reputation and confidentiality of a public company that owns intellectual property.

3) It is important that Georgian state-owned companies develop the best strategies for protecting intellectual property in the field of cybersecurity in a timely manner, take into account relevant international practices, and correctly understand from the outset the importance of their intellectual property in the field of cybersecurity and the potential impact of this property on the organization. With a correct understanding of the value, it will be possible to rank protection priorities and allocate appropriate resources. It is also necessary to establish reliable control over the organization's intellectual property in order to limit unauthorized access to it as much as possible. This includes state-owned companies: a) implementing strong authentication mechanisms, b) managing access based on roles, and c) conducting regular audits to ensure compliance. A state-owned company should ensure a secure network infrastructure – implement reliable network security measures to protect the organization's intellectual property. Firewalls, intrusion detection systems, and encryption protocols should be used to protect data both in transit and when stored. Security systems and software should be regularly updated and refined, including with the latest security patches, the regular use of which helps eliminate the causes of vulnerability and reduces the risk of unauthorized access or data leakage. It is important to implement advanced monitoring and anomaly detection systems to identify any unusual activity or potential violations. It is necessary to use intrusion detection and breach prevention systems, security-critical information, and event management tools in order to proactively detect threats and respond to them. It is important to implement secure data storage practices. Comprehensive, effective plans for responding to cybersecurity incidents need to be developed. To test the effectiveness of the current plan, it should include defining roles and responsibilities, establishing communication channels, and conducting regular exercises. Regular audits and reviews should be conducted to identify any gaps or vulnerabilities in the company's cybersecurity practices. This includes system penetration testing, vulnerability assessments, and compliance audits. It is also necessary to address the issue of employees' training. The company needs to be informed about the latest cybersecurity trends, threats, and best practices.

References

Law of Georgia on State Secrets (2025). URL: https://mod.gov.ge/uploads/public/_%E1%83%90%E1%83%A5%E1%83%A2%E1%83%94%E1%83%91%E1%83%98/saxelmwifo_saidumloebis_shesaxeb_saqartvelos_kanoni.pdf

Law of Georgia on Personal Data Protection (2025). URL: https://pdps.ge/files/content/%E1%83%9E%E1%83%94%E1%83%A0%E1%83%A1%E1%83%9D%E1%839C%E1%83%90%E1%83%9A%E1%83%A3%E1%83%A0%20%E1%83%9B%E1%83%9D%E1%83%9C%E1%83%90%E1%83%AA%E1%83%94%E1%83%9B%E1%83%97%E1%83%90%20%E1%83%93%E1%83%90%E1%83%AA%E1%83%95%E1%83%98%E1%83%A1%20%E1%83%A8%E1%83%94%E1%83%A1%E1%83%90%E1%83%AE%E1%83%94-%E1%83%91%20%E1%83%9B%E1%83%9D%E1%83%A5%E1%83%9B%E1%83%94%E1%83%93%E1%83%98%20%E1%83%99%E1%83%90%E1%83%9C%E1%83%9D%E1%83%9C%E1%83%98_1711019935.pdf

Georgia approved the National Cybersecurity Strategy for 2021–2024 (2021). URL: https://civil.ge/ka/archives/446832
Strategies to Protect Your Intellectual Property Effectively (2025). URL: https://www.zoppi.co.uk/blog/strategies-to-protect-your-intellectual-property-effectively
Cyber-Security Breaches (2025). URL: https://www.dataguard.com/cyber-security/breaches/

submitted 28.12.2025;
accepted for publication 14.01.2026;
published 28.02.2026

Contact: dr.chiladze@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

DOI:10.29013/ESR-26-1.2-15-21

EXECUTION ARCHITECTURE IN ORGANIZATION MANAGEMENT SYSTEMS: METHODOLOGICAL FOUNDATIONS OF DESIGN AND PRACTICAL IMPLEMENTATION EXECUTION ARCHITECTURE IN ORGANIZATION MANAGEMENT SYSTEMS: METHODOLOGICAL FOUNDATIONS OF DESIGN AND PRACTICAL IMPLEMENTATION

Shurtakova Alena [1]

[1] Business consultant, McKinsey & Company, USA, Sausalito

Cite: *Shurtakova, A. (2026). Execution Architecture in Organization Management Systems: Methodological Foundations of Design and Practical Implementation. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-15-21

Abstract

The article will focus on the execution architecture, an important element of an organization's management system that provides a link between strategy and the company's day-to-day operations. It was noted that many organizational problems are related to insufficient detail of processes, unclear distribution of responsibilities and lack of effective control. The text reveals the content of the execution architecture, including processes, roles, interactions, solutions, and metrics. The article systematizes the methodological principles on which the system is built and analyzes the causes of possible failures in its operation. Using the example of various industries, it is shown how the formalization of processes and the introduction of control mechanisms can significantly increase the sustainability and manageability of activities. The prospects of using this approach in the context of digital transformation and the introduction of artificial intelligence are also considered.

Keywords: *execution architecture, organization management system, process approach, operational model, management decisions, responsibility allocation, system failures, execution control, KPIs, digital transformation, artificial intelligence, organizational design.*

Relevance of the study

In modern conditions of rapid economic development, effective implementation of strategic goals at the level of the organization's daily work is of particular importance. Despite the widespread use of strategic management methods, operational models, and key performance indicator (KPIs) systems, there is still a gap in practice between the goals set and the actual results of achieving them. This problem has been repeatedly mentioned in scientific and applied literature.

In many organizations, the processes of completing tasks remain insufficiently formalized and largely depend on operational decisions and the individual experience of managers. This can lead to unstable results, reduced manageability, and a high dependence of efficiency on the human factor.

In the era of digital transformation and the increasing complexity of organizational systems, the need for reliable and reproducible execution with limited resources is particularly acute. However, the existing management approaches focus mainly on the strategic and structural levels, while the level of direct execution remains poorly understood.

In this regard, the study of execution architecture in organization management systems is of great scientific and practical interest. It allows you to ensure consistency between the strategic goals and the actual activities of the organization.

The purpose of the study

The purpose of this study is to reveal the essence of the execution architecture in the organization's management system. In the course of our work, we will define its methodological foundations and identify its role in overcoming system failures, ensuring the sustainable functioning of processes and improving performance in the context of digital transformation.

Materials and research methods

The research analyzed scientific and practical works on process management, organizational design, performance, digital transformation and operational efficiency. Special attention was paid to ISO 9001:2015 standards, the Balanced Scorecard concept, lean manufacturing principles, as well as experience in implementing personnel management systems, routing requests, and digital management platforms.

General scientific methods of analysis and synthesis, generalization, comparison, a systematic approach and structural and functional analysis were used in the work.

The results of the study

There is no clear definition of execution architecture in scientific and practical sources, so its content is revealed through generally accepted categories: processes, allocation of responsibility, interaction, control and indicators. According to the ISO approach, an organization is a system of interconnected processes, each with its own inputs, outputs, resources, and control methods. Based on this, execution is considered as a controlled set of actions and decisions aimed at achieving certain results (Khudaiberdina, D.M., Rossieva, D.V. (2017), p. 2).

The execution architecture is a formalized order of work execution. Unlike a strategy that sets goals and a structure that defines functions, this level describes exactly how an activity takes place: what processes are performed, in what sequence, by whom they are implemented, and how they are controlled. The ISO 9001:2015 standard requires a clear definition of the processes and their interrelationships, the appointment of responsible persons and the establishment of evaluation criteria. This allows us to consider execution as a system control element (The process approach in ISO 9001:2015).

The key content of the execution architecture includes several interrelated elements, which are shown in the figure.

Special attention should be paid to the decision-making system. Research conducted by McKinsey shows that in a complex organizational structure, the quality of decisions can decrease and responsibility can be blurred. This requires a clear definition of the authority and procedures to be applied in the decision-making process. Thus, execution includes not only processes, but also the management logic of decision allocation.

It is also important to have a system of indicators. The concept of a Balanced Scorecard shows that activities need to be assessed not only by financial, but also by operational and process indicators. This allows you to establish a link between the set goals and their actual achievement (Kurshin, A.Yu. (2013), p. 135).

The methodological principles of execution architecture design are based on generally accepted approaches to process management, organizational design, and control over results. Open sources emphasize the importance of a systematic description of processes, the allocation of responsibilities, the establishment of control criteria and ensuring their interrelation. The execution architecture design process is the sequential transformation of strategic goals and an operational model into specific processes, roles, solutions, and controls. This allows you to ensure reproducible performance of activities, which is the key to success.

Table 1 shows the key methodological elements used in the design of the execution architecture.

Figure 1. *The structure of the execution architecture in the organization's management system*

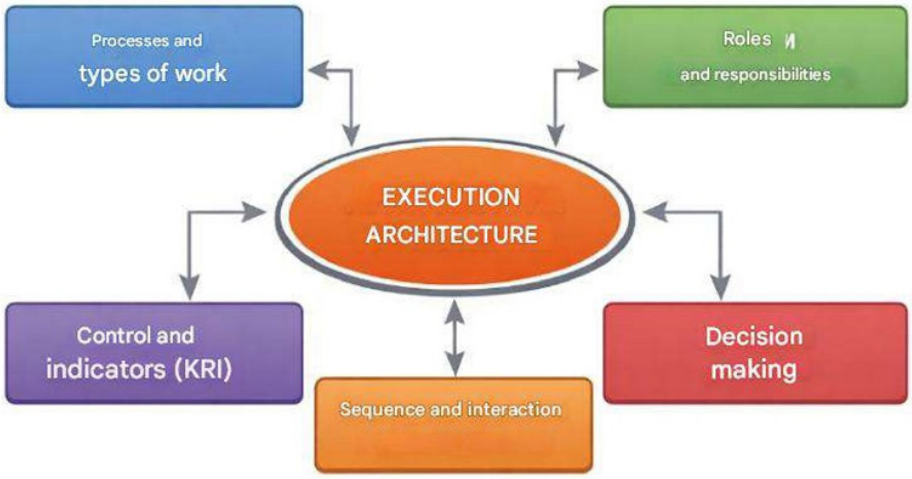


Table 1. *Methodological foundations of execution architecture design*

Stage / element	Content	Result
Analysis of goals and indicators	Setting strategic goals and key performance indicators (KPIs) that will be implemented at the operational level	A list of target indicators has been formed
Process allocation	Identify the processes needed to achieve the goals	List of organization processes
Decomposition of activities	Separation of processes into separate types of work and operations	Structure of types of work
Definition of consistency and interaction	Determining the sequence of processes and their interrelationships	The scheme of processes and interactions
Allocation of responsibilities	The appointment of those responsible for the processes, the definition of their roles and powers	The responsibility matrix
Decision-making design	Setting levels and procedures for decision-making, as well as clear boundaries of authority	A map of solutions
Setting control points	Establishing the stages of monitoring and control over the implementation of processes	List of control points
Formation of the system of indicators	Evaluation of the effectiveness of processes and results	The metric system
Defining corrective actions	Definition of procedures aimed at eliminating deviations	Response regulations
Documentation	Description of processes, roles, indicators, and procedures	Regulations, schemes, instructions
Integration into information systems	Transfer of execution logic to digital and information solutions	Automated execution system

A source: compiled based on ISO 9001:2015 standards, Balanced Scorecard concept, organizational design model, as well as practical recommendations on process management and decision-making.

In management practice, systemic failures constantly occur, which lead to non-fulfillment of planned targets, missed deadlines, reduced quality of services and increased operating costs. These failures are often caused not by a lack of strategy or resources, but by inconsistent processes, unclear allocation of responsibilities, and lack of reliable control mechanisms for their implementation.

According to ISO standards, the effectiveness of a management system depends on an organization's ability to manage processes as a single system, including their regular monitoring and continuous improvement (Table 2).

Table 2. *The main causes of system failures and the corresponding elements of the execution architecture*

The reason for the failure	The manifestation	An element of the execution architecture that eliminates the problem
Inconsistency of processes	Delays, duplication of functions, loss of information	Determining the sequence and interaction of processes
Ambiguity of responsibility	Shifting tasks, lack of process owners	Securing roles and powers
The complexity of decision-making	Slowing down the reaction, reducing the quality of solutions	Formalization of the decision-making procedure
Lack of control	Inability to detect deviations	Establishment of control points and monitoring
Lack of indicators	Inability to evaluate effectiveness	Introduction of the KPI and metrics system
Dependence on the human factor	Instability of results	Standardization and documentation of processes

A source: compiled based on ISO 9001:2015 standards, concepts of process management and operational efficiency.

Fragmented management is one of the main causes of system failures. When there is no clear logic of execution, activities are distributed between departments without a clear understanding of the boundaries of responsibility and mechanisms of interaction. This can lead to duplication of functions, delays in information transmission, and the formation of so-called "bottlenecks" in processes. Research in the field of process management shows that the inconsistency between the stages of work is one of the main reasons for the decrease in efficiency (Shelygov, A.V., Gulina, I.V., Isaeva, O.G. (2019), p. 23).

Another factor complicating the decision-making process is uncertainty. In complex organizational structures, the number of participants involved in the process is growing, which slows it down and reduces the quality of decisions made. Management analysis materials emphasize that the lack of clearly defined authority and decision-making procedures leads to a blurring of responsibility and a decrease in manageability. This is especially important in operational activities, where it is necessary to respond quickly to emerging deviations.

System failures can also be related to the fact that processes are not transparent enough and do not have clear measurable evaluation criteria. Without established indicators and control points, it is impossible to objectively assess the progress of work and detect deviations in a timely manner. ISO standards emphasize the importance of monitoring, measuring and analyzing processes as a key factor for their effective functioning and continuous improvement.

The execution architecture is a tool for a comprehensive solution to the problems described above. Its key task is to ensure the coherence of processes, identify areas of responsibility, and streamline the decision – making process and implement control mechanisms. By formalizing the sequence of actions and coordinating between depart-

ments, the likelihood of failures caused by inconsistencies and uncertainty is reduced.

The key advantage is to reduce the dependence of results on the individual efforts of managers. When there is a well – defined execution system, activities become reproducible and deviations become controllable. This corresponds to the principles of the process approach, according to which sustainable results are achieved through systematic process management, rather than through individual management decisions.

The practical application of execution architecture in organizations of various fields confirms that the most important factor contributing to long-term effectiveness is not only the availability of strategies and processes, but also a clear system for their implementation. It is important to note that the introduction of a process approach, performance management systems and digital solutions helps to increase transparency of operations, reduce costs and ensure stability in the performance of tasks.

In modern manufacturing and service companies, the concept of Lean production is widely used, which is aimed at minimizing losses and standardizing work processes. Practice shows that the introduction of work standards, visual management methods and regular monitoring can significantly reduce the variability of results and increase productivity. Similar approaches are used in the service sector, as well as in administrative processes. Standardization of operations and constant monitoring of their implementation ensure the stability of the quality of services provided and administrative procedures provided.

Personnel and operations management systems, known as Workforce Management, are widely used in retail and service industries. According to open sources, these systems allow you to effectively plan the workload of employees, distribute tasks and monitor their performance depending on demand. This is especially important in conditions of unstable customer flow and limited resources. The experience of implementing such solutions shows that they are able to increase labor productivity and improve the quality of service through a more rational distribution of workload (Lesnikova, N.Ye., Yakovenko N.Yu. (2017), p. 304).

In the field of customer service and in contact centers, systems designed for routing requests and queue management are actively used. According to research conducted in this area, the introduction of automated routing and task allocation can significantly reduce waiting times and increase service availability without the need for additional resources. This is achieved by optimizing load distribution, standardizing request-processing processes, and implementing quality control mechanisms, which in turn significantly improves customer service.

Special attention is paid to the use of information and digital technologies. Reports on digital transformation emphasize that the introduction of information systems contributes to the formalization of processes, the consolidation of work rules and automatic monitoring of their compliance. At the same time, technology is considered as a tool for implementing management logic, rather than as the main factor in improving efficiency.

Table 3 provides examples of practical applications of execution architecture in various industries.

Table 3. *Examples of practical implementation of execution architecture in various industries*

Branch	Implementation tools	Practical effect
Production	Lean manufacturing, standardization of operations	Loss reduction, productivity growth
Retail trade	Workforce Management (WFM), staff workload planning	Improving the efficiency of labor use
Service sector	Service standards, process regulations	Stability of service quality
Contact centers	Routing and queue management systems	Reduced waiting time, increased availability

Branch	Implementation tools	Practical effect
Organizations in general	ERP, BPM systems, digital management platforms	Increasing transparency and manageability of processes

A source: compiled based on ISO 9001:2015 standards, lean manufacturing concepts, and the practice of using personnel management systems.

The experience of various industries shows that execution architecture is a set of processes, allocation of responsibilities, and implementation of standards and use of digital tools. At the same time, specific solutions may vary depending on the specifics of the industry, the level of maturity of the organization and the external conditions. However, the basic elements remain unchanged.

Thus, the experience of various industries demonstrates the universality of the approach to the development of execution architecture. Regardless of the field of activity, sustainable results are achieved if processes are formalized, responsibilities are clearly allocated, control mechanisms are implemented, and technology is used to support the performance of work. This allows organizations to ensure reproducibility of activities and reduce dependence on random factors.

In the era of digital transformation, formalized management systems that ensure the stable functioning of processes are becoming increasingly important. Open sources emphasize that the effectiveness of digital technologies and artificial intelligence directly depends on the degree of structuring and a clear description of the processes into which they are integrated.

The future of execution architecture is related to the integration of control logic into information systems. Artificial intelligence opens the door to automating task allocation, load forecasting, routing operations, and decision support. The use of data and analytics facilitates the transition to more proactive management.

The key aspect is the implementation of monitoring and control systems that are capable of operating in real time. This makes it possible to quickly identify any deviations and promptly take the necessary corrective measures. At the same time, the importance of maintaining managerial control and a clear division of responsibility in the implementation of intelligent technologies is emphasized.

Conclusions

Execution architecture is an important component of the modern management system of an organization, contributing to the implementation of strategic goals in everyday practice. Its importance lies in clearly defining processes, allocating responsibilities, streamlining the decision-making process, and setting benchmarks and performance indicators. The analysis shows that the lack of such a level of design often leads to system failures, instability of results and a high dependence of activities on the human factor.

The experience of various industries shows that the implementation of execution architecture contributes to the improvement of transparency, manageability and reproducibility of processes. In the context of digital transformation, this approach is of particular importance, as it lays the foundation for the effective use of information systems and artificial intelligence in the management of an organization.

References

Kurshin, A.Yu. (2013). Application of BSC (Balanced Scorecard) Technology in Innovative Project Management // Bulletin of Bryansk State University. – No. 3. – Pp. 135–138.

Lesnikova, N.Ye., Yakovenko N.Yu. (2017). Process Approach as an Effective Tool of Strategic Management // Bulletin of Civil Engineers. – No. 3 (62). – pp. 300–307. – DOI 10.23968/1999–5571–2017–14–3–300–307.

Khudaiberdina, D.M., Rossieva, D.V. (2017). Process Approach in the Quality Management System: Theoretical and Practical Foundations of Implementation // Collection of Ma-

terials of the IX All-Russian Scientific and Practical Conference of Young Scientists with International Participation “Young Russia”. – Pp. 1–4.
Shelygov, A.V., Gulina, I.V., Isaeva, O.G. (2019). Evaluation of the effectiveness of business processes of a print media organization // Moscow: Limited Liability Company “ITRK Publishing House”. – 243 p.
The process approach in ISO 9001:2015 [Electronic resource]. – Access mode: https://www.iso.org/files/live/sites/isoorg/files/archive/pdf/en/iso9001–2015-process-appr.pdf.

submitted 12.02.2025;
accepted for publication 26.02.2026;
published 28.02.2026

Contact: ashurtakova@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

DOI:10.29013/ESR-26-1.2-22-29

DIAGNOSTICS OF PERSONNEL'S READINESS TO ADAPT AND IMPLEMENT CHANGES AS A BASIS FOR ORGANIZATIONAL STABILITY IN THE FACE OF EXTERNAL SHOCKS

Alexey Volvak [1]

[1] Independent Researcher, USA, California, West Hollywood

Cite: *Volvak, A. (2026). Diagnostics of Personnel's Readiness to Adapt and Implement Changes as a Basis for Organizational Stability in the Face of External Shocks. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-22-29

Abstract

The article discusses the methodology and practical aspects of diagnosing the staff's ability to adapt and implement organizational changes, which is a key factor in the organization's resilience to external shocks. The importance of the adaptive potential of employees for maintaining the effective functioning and development of an organization in conditions of uncertainty is substantiated, and the main components of adaptability are listed. The article presents a diagnostic model that includes multi-level tools: questionnaires to assess values, tolerance to uncertainty and orientation towards change, situational tests and problem books, 360° feedback, analysis of behavioral indicators, HR analytics, which includes data on staff turnover, the level of absenteeism and the dynamics of key performance indicators. The article discusses the key stages of implementing a diagnostic system: setting goals, selecting appropriate tools, testing, interpreting results, developing individual and collective development programs, and regularly monitoring effectiveness. It also describes how diagnostic results can be used for preventive risk management in the face of external shocks. This includes strategy adjustments, process optimizations, employee training and retraining, and talent pool formation. At the end, practical recommendations are presented on integrating diagnostics into the personnel management system and assessing its contribution to the overall sustainability of the organization.

Keywords: *staff adaptability, diagnostics of readiness for change, organizational stability, change management, HR analytics, competence to change, training and development, stress tolerance, risk management*

Relevance of the study

In today's world, where high uncertainty reigns and external shocks often occur, the ability of organizations to quickly adapt and implement changes is a key factor determining their survival and competitiveness.

The main resource for this ability is the staff. The level of psychological flexibility, professional skills, motivation and willingness to change among employees directly affects the speed and quality of the introduction of new practices, the reorganization of pro-

cesses and the ability to respond to external threats.

Despite the growing need, many companies have difficulty identifying the adaptive potential of their employees. This leads to mistakes in planning changes, the risk of their unsuccessful implementation, and a decrease in the overall sustainability of the organization. In this regard, the development and implementation of a comprehensive methodology for diagnosing staff's ability to adapt and implement organizational changes is becoming increasingly relevant from both a practical and scientific point of view. This methodology will allow you to rank risks, purposefully develop key competencies and increase the organization's readiness for external challenges.

The purpose of the study

The purpose of this study is to create and test a methodically sound and practice-oriented system for diagnosing staff's willingness to adapt and implement organizational changes. We also intend to evaluate its effectiveness in predicting the organization's resilience to external challenges and offer recommendations on the use of diagnostic results in the practice of strategic personnel management.

To achieve this goal, you need to complete several tasks: identify the key elements of adaptability at the individual and team levels; find and test suitable tools for measuring adaptability; identify the relationship between indicators of adaptability and indicators of organizational sustainability, such as staff turnover, productivity, and the speed of change implementation; create an algorithm for interpreting and using the results obtained in the risk management process.

Materials and research methods

The empirical basis for the study was data collected from several organizations from different sectors of the economy: manufacturing, services, and IT. The study involved employees at various levels: operational staff, specialists, and middle managers.

The materials include the results of standardized psychological questionnaires aimed at assessing tolerance to uncertainty, resistance to stress, motivation to learn and orientation towards change. Assessment centers and situational tests simulating decision-making in the face of change were also conducted. In addition, 360° feedback data was obtained; HR metrics such as staff turnover, absenteeism, and KPIs before and after changes were analyzed. High-quality interviews were also conducted with managers and key employees who provided valuable insights into this area.

The research methodology combines both quantitative and qualitative approaches. Using factor analysis and correlation regressions, we have determined the structure of adaptability and its relationship with organizational outcomes. Cluster analysis allowed us to identify different types of adaptive behavior. The content analysis of interviews and observations helped to identify contextual factors and mechanisms contributing to change. The validity of the research tools was verified through comparison with external criteria (behavioral indicators) and repeated measurements (test retest) in pilot samples.

Based on the collected data, a systematic diagnostic protocol was developed. It includes several stages: defining goals and identifying critical competencies; selection and combination of suitable assessment tools; carrying out measurements; multidimensional interpretation of the results; development of recommendations on development and risk management. The results of the testing were evaluated based on forecasts of the success of the implementation of changes and changes in key indicators in the field of personnel management in subsequent periods.

The results of the study

The process of diagnosing the staff's ability to adapt and successfully implement organizational changes, which is a key factor in the organization's resilience to external challenges, can be traced through several important stages in the development of human resources management theory and practice and organizational research.

In the middle of the 20th century, after the Second World War, the first theoretical approaches to changes in organizations appeared. Kurt Levin's work on behavioral change models and his concept of "defrost–change–freeze" laid the foundation for understanding transformation processes and the role of the human factor in them.

At the same time, the classical directions of organizational development and the socio-technical approach were developing. In these areas, the focus shifted from structural reforms to human interaction with technology and processes. This, in turn, aroused interest in diagnosing employees' readiness for new roles and their ability to adapt.

In the period from 1960 to the 1980s, personnel assessment methods were actively developed, such as assessment centers; situational exercises; 360° feedback tools. These methods have made it possible to effectively record behavioral manifestations of flexibility, leadership in the face of uncertainty and the ability to adapt to changes. During the same period, a psychometric base appeared studies of personal characteristics, including the so-called "Big Five", as well as tolerance to uncertainty and stress tolerance, which began to be considered as key factors determining the ability to adapt.

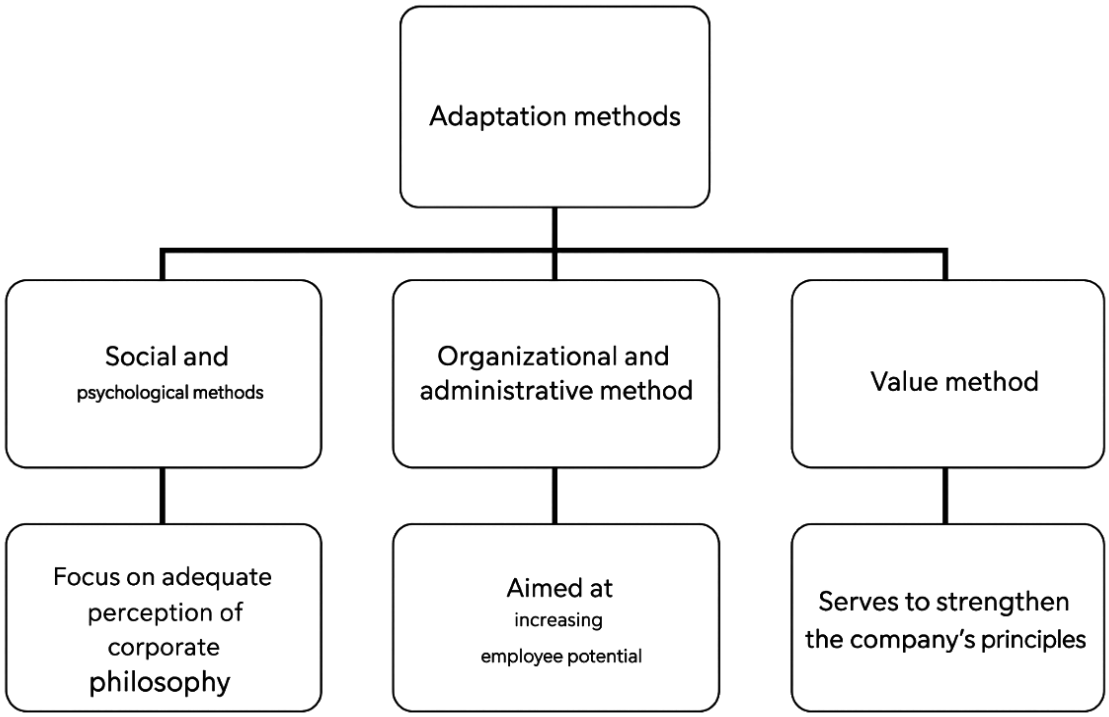
In the 1990s and later, in the context of globalization and rapid technological progress, the concepts of organizational sustainability and crisis management began to pay special attention to the adaptive potential of personnel as a key factor in the organization's resilience. During this period, there was an increased interest in multilevel research linking individual abilities, group dynamics, and organizational system characteristics.

At this stage of the development of research in this field, there is a combination of quantitative and qualitative methods. Factor analysis is used to identify adaptability patterns, and longitudinal studies help track changes. Case studies and content analysis are used to understand the mechanisms underlying the introduction of new approaches.

Since the beginning of the 21st century, digitalization, the proliferation of flexible and project-based forms of work, as well as the emergence of the concepts of VUCA and antifragility have made tools for the rapid diagnosis of adaptivity especially relevant. These tools include rapid questionnaires, online assessments, decision-making simulators, and analysis of social networks within organizations (Tyulkina, Yu.S., 2018).

At the same time, research on psychological resilience, learning ability and meta-competencies such as self-regulation, proactivity, and learning ability was actively developing. Methods have been developed to predict the impact of these qualities on key HR indicators, including staff turnover, productivity, and the speed of change implementation (Fig. 1).

Figure 1. *Methods of personnel adaptation (Temiraeva, E.V., 2019)*



The COVID-19 pandemic has acted as a catalyst for large-scale changes in personnel management: It clearly demonstrated the critical dependence of business survival on the level of adaptability of employees, stimulated the mass introduction of remote diagnostic tools and accelerated the integration of competence assessment results into a risk management strategy and continuous professional development.

Today, we are witnessing a trend towards the creation of complex multidiagnostic systems that include psychometry, behavioral analytics, big data, and adaptive development programs. Special attention is paid to checking the predictive validity of tools and introducing diagnostics into the daily practice of HR specialists and top managers. This allows organizations to become more resilient to external challenges.

It is worth noting that leading international companies are actively implementing digital tools for personnel assessment and platforms for continuous assessment. Companies such as SHL, Hogan, Korn Ferry, as well as the Workday and Visier platforms, use them to regularly measure behavioral competencies such as proactivity, flexibility, stress tolerance, and learning ability. These indicators are closely related to business results, which makes it possible to predict the readiness of teams for various transformations and determine priorities in the development of key groups (Van Den Heuvel, 2020).

Organizational Network Analysis (ONA) is a method used by companies such as Google, Microsoft, and large consulting firms. It helps to identify existing communication channels, "bridges" of knowledge and opinion leaders. With the help of these maps, you can predict where changes may encounter resistance, and direct efforts to accelerate their implementation.

During the COVID-19 pandemic, Microsoft and some major technology companies used daily employee surveys and wellbeing metrics combined with productivity analytics to quickly assess how they were adapting to remote work. Based on this data, they were able to adjust support, training, and task allocation programs, which helped them, maintain operational sustainability. At the same time, retail and logistics companies, such as large delivery chains and supermarkets, have implemented accelerated assessment processes for hiring and retraining staff to cope with peaks in demand. They combined online learning tests, work situation simulations, and short microtraining programs, which reduced the time, required new employees to reach productivity levels and reduced staff turnover during the crisis.

Many banks and insurance companies use scenario modeling and stress testing methods involving key employees. These tests are accompanied by behavioral assessments, which makes it possible to identify those who are able to make effective decisions in conditions of high uncertainty. The results of such studies help to form crisis teams and distribute responsibility within the organization.

Examples of the use of gamified simulations and situational tests can be seen in large companies engaged in the production of consumer goods (FMCG) and pharmaceuticals. In these organizations, training through imitation of market shocks and assessment of the reaction of teams has shown high efficiency in predicting the ability to effectively implement changes (Park, S., Park, S., 2021).

Data integration is actively used in the field of HR analytics. The assessment results are associated with indicators of turnover, satisfaction, NPS (consumer loyalty index) and employee productivity. This allows us to create predictive models of the vulnerability of departments and economically justify investments in the development of so-called resistant competencies (Table 1).

Table 1. *Data integration in HR analytics*

No	Indicator	Characteristic
1	Identification of data sources	HR Management Systems (HRMS). Platforms for performance monitoring. Questionnaires and surveys for employees. Information about salaries and bonuses. Social media and professional platforms such as LinkedIn.

No	Indicator	Characteristic
2	Selection of integration tools	ETL processes that include data extraction, transformation, and loading. An API for simplifying data exchange. BI-tools (Business Intelligence) designed for visualization and analysis of information.
3	Selection of integration tools	Cleaning and tidying up the data. Checking for duplicates and errors. Ensuring that information is up-to-date.
4	Analysis and visualization	Create dashboards and reports reflecting key performance indicators (KPIs). Research on staff turnover, productivity, and employee engagement levels.
5	Ensuring data security	Obtaining employees' consent to the processing of their personal data. Compliance with data protection standards, including GDPR requirements.
6	Continuous improvement	Regular updating of analysis methods. Actively receive user feedback to improve tools and processes.

There are also fast online tools for rapid assessment of readiness for crash scenarios. These include short questionnaires, mobile apps, and automated interviews. These tools allow you to get an idea of staff readiness within 24–72 hours and quickly make management decisions. In some countries, government and public utilities use emergency preparedness assessments and training based on simulations. Such programs help identify risk areas and form interagency teams that are highly adaptable.

There is a steady trend towards integrating diagnostic results into continuing education and career development programs for staff. The introduction of tools such as mentoring, targeted coaching courses and a system of microbages on key meta-competencies makes it possible to transform improving organizational sustainability from a one-time measure into a systematic, embedded process.

An analysis of modern practices shows that operational, multidimensional, and business metrics-based diagnostics of staff adaptability is one of the key factors that enable organizations to successfully cope with external challenges and respond promptly to them.

However, it should be noted that the diagnosis of staff adaptability faces a number of complex and often interrelated problems that may reduce its practical value and accuracy.

Firstly, there is some conceptual ambiguity: the terms "adaptability", "resilience" and "changeability" are used in different studies and practices in different ways. This makes it difficult to choose suitable indicators and tools for their assessment.

Secondly, significant problems remain with the validity and reliability of the assessment tools used. Many questionnaires and assessment centers measure related psychological constructs (such as loyalty and motivation), but demonstrate low predictive ability regarding employee behavior in real-world crises. In addition, the high validity of the results obtained in laboratory simulations is not always reproduced in the field.

The third problem is the contextual dependence of the indicators. How employees respond to changes largely depends on organizational culture, leadership, resources, and the external situation. Because of this, generalized data often loses its meaning when compared between different divisions or territories.

Then there are the methodological and practical difficulties with data processing. The low proportion of responses, the tendency to socially approved responses, as well as the self-selection of participants for trainings and surveys make forecasting less reliable. Indirect indicators are often used, such as engagement and the number of courses completed, which may be related to adaptability but are not a direct measure of it. This can lead to errors when making decisions about personnel interventions. Another major problem is the system separation of data. Assessment results are stored in separate HR systems and are not integrated with operational metrics. This makes it difficult to prove the business effect

and justify investments in the development of competencies.

Organizational and cultural barriers are no less significant. The low level of employee confidence in the use of diagnostic results, fear of possible negative personnel consequences, and confidentiality lead to information distortion and resistance to initiatives. Managers often do not have the necessary skills to interpret the results and translate them into practical plans, which creates a gap between diagnosis and real development. In addition, there are financial and time constraints: high-quality assessments and long-term development programs require significant investment of time and resources, and in times of crisis, organizations may lack such opportunities.

Technical risks include: bias in algorithms and automated assessments; problems with adapting tools to different cultures and languages; vulnerability to manipulation when behavior is adjusted to the test. In addition, simulations and gamified tests can have a significant training impact. People learn to successfully pass tests, but this does not guarantee their real adaptability in an ever-changing environment.

Finally, an excessive focus on diagnostics as the only factor in increasing organizational sustainability is a strategic mistake. Even with improved staff performance, the organization's resilience to external shocks will not be achieved without appropriate changes in organizational structures, business processes, and leadership practices.

Taken together, these problems require careful design of diagnostic programs, a combination of methods, integration of data with business metrics, and attention to ethical and cultural aspects, otherwise diagnostics can create a false sense of readiness and lead to erroneous personnel decisions.

In our opinion, an integrated approach based on a clear conceptual framework, methodological rigor, and organizational transformation is needed to solve the problems of diagnosing staff's ability to adapt and implement changes.

First, it is necessary to standardize definitions of key concepts and create a common model of adaptability that will include behavioral indicators, contextual factors (such as culture, resources, and leadership), as well as expected business results. This will allow us to identify the most appropriate metrics and link them to the goals of the organization.

Secondly, the use of mixed assessment methods allows increasing the validity and reliability of diagnostic tools. To do this, it is necessary: to combine objective behavioral data (obtained through simulations, case studies, and digital trace analysis); to use standardized psychometric scales with proven validity; to include a 360° assessment; to supplement quantitative data with the results of qualitative interviews.

Regular calibration of instruments carried out as part of pilot studies and comparing the results with real key performance indicators (KPIs), can significantly reduce the gap between the predictive power of tests under controlled conditions and their real usefulness in the workplace.

Thirdly, diagnostic programs must be built on a longitudinal basis the base. Regular measurements and systematic tracking of indicators make it possible to: record the dynamics of changes in personnel competencies and behavioral patterns; identify stable trends and patterns; objectively evaluate the effectiveness of implemented interventions and development programs over time. This approach is significantly more informative than one-time diagnostic slices and contributes to making more informed management decisions.

Integration of data with operational and financial indicators should become the norm. The results of assessments and training should be linked to productivity, staff turnover, and the quality of decisions made and the stability of processes. This will allow you to demonstrate business efficiency and justify investments. Technically, integration is carried out through a single HR analysis platform that provides standardized data formats and regular reports to management.

In order to avoid distortion and social desirability, the principles of anonymization, honest communication about diagnostic purposes, confidentiality guarantees, and data usage policies are being implemented. Managers are trained in the correct interpretation of results and constructive feedback, which increases trust and reduces fear of possible consequences.

Overcoming cultural and leadership barriers requires consistent development of leadership and learning culture in the organization. To do this, development programs should: include trainings on the formation of adaptive thinking; provide for the implementation of practical projects to optimize and change business processes; ensure development through mentoring and staff rotation to expand the professional experience of employees; integrate into the KPIs of managers indicators reflecting the effectiveness of change support and team development. Such an integrated approach contributes to the formation of a sustainable culture of continuous learning and increases the adaptability of the organization.

Financial constraints can be overcome if diagnostic activities are properly prioritized. It is recommended to start with the most important departments, and then scale successful practices. In addition, modular and less expensive solutions should be used, such as short online simulations and micro learning. It is also important to evaluate the economic benefits of investments.

Technical risks and possible bias of algorithms are minimized by ensuring transparency of models, regular audits for discrimination, as well as localization of content and testing in various cultural contexts. The opposition between "skill-setting" and actual behavior is overcome by integrating learning into work processes. It evaluates not only the completion of courses, but also the application of skills in projects, as well as the ability to change decisions and behavior in stressful situations.

Finally, the implementation strategy should be iterative. It is necessary to conduct pilot projects with clear hypotheses, promptly collect feedback, adjust tools and scale successful approaches. The goals should be transparent, the participation of all levels of the organization should be active, and HR initiatives should be consistent with the business strategy. This is the only way diagnostics will become a tool that contributes to a real increase in resilience, rather than a formal procedure.

Conclusions

Assessing staff's readiness to adapt and implement organizational changes is a key factor determining an organization's resilience to external influences. A successful response to uncertainty depends on a combination of individual flexibility, collective willingness to change, and the organizational environment in which the team operates.

An integrated approach to diagnosis, including proven psychometric tools, assessment centers, real-life situation simulations, 360° feedback, digital trace analysis, and high-quality interviews, allows you to get the most complete picture. It can be used to identify both potential resources and barriers that hinder adaptation at the level of competence, motivation and context.

The longitudinal design of measurements is more important than single slices, since the dynamics of responses to changes and the learning effect demonstrate real resilience and help assess the impact of interventions; linking diagnostic metrics with operational KPIs and business results transforms conclusions into manageable solutions and evidence of economic impact.

In order to minimize distortions and increase the level of confidence in the results, it is necessary to ensure transparency of the methodology, anonymity of data, as well as train managers to interpret information correctly and implement feedback mechanisms. In addition, cultural characteristics and leadership practices should be taken into account when adapting tools.

Management recommendations include integrating diagnostic results into HR strategy through targeted leadership and team development programs, systematic pilots with clear hypotheses, success metrics, and rapid iterative scaling, as well as enabling change support in managers' KPIs to strengthen accountability. Technical and ethical risks such as algorithm bias and leakage of personal data require regular model audits, local verification of tools, and compliance with strict security and privacy policies.

As a result, comprehensive, scientifically based and manageable diagnostics of personnel's adaptability allows not only identifying weaknesses and growth points, but also serves as an effective tool for actively managing the sustainability of the organization. This increases the chances of the company's survival and competitiveness in an environment where external challenges are becoming more frequent and unpredictable.

References

Temiraeva, E.V. “Personnel Adaptation to Change in the Organization” // Vestnik nauki i obrazovaniia [Bulletin of Science and Education], – No. 17 (71). 2019. – P. 33–36.
Tyulkina, Yu.S. “The Essence and Principles of Personnel Adaptation”// Vestnik of Voronezh State University, – No. 1. 2018. – P. 109–113.
Park, S., Park, S. “How Can Employees Adapt to Change? Clarifying the Adaptive Performance Concepts” // Human Resource Development Quarterly, 2021. – Vol. 32. – No. 1. – P. E1–E15.
Van Den Heuvel, M.H., et al. “How Do Employees Adapt to Organizational Change? The Role of Meaning-Making and Work Engagement” // the Spanish Journal of Psychology. 2020. – Vol. 23. – 56 p.

submitted 21.01.2026;
accepted for publication 05.02.2026;
published 28.02.2026

Contact: alexey.volvak@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

DOI:10.29013/ESR-26-1.2-30-34

INDUSTRIAL DEVELOPMENT IN BELARUS UNDER EXTERNAL SHOCKS: INSTITUTIONAL STRUCTURE, CONSTRAINTS, AND ADAPTATION

Viktar Karpovich [1]

[1] Belarusian National University of Technology, Minsk

Cite: *Karpovich, V. (2026). Industrial Development in Belarus Under External Shocks: Institutional Structure, Constraints, and Adaptation. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-30-34

Abstract

The study analyzes the industrial development of Belarus from 2015 to 2024 under consecutive external shocks, including the COVID-19 pandemic, sanctions, and persistent structural constraints. Using official statistical data and institutional analysis, the research evaluates output dynamics, investment activity, employment trends, and the role of state-affiliated enterprises. The results show that the sector demonstrated notable resilience through the reconfiguration of production and logistics chains and sustained investment, particularly in the energy segment. However, high material intensity, declining profitability, labor shortages, and structural concentration continue to limit technological upgrading and long-term competitiveness. The study contributes to the literature on industrial resilience by identifying the mechanisms of adaptation in a medium-sized, state centric economy and outlines strategic priorities for sustainable industrial development, including modernization, energy-efficiency improvements, SME support, and export diversification.

Keywords: *industry of Belarus, industrial production index, manufacturing, investment, profitability, labor resources, material intensity, structural changes, energy sector, industrial policy*

Introduction

The industrial sector of the Republic of Belarus remains a central pillar of the national economy, shaping production dynamics, export performance, and employment (Belstat, 2024; World Bank, 2023). During 2015–2024, its development unfolded amid substantial external turbulence–from the aftermath of the mid-2010s recession and the COVID-19 pandemic to the large-scale sanctions pressure of 2022 (IMF, 2023; Bertelsmann Stiftung, 2024) and the subsequent restructuring of foreign economic relations. These shocks produced heterogeneous output dynamics, disrupted established production chains, and altered the relative roles of individual industries (EBRD, 2024). Such conditions make a comprehensive analysis of this period particularly relevant.

Scientific research on industrial development in Belarus and the EAEU countries is concentrated around several key areas (Shutsilin et al., 2021; Ustinovich et al., 2024).

The literature provides detailed examinations of structural changes in industry, the impact of macroeconomic factors and external shocks, and emphasizes the need for modernization and increased sectoral resilience (Sidarava, 2023; Zatalhutskaya & Fedziunio, 2023). Significant attention in the literature is devoted to enterprise-level efficiency and profitability, cost structures, and the material intensity of production (OECD, 2024), all of which continue to constrain industrial growth. Another substantial body of research examines innovation activity and technological development, emphasizing the low rate of new technology adoption and the strong dependence on imported equipment (UNECE, 2022). A considerable number of studies also analyze the effects of sanctions, shifts in logistics, and the reorientation of export flows (World Bank, 2023; UNCTAD, 2024b). In addition, scholars highlight the role of the state and large industrial holdings, which shape the structure of industrial output and largely determine the system's overall adaptability.

Although the existing body of research is extensive, most studies address isolated dimensions of industrial development – such as enterprise efficiency, innovation performance, sanctions-related disruptions, ownership transformations, or labor-market dynamics – rather than examining the industrial system in an integrated manner (EBRD, 2022). Holistic assessments that encompass the full 2015–2024 period and account for the cumulative impact of multiple, sequential external shocks remain comparatively scarce. This limitation highlights the need for a comprehensive analysis capable of capturing both the structural evolution and the adaptive capacity (OECD, 2023) of the industrial sector. The present study responds to this gap by offering a systematic examination of the dynamics, structural characteristics, and resilience mechanisms of Belarus's industry under conditions of persistent external constraints and internal structural pressures.

Materials and Methods

The study draws on official statistical data from Belstat (Belstat, 2024) and sectoral reports for 2015–2024 and employs descriptive statistics, structural and comparative analysis, as well as trend evaluation of key industrial indicators, including output dynamics, employment, investment, profitability, and cost structure. The methodological approach integrates macro-level quantitative assessment with an institutional analysis of ownership patterns and the role of state-affiliated holdings (Bertelsmann Stiftung, 2024; EBRD, 2022), enabling a comprehensive examination of industrial resilience under consecutive external shocks and persistent internal structural constraints.

Results

In 2015–2024, the industrial sector of the Republic of Belarus followed a complex yet generally upward development trajectory, passing through several structural phases: recovery after the mid-2010-s crisis, adaptation to pandemic-related restrictions, the sharp sanctions shock of 2022, and subsequent recovery in 2023–2024. The industrial production index shows that after the decline in 2022 (94.6% year on year), the sector not only compensated for the losses but also entered a phase of stable growth – 107.7% in 2023 and 105.4% in 2024 (Belstat, 2024). This indicates high adaptability of production chains and the ability of enterprises to rapidly restructure sales markets and logistics.

The total volume of industrial output in current prices demonstrates significant growth; however, its interpretation requires accounting for inflation and changes in the price environment. The physical volume index provides a more accurate picture, confirming the sector's recovery and strengthening in the final two years of the analyzed period.

The number of industrial organizations increased from 15.9 thousand in 2015 to 17.4 thousand in 2024 (Belstat, 2024). Growth was particularly notable in 2023–2024, reflecting rising entrepreneurial activity, expansion of the small and micro enterprise segment, and changes in statistical methodology (inclusion of temporarily inactive organizations).

Manufacturing consistently accounts for around 90% of national industrial output. In 2023–2024, it became the main driver of recovery: the physical volume index reached 109.1% and 105.5%, respectively (Belstat, 2024). The sector is characterized by high employment (84–85% of industrial workers) and stable profitability, although the profit margin

declined from 12.0% in 2022 to 8.7% in 2024, reflecting rising costs and external pressures.

The electricity, gas, steam, and hot water supply sector exhibits moderate yet consistently stable development. Its share in total industrial output declined from 10% in 2015 to 7% in 2024; however, investment in fixed assets increased substantially, contributing to lower asset depreciation and strengthening the sector's infrastructural foundation. These improvements create favorable conditions for the further expansion of the energy sector as a critical pillar supporting long-term industrial growth.

The water supply, waste management, and pollution remediation sector maintains a stable share of 1.6–1.7% and shows moderate growth in physical output. It remains labor-intensive and characterized by relatively low wages, yet it possesses development potential within the broader framework of ecological modernization.

The mining sector accounts for a small share of industrial output (1.1–1.4%) but is characterized by pronounced volatility in financial performance and the highest level of fixed asset depreciation (around 59%). At the same time, wages in the sector significantly exceed the industrial average, reflecting its high capital intensity and the complexity of extraction operations.

Numerically, the private sector dominates industry (92% of firms), though its output is outweighed by state-linked companies–which, despite being just 2–3% of firms, generate nearly half of total output. Enterprises with foreign capital play a minor role (5.8–6.5%) and have contributed less since 2021 following investor departures. Industrial employment declined from 936.8 thousand in 2015 to 833 thousand in 2022, showing a modest recovery thereafter amid demographic shifts, migration flows, and increasing automation. By 2024, net hiring had reached 102.4%, indicating rising labor demand and persistent worker shortages.

Industrial wages consistently exceeded the national average (105.8% in 2024), reinforcing the sector's attractiveness for employees. The highest wages were recorded in mining (167% of the industrial average), while the lowest were observed in the utilities sector.

Industrial profit margins peaked in 2022 (10.8%) before declining to 8.3% in 2024, with a similar pattern in manufacturing. This trend reflects rising production costs and limited opportunities for price adjustments. Profit from product sales stabilized in 2023–2024 but did not increase despite higher physical output, confirming a continued pattern of margin compression.

The value of fixed assets in Belarusian industry doubled between 2021 and 2025, reflecting large-scale investment and asset revaluation. The most intensive renewal is observed in the energy sector, where the share of depreciation in production costs increased while asset wear declined.

The cost structure of industrial production remains stable: material costs account for 74–78% of total expenses, confirming the material-intensive nature of Belarusian industry. Labor costs represent 10–12%, and depreciation 5–6%. Such a structure limits the potential for rapid productivity growth and underscores the need for technological modernization.

Discussion

The results of the analysis of Belarusian industrial development significantly expand our understanding of the mechanisms of industrial resilience under long-term external shocks and confirm that the adaptation process represents a more complex and multi-level system than is reflected in existing theoretical models. International studies emphasize that economies characterized by high material intensity, limited technological development, and the dominance of state-owned and affiliated enterprises tend to be more vulnerable to external constraints (OECD, 2024; UNIDO, 2024). However, the trends identified in the study show that Belarus's industrial sector has developed adaptive mechanisms that helped mitigate the impact of sanctions, logistical disruptions, and pandemic-related restrictions.

First, the recovery of the industrial production index in 2023–2024 demonstrated the ability of enterprises to rapidly reconfigure their production and distribution chains. This observation is significant for the international discussion on industrial resilience, as it confirms that effective compensatory strategies are possible even under limited access to technology and external markets. Unlike the typical scenarios described in EBRD and

World Bank studies, the adaptation of Belarusian enterprises was driven not only by cost reduction but also by logistics reorientation, the search for new markets, and the partial restoration of export flows.

Second, the institutional structure of the industrial sector exhibited a dual nature. Proponents of classical and neoclassical economic theory traditionally view the high concentration of assets in state-owned holdings as a factor that limits innovation dynamics and flexibility (EBRD, 2022; Sidarava, 2023). However, the results of the study show that this structure ensured the resilience of key production segments under sanctions pressure. Thus, the institutional configuration performed not only a constraining but also a stabilizing function, refining existing understandings of the state's role in industrial adaptation and requiring a reconsideration of several theoretical assumptions.

Third, the identified structural constraints – high material intensity, declining profitability, and labor shortages – confirm international organizations' conclusions about long-term risks for economies with limited technological modernization (UNECE, 2022; OECD, 2023). The observed decline in profit margins alongside growing physical output suggests that Belarusian industries predominantly adjust through existing technological systems rather than achieving substantial increases in efficiency or productivity. This highlights the necessity of transitioning from immediate responses to proactive strategies aimed at comprehensive modernization aligned with global guidelines for sustainable industrial development.

Conclusion

The analysis shows that Belarus's industrial sector demonstrated notable resilience during 2015–2024, successfully adapting to pandemic-related disruptions, sanctions, and long-standing structural constraints. Output recovery in 2023–2024, the stable role of manufacturing, and sustained investment–especially in the energy segment–confirm the sector's capacity to maintain growth under adverse external conditions. At the same time, persistent systemic challenges, including high material intensity, declining profitability, labor shortages, and the structural dominance of large enterprises, continue to limit technological renewal and long-term competitiveness. Ensuring sustainable development requires a transition from reactive adaptation to proactive modernization. Key priorities include technological upgrading, improvements in energy efficiency, expansion of SME participation, infrastructure renewal, and diversification of export and logistics channels. The findings highlight the need for a comprehensive industrial strategy capable of strengthening resilience and supporting long-term structural transformation.

References

Belstat. (2024). *Industry of the Republic of Belarus 2024*. National Statistical Committee of the Republic of Belarus.

Bertelsmann Stiftung. (2024). *BTI 2024: Belarus country report*. Bertelsmann Stiftung.

Shutsilin, V., Filiptsou, A., & Vashkevich, Y. (2021). Industrial development, structural changes, and industrial policy in Belarus. In *Modeling economic growth in contemporary Belarus*. Emerald Publishing.

Sidarava, A. (2023). Belarus: Institutional cycles and the historical roots of the contemporary institutional matrix. *UR Journal of Humanities and Social Sciences*.

Ustinovich, I. V., Yakushenko, K. V., & Hrytsevich, S. A. (2024). Deepening the interaction between industrial and scientific organisations of the Republic of Belarus. *Journal of the Belarusian State University. Economics*, (1).

Zatalhutskaya, N. N., & Fedziunio, M. A. (2023). *Industrial development of the regions of Belarus: Current state and prospects*. Belarusian State University of Transport.

EBRD. (2022). *Belarus country diagnostics: Structural constraints and growth potential*. European Bank for Reconstruction and Development.

EBRD. (2024). *Transition report 2023–24: Transitions in a changing world*. European Bank for Reconstruction and Development.

IMF. (2023). *Republic of Belarus: 2023 Article IV consultation—Staff report*. International Monetary Fund.
OECD. (2023). *OECD economic surveys: Belarus 2023*. OECD Publishing.
OECD. (2024). *Productivity growth in the global economy: Trends and drivers*. OECD Publishing.
UNCTAD. (2024). *Handbook of statistics 2024*. United Nations Conference on Trade and Development.
UNECE. (2022). *Innovation for sustainable development review: Belarus*. United Nations Economic Commission for Europe.
UNIDO. (2024). *Industrial development report 2024: Structural transformation for inclusive and sustainable industrial development*. United Nations Industrial Development Organization.
World Bank. (2023). *Belarus economic update: Navigating structural challenges*. World Bank.
World Bank. (2023). *Logistics performance index 2023: Connecting to compete*. World Bank.

submitted 11.02.2026;
accepted for publication 25.02.2026;
published 28.02.2026

Contact: karpovich_vf@list.ru

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

DOI:10.29013/ESR-26-1.2-35-40

POTENTIAL FOR THE DEVELOPMENT OF VIETNAM'S HEALTHCARE SECTOR IN THE NEW ERA: PRIVATE HEALTH ECONOMICS AS A NEW PILLAR OF VIETNAM'S SOCIAL SECURITY

Nguyen The Hung [1]

[1] PhD Candidate Chairman of the Board, MEDIC Healthcare Systemy

Cite: *Nguyen The Hung (2026). Potential for The Development of Vietnam's Healthcare Sector in the New Era: Private Health Economics as a New Pillar of Vietnam's Social Security. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-35-40

Abstract

Amid Vietnam's ongoing transition toward a two-tier local government model, social security is increasingly positioned as a central pillar in the national strategy for sustainable development. This paper examines the rising role of the private healthcare sector within Vietnam's social security system. Drawing on the theoretical lenses of quasi-public goods, new institutional economics, and dynamic comparative advantage (Samuelson, 1954; Balassa, 1965; North, 1990), the paper analyzes market potential, key barriers, and policy directions for developing private health economics in Vietnam for the period 2025–2035. Using empirical evidence from the WHO Global Health Expenditure Database and industry datasets (WHO, 2023; Ken Research, 2023; IQVIA Vietnam, 2024), together with policy review (Communist Party of Vietnam, 2017; National Assembly of Vietnam, 2023; Ministry of Health, 2020), the paper argues that private healthcare can become a dual growth engine—improving population health outcomes while also supporting local economic growth during the post-merger administrative restructuring process.

Keywords: *private healthcare; health economics; social security; digital transformation; Vietnam.*

1. Introduction

Vietnam is entering a major turning point in healthcare reform. As local governance shifts toward a two-tier model, enhancing quality of life—both materially and spiritually—has become a strategic priority. Healthcare, especially primary care, is the frontline of public service delivery and a foundation of social security. However, Vietnam's per-capita health expenditure remains modest—about USD 173 per person per year—equivalent to around 30% of Thailand and 12% of Japan (WHO, 2023). This situation is both a challenge and a major "policy and investment space" for private healthcare in the new era.

2. Theoretical Foundations

2.1. Quasi-public goods

According to Samuelson (1954), pure public goods are non-excludable and non-rivalrous. In practice, healthcare services—particularly primary care-often exhibit char-

acteristics of quasi-public goods: they can be socialized (i.e., delivered by non-state actors) while still requiring strong state stewardship to ensure equity, quality, and access.

2.2. Dynamic comparative advantage

Balassa (1965) argued that countries can create comparative advantage in higher-technology and higher-value sectors through strategic policy and targeted investment. Applied to healthcare, Vietnam may build dynamic advantages in areas such as regenerative medicine, community health, AI-assisted diagnostics, and specialized hospitals—provided that supportive policies and enabling ecosystems are in place.

2.3. New institutional economics

North (1990) emphasized that institutions—laws, fiscal policies, licensing procedures, and digital data infrastructure—are critical determinants of economic development. In healthcare, institutional reform is a necessary condition for private providers to develop transparently and sustainably, while aligning market incentives with social security objectives.

3. Methodology

The paper applies a synthesis-based analytical approach. Quantitative evidence is drawn from industry and international datasets (Ken Research, 2023; WHO, 2023; IQVIA Vietnam, 2024), while qualitative insights are derived from observed local healthcare models in provinces and major cities (e.g., Thanh Hoa, Ho Chi Minh City, and Binh Duong). Key policy documents—including Resolution No. 20-NQ/TW (Communist Party of Vietnam, 2017), the Law on Medical Examination and Treatment (amended) (National Assembly of Vietnam, 2023), and the Medical Digitalization Program to 2025 with orientation to 2030 (Decision No. 5316/QD-BYT) (Ministry of Health, 2020)—are reviewed to establish the legal and strategic context.

4. Results and Analysis

4.1. Market potential

4.1.1. Low per-capita health spending: USD 173 per person per year

Regional and international comparison (WHO, 2023):

Table 1.

Country	Health spending per capita	Share relative to Vietnam
Vietnam (2023)	USD 173	100%
Thailand	~ USD 600	~ 347%
Malaysia	~ USD 730	~ 422%
Japan	~ USD 4,500	~ 2,600%

Source: WHO (2023)

Vietnam's per-capita health expenditure is significantly lower than that of ASEAN peers and OECD countries, indicating: Substantial room for market expansion, especially among the growing urban and middle-income population with a higher willingness to pay for quality healthcare; Strong potential for high-end and specialized services – particularly in the non-public sector, which is often more flexible in service design and pricing.

4.1.2. Private outpatient visit share is 15–20%, yet growing at ~14% per year

Trend assessment: Vietnam's private visit share remains far below countries with mature mixed healthcare models (e.g., Thailand ~40%, Singapore ~60%, the U.S. >70%). However, a ~14% annual growth rate is very high – exceeding overall health-sector GDP growth (~7–8%)—suggesting a gradual shift from public to private providers, especially for high-tech services (imaging, laboratory testing, outpatient treatment).

Implications: Private healthcare is not yet dominant in total visits, but it is gaining a growing share of revenue by focusing on higher-quality, higher-value services; Private enterprises have significant opportunities to scale integrated models: hospital–satellite clinics–diagnostic centers–pharmacies; Segments such as periodic health checkups, fast-track services, and telehealth are increasingly attractive to technology-oriented investors.

4.1.3. Rapid population ageing: ≥20% of the population will be aged 60+ by 2035

Demographic dynamics:

+ 2024: about 13% of the population aged 60+ (~13 million people).

+ 2035 (projection): about 20% aged 60+ (~21 million people).

Rapid ageing is expected to drive: Higher demand for continuous care, rehabilitation, nursing, and end-of-life care; Higher average health spending among the 60+ group (approximately 3–5 times higher than the under-60 group); Growing demand for personalized care, home-based care, integrated nursing and hospital services.

Strategic development directions: Community health models, family medicine, and premium nursing-care centers are likely to become high-growth markets; Integration of healthcare with insurance and personal finance (e.g., retirement–health–life bundled products) may become a strategic product line for banks, insurers, and healthcare providers.

4.1.4. Private healthcare as a "high-control, high-potential investment lowland"

The notion of a "high-control, high-potential investment lowland" reflects three core characteristics:

Table 2.

Feature	Explanation
Large market space	Low spending, large population, and a rapidly changing market structure.
Fast growth	High growth rates in the non-public sector and in high-technology service segments.
Manageable policy risk	Policy environment is becoming more transparent: new law, PPP mechanisms, digital transformation agenda, and incentives for socialized healthcare investment (National Assembly of Vietnam, 2023; Ministry of Health, 2020).

Source: Authors' synthesis

For investors and policymakers, the private healthcare sector is no longer merely an "auxiliary" to public healthcare; it is increasingly becoming a dual pillar—supporting social security while also contributing to regional economic growth.

4.2. Growth outlook

Table 3.

Indicator	2024	2035 (Forecast)
Hospital industry size	USD 11.5 billion	≥ USD 22 billion
International investment into healthcare	USD 400 million/year	> USD 1 billion/year
Number of private hospitals	384 facilities	≥ 600 facilities

Source: Industry synthesis (Ken Research, 2023; IQVIA Vietnam, 2024).

4.3. Formation of a private health-economy ecosystem in Vietnam

4.3.1. Cluster-based models of private healthcare services

Modern private healthcare ecosystems are increasingly moving from standalone units (single hospitals/clinics) toward cluster-based integrated service models. A typical integrated value chain includes:

Table 4.

Component	Role in the ecosystem
Private hospital	Center for high-technology treatment and specialized care.
Satellite clinics	Provide initial services, screening, and routine follow-up.

Component	Role in the ecosystem
Laboratory & diagnostic imaging centers	Standalone or integrated units supporting rapid clinical decision-making.
Private pharmacies	Medication logistics, counseling, and home-care support.
Rehabilitation units	Post-treatment care, nursing, and physiotherapy.
Digital technology platforms	Electronic health records, telehealth, and internal management.
Health care centers	Family health support and preventive care.
Community service centers	Elderly care and recovery/wellness centers.

Source: Authors' synthesis.

Key advantages: Extends the customer journey: prevention – treatment – long-term care; Optimizes management costs through shared technology, data, and supply chains; Enhances scalability and replication across provinces; Facilitates integration with insurance, finance, and aftercare services.

Illustrative examples (as observed in practice):

Hoan My: network of general clinics connected with tertiary hospitals and integrated HIS platforms.

Medic Group: hospital–clinic–pharmaceutical–technology ecosystem with internal operational platforms.

Medipha: integration of medical supplies distribution, pharmaceutical supply, and EMR/IT solutions.

4.3.2. M&A activities: reshaping private healthcare ownership

Notable developments (2020–2024):

Table 5.

Year	Transaction	Notes
2020	Thomson Medical Group (Singapore) acquired 100% equity in FV Hospital (Ho Chi Minh City).	Cross-border investment in premium hospital assets.
2021	Hoan My Group acquired Dong Nai International Hospital.	Strengthening treatment capacity in the Southeast region.
2022	JPE Partners (Korea) invested in Vietlife.	Technology and operational process upgrades.
2023	SK Group invested in Vinmec (Vingroup).	Development of high-quality hospitals, AI and robotics support.
2024	Investment negotiations in specialty clinic chains in Hanoi and Da Nang.	Focus on dentistry, ophthalmology, endocrinology.

Source: Authors' compilation from industry information (2020–2024).

Key observations:

International capital increasingly prioritizes healthcare chains with established technology and data foundations.

Private equity/venture capital investors not only provide capital but also participate in governance and strategy.

M&A can help standardize service quality, improve bargaining power with insurers/suppliers, and optimize multi-site operations.

Risks that require governance attention:

Market concentration may raise localized monopoly risks.

Ethical risks may arise if investors prioritize profit over community health outcomes.

4.3.3. Healthcare–Technology–Education alliances as a sustainability foundation

Modern private healthcare ecosystems increasingly integrate both horizontally (multi-service) and vertically (multi-sec-

tor), enabling systems that can: Self-supply, self-train, and self-operate within integrated chains; Use technology to personalize care pathways and improve outcomes; Secure human resources through internal training systems or partnerships with universities.

Illustrative alliance models:

Table 6.

Consortium	Alliance components	Value created
Vinmec – VinUni – VinBrain	Hospital – university – AI diagnostics	Training – care – research – technology transfer
Medic Group	Hospital – clinics – pharmaceuticals – technology – training	Closed ecosystem; cluster-based local governance
Medipha	Pharmaceutical & equipment distribution – health IT – maintenance services	Supply-chain optimization; public–private operational integration
TTH	Hospital – clinics – pharmaceuticals – technology – training	Closed ecosystem; cluster-based local governance
Hung Vuong Healthcare System	Hospital – clinics – pharmaceuticals – technology	Closed ecosystem; cluster-based local governance

Source: Authors' synthesis.

Overall, Vietnam's private healthcare ecosystem is shifting from single-unit models to integrated cluster-based systems. Key drivers include (1) changing patient demand for convenience, comprehensive packages, and quality; (2) M&A-driven restructuring and digital integration; and (3) cross-sector alliances with technology and education to build endogenous capabilities for workforce development and digital transformation.

5. Discussion

5.1. Major barriers

Overlapping public–private policies (bed planning, land allocation, social health insurance); Limited availability of "clean land" and unclear PPP models in practice; Shortage and uneven distribution of high-quality healthcare human resources across provinces.

5.2. Notable policy directions that may reshape sector quality

Digital transformation: electronic health records, AI-assisted diagnosis, and surgical robotics (Ministry of Health, 2020).

Development of specialized medical zones in major cities. Policy "nudges" to encourage routine health checkups among the population.

6. Policy Recommendations

6.1. Establish a comprehensive healthcare ecosystem with public–private coordination to deliver multi-tier services and universal coverage.

6.2. Optimize existing public assets and healthcare workforce to reduce post-merger inefficiencies. Idle public healthcare assets may be leased for private operation of primary care under clear conditions (e.g., 10–20 years lease–operate contracts, preferential lease fees tied to serving social health insurance at commune level, prioritizing domestic healthcare enterprises).

6.3. Attract domestic and foreign private investment to form internationally accredited high-quality medical centers.

6.4. Ensure policy fairness without discrimination by ownership type (public vs. private). Allocation should be based on capability, technical standards, and contribution to social security and community needs. Enable flexible arrangements such as rotational public doctors serving private facilities and regulated dual practice after hours, alongside targeted training funds for nurses and technicians.

6.5. Codify the principle of avoiding redundant public investment where private investment already meets regulatory requirements.

6.6. Transform the role of the state from direct provision to supervision, regulation, and market creation.

6.7. Improve interoperability of health and population databases. Consider opening secure

APIs to connect national databases and health-demographic maps, enabling private providers to update data for social health insurance and national statistics while ensuring data security and shared connectivity standards.

7. Conclusion

In the new development phase, healthcare is not only a domain of public spending but also a strategic economic sector with strong profitability and social spillovers. With an appropriate institutional framework, investment-friendly policies, and robust digital transformation, private healthcare can become a key pillar of Vietnam's social security system while simultaneously serving as a driver of regional economic development in the period 2025–2035.

References

Balassa, B. (1965). Trade liberalisation and "revealed" comparative advantage. The Manchester School, – 33(2). – P. 99–123.
Communist Party of Vietnam. (2017). Resolution No. 20-NQ/TW on strengthening the protection, care and improvement of people's health in the new situation.
IQVIA Vietnam. (2024). Vietnam pharma market forecast. (Industry report).
Ken Research. (2023). Vietnam hospital market outlook 2029. (Industry report).
Ministry of Health (Vietnam). (2020, December 22). Decision No. 5316/QD-BYT approving the medical digitalization program until 2025, with orientation to 2030.
National Assembly of Vietnam. (2023). Law on Medical Examination and Treatment (amended)
North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge University Press.
Samuelson, P. A. (1954). The pure theory of public expenditure. Review of Economics and Statistics, – 36(4). – P. 387–389.
World Health Organization. (2023). Global Health Expenditure Database.

submitted 13.02.2026;
accepted for publication 27.02.2026;
published 28.02.2026

Contact: ncsnthung@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 2. IT Technology

DOI:10.29013/ESR-26-1.2-41-46

HYBRID DEEP MODEL FOR UZBEK LANGUAGE PUNCTUATION PREDICTION

Maksud S. Sharipov [1]***, Hushnudbek S. Adinaev*** [2]***, Shahzodbek S. Ganijonov*** [3]

1 Department of Computer Sciences, Urgench State University, Urgench, Uzbekistan

[2] Department of CE, Urgench State University, Urgench, Uzbekistan

[3] 10th grade, school No.15, Urgench, Uzbekistan

Cite: *Sharipov, M.S., Adinaev, H.S., Ganijonov, S.S. (2026). Hybrid Deep Model for Uzbek Language Punctuation Prediction. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-41-46

Abstract

Automatic punctuation restoration is one of the important tasks in natural language processing, especially for low-resource languages such as Uzbek, where this problem remains particularly relevant. The lack of sufficiently annotated corpora negatively affects the performance of downstream applications, including speech recognition, machine translation, and semantic text analysis. This study proposes a hybrid deep learning model designed to predict punctuation marks in Uzbek texts. The proposed approach combines BERT-based contextual vector representations, BiLSTM for modeling sequential dependencies, and a rule-based post-processing stage grounded in linguistic knowledge. This architecture effectively leverages the semantic capabilities of transformer models and the temporal dependency modeling strengths of recurrent networks, while the rule-based correction component improves the accuracy of punctuation detection in ambiguous boundary cases. Experimental results obtained on an annotated Uzbek corpus demonstrate that the proposed model outperforms existing neural and statistical approaches in terms of precision, recall, and F1-score. The findings confirm that integrating deep neural architectures with linguistic rules significantly enhances punctuation restoration performance for low-resource languages. This work presents a practical and extensible approach for advancing Uzbek language processing and improving the accuracy of various applied NLP systems.

Keywords: *punctuation marks; NLP; BERT model, BiLSTM model, Rule-based; F1 metrics*

1. Introduction

Natural Language Processing (NLP) has become one of the fastest-growing areas of artificial intelligence in recent years. The effectiveness of many practical applications – such as automatic text analysis,

speech recognition, machine translation, and question-answering systems – directly depends on the correct reconstruction of textual structure. From this perspective, automatic punctuation detection and restoration represents a crucial preprocessing step. This task is particularly important for texts derived from spoken language or written without punctuation marks.

Although punctuation restoration has been extensively studied for high-resource languages, research remains relatively limited for low-resource languages such as Uzbek. The scarcity of annotated corpora, the complexity of linguistic characteristics, and the challenges of directly transferring existing models necessitate the development of effective, language-adaptive approaches. As a result, incorrect or missing punctuation negatively impacts the performance of downstream systems, including speech recognition, machine translation, and semantic analysis.

In recent years, deep learning–based approaches – particularly recurrent neural networks and transformer architectures – have demonstrated strong performance in modeling sequential dependencies. Pretrained language models such as BERT enable the extraction of rich contextual representations, while BiLSTM networks effectively capture temporal dependencies within sequences. However, in certain ambiguous cases, purely neural approaches may fail to achieve sufficient accuracy. Therefore, incorporating linguistic rule-based post-processing mechanisms is considered a practical solution to improve robustness.

This paper proposes a hybrid deep learning model for punctuation prediction in Uzbek texts that integrates BERT, BiLSTM, and rule-based post-processing. The proposed approach unifies the semantic representation capabilities of transformer models, the sequential modeling strengths of recurrent networks, and the disambiguation power of linguistic rules within a single architecture. Experiments are conducted on an annotated Uzbek corpus, and model performance is evaluated using precision, recall, and F1-score metrics.

The main contributions of this study are as follows:

(1) proposing a hybrid neural–linguistic model for punctuation restoration in Uzbek; (2) improving accuracy through the integration of deep learning and rule-based approaches; (3) presenting a practical and extensible solution for punctuation restoration in low-resource languages.

2. Related Work

Punctuation restoration and analysis is considered one of the important tasks in the field of Natural Language Processing (NLP). Proper punctuation improves text readability and has a significant impact on the effectiveness of downstream NLP tasks such as syntactic parsing, machine translation, information extraction, and automatic speech recognition (Guhr O., Schumann A.-K., Bahrmann F., Böhme H.-J., 2021). Although punctuation marks were initially regarded as secondary graphical elements, recent studies have demonstrated that they encode essential syntactic and semantic boundaries within text.

Early research on punctuation detection and correction primarily relied on rule-based approaches. These methods employed manually crafted algorithms grounded in grammatical and stylistic rules of a language. For low-resource languages, such approaches remain relevant. One of the notable works for the Uzbek language is the rule-based algorithm proposed by Sharipov et al., in which the usage of periods and commas was analyzed using linguistic rules (Sharipov M. S., Adinaev H. S., Kuriyozov E. R., 2024). While this study laid the foundational groundwork for automatic punctuation analysis in Uzbek, it was reported to have limitations in handling complex contextual structures.

Subsequently, punctuation restoration began to be formulated as a sequence labeling problem, leading to the widespread adoption of statistical models, particularly Conditional Random Fields (CRF). By modeling dependencies between tokens, CRF-based approaches achieved better performance compared to purely rule-based methods (Attia O. et al., 2014). For the Uzbek language, studies have demonstrated that approaches combining BiLSTM and CRF models can achieve high accuracy and F1-scores (Sharipov M., Adinaev H., Sobirov O., 2025).

In recent years, deep learning–based models, especially Bidirectional Long Short-Term Memory (BiLSTM) networks, have been extensively applied to punctuation restoration tasks. These models jointly consider left and right contextual information, enabling effective learning of long-range dependencies within text (Salimbajevs J., 2018). The integration of a CRF layer with BiLSTM further stabilizes sequence-level predictions of punctuation marks.

With the emergence of transformer architectures, significant advances have been achieved in punctuation restoration. In particular, BERT and its multilingual variant mBERT have demonstrated strong performance in restoring punctuation in Uzbek texts (Adinaev H. S., 2025). These models are pretrained on large-scale multilingual corpora and provide deep contextual semantic representations. Furthermore, transformer models such as XLM-RoBERTa and RoBERTa offer effective transfer learning capabilities for low-resource languages (Shymkovych V. et al., 2025).

Recent studies increasingly adopt hybrid architectures that combine transformer models with recurrent neural networks. Models such as BERT–BiLSTM and XLM-RoBERTa–LSTM jointly capture global contextual semantics and sequential dependencies, resulting in improved accuracy (Zhu X. et al., 2024). In some works, punctuation restoration has been jointly learned with capitalization prediction, further enhancing structural coherence of the reconstructed text.

In addition, hybrid systems integrating acoustic and lexical features have been proposed for automatic speech recognition tasks. For example, an acoustic–lexical approach developed for Spanish demonstrated superior performance in question mark detection compared to text-only models (Qiu J. et al., 2026). This indicates that leveraging multi-source information is a promising direction for punctuation restoration.

Recent research also explores punctuation not only as a final prediction target but as an auxiliary signal. Specifically, punctuation-aware sparse attention mechanisms developed for large language models utilize punctuation marks as indicators of semantic boundaries, significantly improving long-context modeling performance (Qiu J. et al., 2026).

3. Methodology

In this study, the task of automatic punctuation restoration in Uzbek texts is addressed using a **hybrid approach**. The proposed method integrates a contextual neural model **(BERT + BiLSTM)** with a **rule-based post-processing** stage. This approach is specifically designed to reduce errors arising in the prediction of low-frequency punctuation marks.

3.1. Dataset Construction

The corpus used in this research contains more than **122 million tokens** and over **8 million sentences,** and was compiled from publicistic, official, and technical texts. Statistical analysis of punctuation marks within the corpus reveals a highly imbalanced distribution, indicating the necessity of additional mechanisms beyond a purely neural model. **Table 1** presents the statistical overview of the dataset.

Table 1. *Statistical summary of the dataset*

№	Label name	Number
1	Number of words (tokens)	122 161 579
2	Number of sentences	8 196 343
3	Number of commas	7 752 610
4	Number of periods	8 283 883
5	Number of question marks	265 449
6	Number of exclamation marks	249 576
7	Number of colons	1 128 044
8	Number of semicolons	219 920

№	Label name	Number
9	Number of ellipses	144 755
10	Number of parentheses	3 730 689
11	Number of quotation marks	1 799 606
12	Number of dashes	805 807
13	Total number of punctuation marks	24 380 339

3.2. Preprocessing

The texts were subjected to Unicode normalization, Uzbek-specific special characters were standardized, and word-level tokenization was performed. Sentence boundaries were identified, and punctuation-free raw text was prepared as input for the model.

3.3. Annotation and Formatting

For each token, corresponding punctuation labels were assigned. The label set includes periods, commas, question marks, exclamation marks, colons, semicolons, ellipses, dashes, parentheses, and quotation marks. The annotated data were stored in CoNLL format and split into training, validation, and test sets with an 80/10/10 ratio.

3.4. Neural Model Architecture

The punctuation restoration task was formulated as a sequence labeling problem. A BERT model adapted for the Uzbek language was selected as the base encoder. Contextual embeddings generated by BERT were passed to a Bidirectional LSTM (BiLSTM) layer to model long-range dependencies between tokens. In the final stage, a fully connected layer was applied to predict the punctuation label for each token.

Figure 1. *Architecture of the proposed BiLSTM–BERT hybrid model with rule-based post-processing*

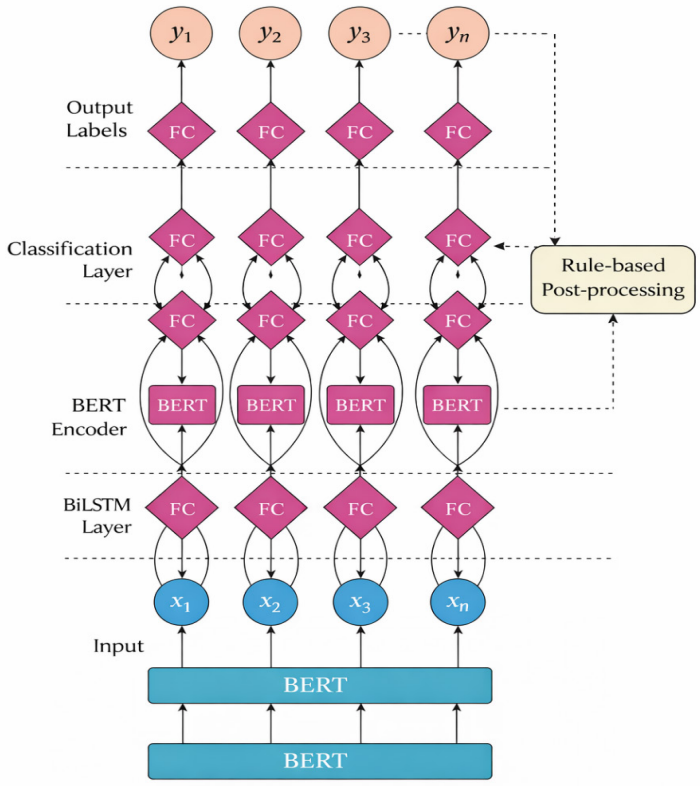
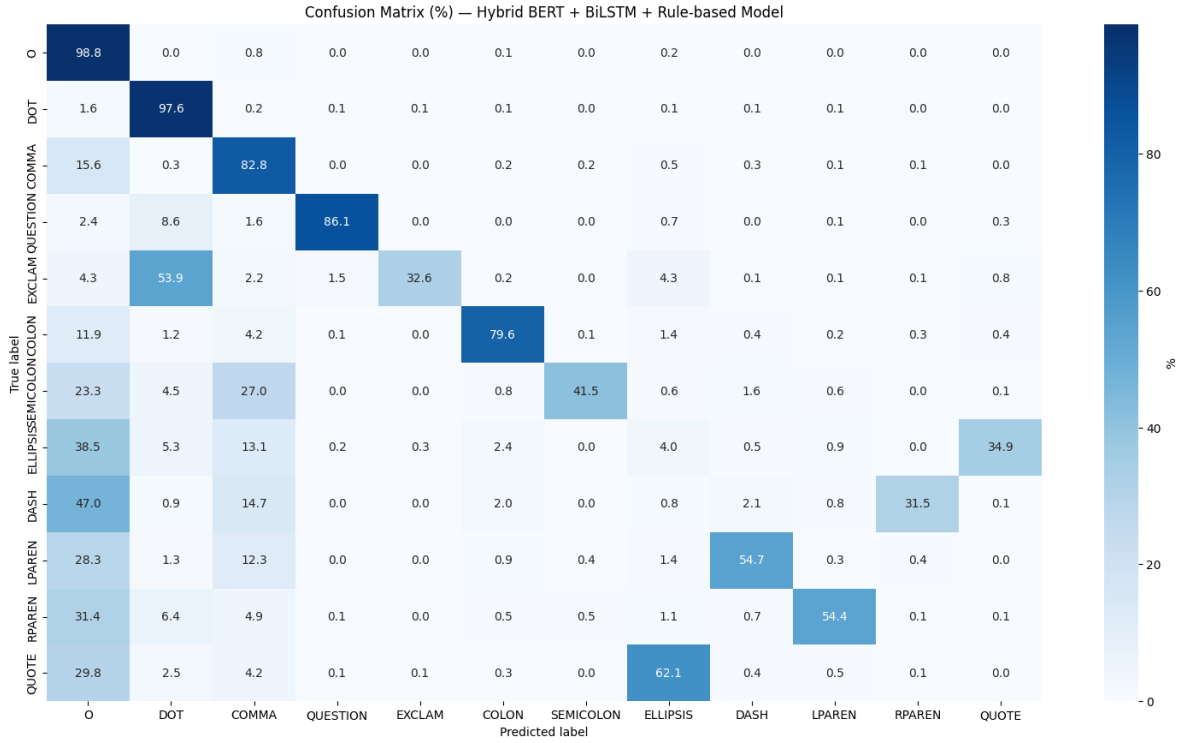


Figure X. Architecture of the proposed BERT–BiLSTM hybrid model for punctuation restoration. Contextual embeddings generated by BERT are processed by a bidirectional LSTM layer and classified at the token level, followed by rule-based post-processsing.

3.5. Rule-Based Post-Processing (Hybrid Stage)

The model outputs were further refined through a rule-based post-processing stage. This stage applies normative rules of the Uzbek language, including the insertion of dashes in reported speech constructions, the use of colons after explanatory and formal expressions, comma placement rules associated with discourse markers, and capitalization at sentence boundaries. This post-processing stage significantly improves the accuracy of low-frequency punctuation marks, which are often challenging for purely neural models.

Figure 2. *Confusion matrix (%) of the proposed BiLSTM–BERT hybrid model with rule-based post-processing*



4. Conclusion

In this study, a hybrid approach was proposed for the task of automatic punctuation restoration in Uzbek texts. The proposed model integrates a contextual language model **(**BERT**)**, a sequence modeling component **(**BiLSTM**),** and a linguistically motivated rule-based post-processing mechanism. This combination effectively unifies the statistical learning capabilities of neural models with the precision of rule-based approaches.

Experimental results obtained on a large-scale, CoNLL-formatted dataset constructed from real Uzbek texts demonstrate that the proposed hybrid model achieves approximately 87% Macro-F1. Confusion matrix analysis shows that the model performs with very high accuracy on frequent punctuation marks such as periods, commas, and question marks. At the same time, the rule-based component plays a crucial role in reducing errors observed in purely neural approaches for punctuation marks such as colons, quotation marks, and parentheses.

Although punctuation marks such as ellipses and dashes remain challenging due to their strong dependence on context, the observed errors can be attributed to inherent semantic and pragmatic ambiguities of the language. Overall, the results confirm that the hybrid approach provides a robust, interpretable, and practically effective solution for punctuation restoration in Uzbek.

5. Future work

Based on the findings of this study, the following directions are considered promising for future research:

Incorporating discourse and pragmatic features to improve the detection of punc-

tuation marks such as ellipses and dashes, it is recommended to introduce mechanisms that model inter-sentential relations and document-level context, such as document-level transformer architectures.

Expanding and adapting the rule system the current set of linguistic rules can be automatically expanded based on statistical observations or enhanced with adaptive mechanisms, including learnable or data-driven rule induction approaches.

Utilizing multi-genre corpora further training the model on literary, journalistic, and social media texts is expected to improve its generalization capability across different writing styles.

Practical integration integrating the proposed model into text editors (e.g., Word add-ins), web applications, or mobile platforms would contribute to the development of automatic text editing tools for the Uzbek language.

Releasing resources as open data Making the dataset, model architecture, and rule sets publicly available would positively impact the advancement of Uzbek NLP research and encourage further studies in this domain.

References

Guhr O., Schumann A.-K., Bahrmann F., Böhme H.-J. “FullStop: Multilingual Deep Models for Punctuation Prediction,” *Proceedings of the SEPP-NLG Shared Task*, 2021.

Sharipov M. S., Adinaev H. S., Kuriyozov E. R. “Rule-Based Punctuation Algorithm for the Uzbek Language,” 2024.

Attia O. et al. “Automatic Spelling and Punctuation Correction for Arabic,” *Computational Linguistics*, 2014.

Sharipov M., Adinaev H., Sobirov O. “Bidirectional LSTM–CRF Models for Punctuation Restoration in Uzbek Texts,” *IEEE UBMK*, 2025.

Salimbajevs J. “Automatic Punctuation Restoration Using Bidirectional LSTM Models,” *IOS Press*, 2018.

Adinaev H. S. “The mBERT Model for Restoring Punctuation in Uzbek-Language Texts,” *European Science Review*, 2025.

Shymkovych V. et al. “Joint Punctuation Restoration and Text Capitalisation with a Hybrid XLM-RoBERTa–LSTM Model,” *IEEE IDAACS*, 2025.

Zhu X. et al. “Resolving Transcription Ambiguity in Spanish: A Hybrid Acoustic-Lexical System for Punctuation Restoration,” *ACL Workshop*, 2024.

Qiu J. et al. “Punctuation-aware Hybrid Trainable Sparse Attention for Large Language Models,” *arXiv:2601.02819*, 2026.

submitted 27.01.2026;
accepted for publication 11.02.2026;
published 28.02.2026

Contact: hushnudbek.adinaev@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 3. Machine engineering

DOI:10.29013/ESR-26-1.2-47-51

PRACTICAL IMPLEMENTATION OF MULTIPARAMETRIC DESIGN OF FUNCTIONAL ELEMENTS OF A POWER MACHINE

Minko Oleksandr [1]

[1] National Aerospace University "Kharkiv Aviation Institute, Kharkiv, Ukraine

Cite: *Minko, O. (2026). Practical Implementation of Multiparametric Design of Functional Elements of a Power Machine. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-47-51

Abstract

The article performs multiparametric design of the stator core of the turbogenerator according to the criteria of electromagnetic and heat-ventilation load. The result of this design was the determination of the basic geometry of the stator core (inner diameter, outer diameter), the determination of the geometry of the tooth zone of the core (number of grooves, depth and width of the groove) and the determination of the cross-sectional area and the number of ventilation channels. The proposed toolkit allows you to determine both radial cooling channels and axial ones. The applied methodology can be used for different types of electric machine and almost all power classes (small machines, medium-sized machines and high-power machines).

Keywords: *electromechanical energy converter, multiparametric model, stator, turbogenerator, multiphysical processes*

Introduction

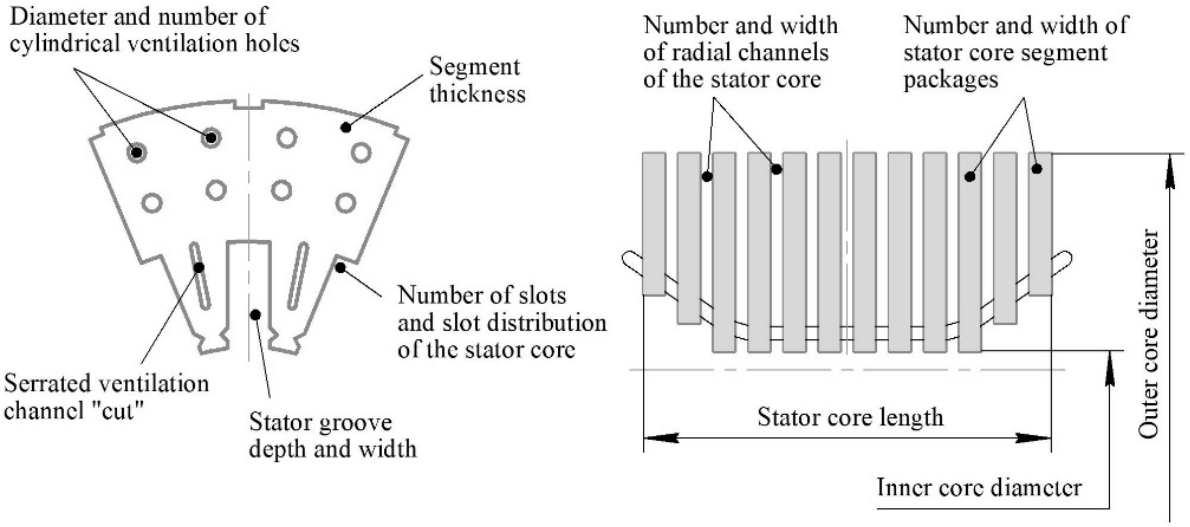
The process of designing electromechanical energy converters is a complex and multifaceted task, which is limited on the one hand by the technical and methodological capabilities of the existing design tools, and on the other hand by the modern requirements of the market for electromechanical equipment, which include the requirements of manufacturability, safety, environmental friendliness and reasonable economy of the future unit. Currently, known design methods are based on a sequential organization of calculation stages, followed by the process of modeling individual phenomena and effects of the functioning of the electric machine and modeling, at the final stage, the future design of the electromechanical energy converter. This approach affects both the timing of design work and the quality of individual results obtained as a result of the design (Lei, G., Zhu, J., Guo, Y., Liu, C., & Ma, B., 2017; Omar, M.F.B., Sulaiman, E.B., Soomro, I.A. et al., 2023).

Research method

To perform multiparametric design of the turbogenerator stator, we will use the ap-

proach specified in (Hammza, T., Abas, E., & Hmoad, N., 2020). The objective function by which multiparametric design is performed is the total electric power of the turbogenerator (TG): $P_{em} = f(l_s; D_a; Q_{air})$, where the variable is l_s – the length of the stator core, mm; the variable D_a – the outer diameter of the stator core, mm; and Q_{air} – the electric power consumption for cooling the TG. The development of the stator core usually comes down to determining the geometry of the core segment, its thickness, the grade of electrical steel and the assembly of radial packages of the stator core, in order to determine the axial length of the stator core. The general view of the stator segment is shown in Fig. 1.

Figure 1. *General view of the stator segment and stator core*



The process of performing multiparametric design of the stator core will be shown gradually from the point of view of the indicators determined by the calculation (Fig. 2).

Figure 2. *Graphical model for performing multiparametric design of the stator core*

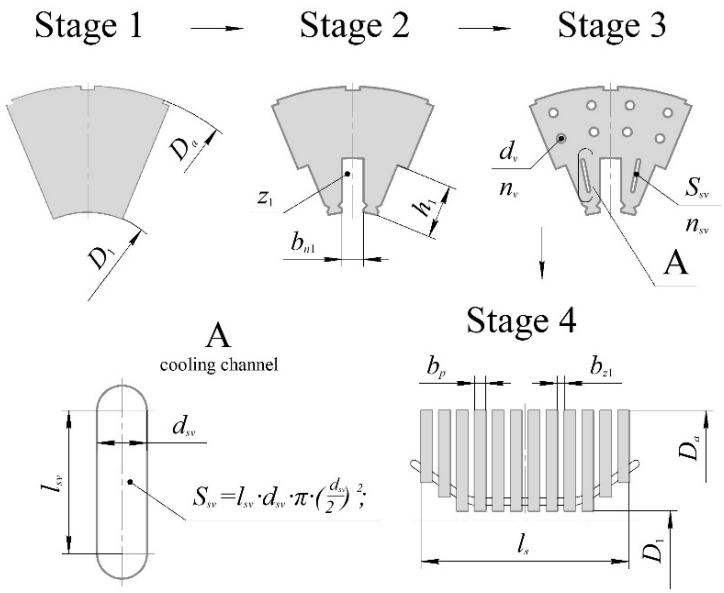


Figure 2 has the following explanation:

In the first stage, the overall dimensions of the core within the stator segment are determined – the outer diameter (D_a), the inner diameter, the so-called bore, (D_1) and the segment thickness (σ_s). In the second step, we determine the geometry of the tooth zone of the segment, namely: the number of grooves (z_1), the groove width (b_{n1}) and the groove depth (h_1). In the third stage, we determine the geometry of the ventilation channels: the number (d_v) and the diameter of the axial channels

(n_v), the number (n_{sv}) and the cross-section of the slot channel (S_{sv}). And at the final stage, the core is assembled from the segments, as a result of which the thickness of the radial package of the stator core (b_p), the width of the radial channel (b_{z1}) and the length of the stator core (l_s) are determined (Berestinov, A.A., Korobatov, D.V., Kulganatov, A.Z., 2023).

Mathematically, the general function of multiparametric design depending on the above-mentioned values has the following form:

$$P_{em}\left(l_s;D_a;Q_{air}\right)=\begin{cases} P_{em}=\dfrac{\pi}{4}\cdot l_s\cdot\left[\left(\dfrac{Q_{air}\cdot\left(2\cdot n_{st}-1\right)}{\upsilon_j\cdot n_{st}\cdot n_{n1}\cdot b_{z1}\cdot\pi}\right)-h_{n1}\right]; \\ P_{em}=\sqrt{3}\cdot\cos\phi\cdot\left(\dfrac{\Phi\cdot f_{w1}\cdot\omega_1\cdot D_1\cdot AS_1\cdot q_1\cdot p\cdot\pi}{0{,}26\cdot z_1\cdot\left(\dfrac{50}{f_n}\right)}\right). \end{cases} \quad (1)$$

where, υ_j – speed of cooling gas in ventilation channels, m/s; n_{st} – number of jets in the stator core ventilation scheme, pcs; f_n – frequency of electric current in the network, Hz; z_1 – number of stator slots, pcs.; a_1 – number of parallel branches of the stator winding; q_{a1} – number of slots per pole and phase; l_s – stator core length, mm; q_1 – number of slots per pole and phase; fw_1 – winding ratio of the stator winding, a.u.; ω_s – number of consecutive turns of the stator winding in the slots; AS_1 – linear load of the electric machine, A/mm; Φ – magnetic flux per stator pole, Vb; p – number of pairs of poles of an electric machine, pcs.; cos φ – power utilization factor, a.u.

Results

The result of the multiparametric calculation of the stator core geometry is given in Table 1, which shows a comparison of the electric power indicator obtained using multiparametric design and the power indicator from previously completed projects on the development of turbogenerators in Ukraine.

Table 1. *The result of multiparametric calculation of the geometry of the stator core of turbogenerators with a capacity of 100–1100 MW*

№	*Pem*	*Da*	D_1	*ls*	Groove geometry			Geometry of ventilation ducts				*P'em*
					z_1	bn_1	h_1	*dv*	*nv*	bz_1	*Ssv*	
1	**100**	2100	1090	4070	72	26,6	151	10	6	10	–	**98,3**
2	**200**	2515	1275	5000	60	38,6	250	12	10	5	–	**197,6**
3	**300**	2550	1275	4980	30	50,8	183	16	10	5	200	**296,9**
4	**500**	2760	1320	6200	48	37,0	245	20	12	4	210	**496,8**
5	**1100**	3300	1970	6440	60	41,5	239	20	16	4	280	**1095,7**

In addition to table 1, it should be noted that the TG with a capacity of 100 MW has purely hydrogen cooling, and in the remaining TGs the stator winding is cooled with water. From the table it follows that the results of multiparametric design quite qualitatively coincide with the results obtained independently, when designing by the classical iterative method (*P'em*). The percentage of error is from 0.39% to 1.7%. The largest percentage of error corresponds to the TG with a capacity of 100 MW, and the smallest – to the TG 1100 MW. The presence of "–" in the S_{sv} column indicates that the core cooling system does not have a "slit" type ventilation hole.

Based on the results of multiparametric design, a design of an electric machine stator for thermal and nuclear power plants was developed, which has improved charac-

teristics of the pressing indicators of the end packages of the stator core, due to the installation of additional mechanical pressure devices, a patent for a utility model (patent No. 66717) was issued (Patent No. 66717 Ukraine, IPC (2006.01) H02K 1/16 Stator of an electric machine).

In addition, it is necessary to determine the flow rate of the cooling medium, which can be carried out based on the temperature of the medium, with a known value of the electrical losses being removed (Jasper Nonneman, Michel De Paepe, Ruud Sprangers, Ilya T'Jollyn, 2026):

$$Q_{qir} = \frac{P_{loss}}{t_m} \cdot C_P, \quad (2)$$

where P_{loss} – heat losses, kW; t_m – temperature of the cooling medium, °C; C_p – specific volumetric heat capacity, J/m^3·C.

In electric machines with indirect and direct cooling of the windings, the temperature and flow rate of the cooling medium can differ significantly, for example, electric machines with direct cooling have an increased value of the medium temperature and a lower flow rate. In addition, in the structural parts of powerful electric machines, the flow rate of the cooled medium can be determined by the speed of its flow and the channel of the hydraulic channel:

$$Q_m = \upsilon_m \cdot S_{channel} \quad (3)$$

where υ_m – the speed of the cooling medium in the channel, m/s; $S_{channel}$ – the channel cross-section, m^2.

In the global practice of designing cooling systems for powerful electric machines, when choosing a cooling medium, it is recommended to use the following provisions (Citation: Wang, Q., Wu, Y., Niu, S., Zhao, X., 2022; Usca-Gomez, H. G., Puma-Benavides, D. S., Zambrano-Leon, V. D., Castillo-Díaz, R., Quinga-Morales, M. I., Solís-Santamaria, J. M., & Llanes-Cedeño, E. A., 2025; Chen, S., Miao, C., Chen, X., Qian, W., & Chu, S., 2025).

1. In electric machines with indirect cooling of the stator and rotor windings, when using an air cooling medium, the value of the temperature heating in the stationary mode of operation of the machine is in the range of 25...30 °C., while it is necessary to take into account the heating of the air in the fan zone, which is 3...6 °C (when using an exhaust ventilation system – heating on the fan is turned off); when using a hydrogen cooling medium (with excess pressure), the value of the temperature heating can be taken as 20...25 °C.

2. In electric machines with indirect cooling of the stator winding and direct cooling of the rotor winding, the cooling agent is hydrogen (at an excess pressure of 0.3 MPa) and the recommended value of the total heating of hydrogen is 15...20 °C, while the heating in the rotor winding is 30...50 °C. Intensification of cooling, in this case, is carried out by increasing the excess pressure of hydrogen.

3. In electric machines with direct cooling of the rotor winding with hydrogen and direct cooling of the stator winding with distilled water, the total heating of hydrogen is 15...20 °C, and the heating of water in the stator winding fluctuates in the range of 15...30 °C.

For preliminary calculations of the flow rate of the medium being cooled, the above recommendations for determining the temperature of the agent (t_m) can be used.

From the expression (3) it follows that the flow rate of the cooling medium also depends on the thermophysical properties of the medium itself, including: specific heat capacity, density, kinematic viscosity, coefficient of volumetric expansion, coefficient of thermal conductivity, etc. The given physical properties are not constant and depend on the temperature and pressure of the cooling medium inside the electric machine.

For working design, it is advisable to use formulas for approximate calculation of the thermophysical properties of the most common agents, obtained by mathematical approximation methods based on experimental studies of the physical characteristics of the cooling medium. The determination of the thermophysical properties of the medium was carried out depending on its temperature (Ching-yu Yang. 2000).

References

Lei, G., Zhu, J., Guo, Y., Liu, C., & Ma, B. (2017). A Review of Design Optimization Methods for Electrical Machines. Energies, – 10(12). 1962. URL: URL: https://doi.org/10.3390/en10121962

Omar, M.F.B., Sulaiman, E.B., Soomro, I.A. et al. Design Optimization Methods for Electrical Machines: A Review. J. Electr. Eng. Technol. 18, 2783–2800 (2023). URL: https://doi.org/10.1007/s42835–022–01358-y

Hammza, T., Abas, E., & Hmoad, N. (2020). Optimum Design of Journal Bearings Dimensions for Rotating Ma-chines. Engineering and Technology Journal, – 38(10A). – P. 1481–1488. URL: https://doi:10.30684/etj.v38i10A.1093

Berestinov, A.A., Korobatov, D.V., Kulganatov, A.Z. (2023). Monitoring of Parameters of Power Plants Based on Renewable Energy Sources. In: Radionov, A.A., Gasiyarov, V.R. (eds) Advances in Automation IV. RusAutoCon 2022. Lecture Notes in Electrical Engineering, – Vol. 986. Springer, Cham. URL: https://doi.org/10.1007/978–3–031–22311–2_9

Patent No. 66717 Ukraine, IPC (2006.01) H02K 1/16 Stator of an electric machine / Minko O. M., Penskoy V. F., Zhukov O.Yu., Kobzar K. O.; applicant and patent holder SE plant "Electrotyazhmash" – u 2011 09022; appl. 19.07.2011; publ. 10.01.2012, Bull. No. 1.

Jasper Nonneman, Michel De Paepe, Ruud Sprangers, Ilya T'Jollyn, (2026). Method for Thermal Property Characterization from in Situ Measurements Applied to the Performance Evaluation of Electric Machine Windings, IEEE Transactions on Transportation Electrification, 10.1109/TTE.2025.3635912, 12, 1, (1918–1927).

Citation: Wang, Q., Wu, Y., Niu, S., Zhao, X. 2022. Advances in Thermal Management Technologies of Electrical Machines. Energies, – 15. – 3249 p. URL: https://doi.org/10.3390/en15093249

Gundabattini E., Kuppan R., Gnanara D., Solomon A., Kalam A., Kothari D. P., Rosli Abu Baka (2021) A review on methods of finding losses and cooling methods to increase efficiency of electric machines. Ain Shams Engineering Journal Volume 12, Issue 1, March 2021. – P. 497–505. URL: https://doi.org/10.1016/j.asej.2020.08.014

Usca-Gomez, H. G., Puma-Benavides, D. S., Zambrano-Leon, V. D., Castillo-Díaz, R., Quinga-Morales, M. I., Solís-Santamaria, J. M., & Llanes-Cedeño, E. A. (2025). A Review and Case of Study of Cooling Methods: Integrating Modeling, Simulation, and Thermal Analysis for a Model Based on a Commercial Electric Permanent Magnet Synchronous Motor. World Electric Vehicle Journal, – 16(8). – 437 p. URL: https://doi.org/10.3390/wevj16080437

Chen, S., Miao, C., Chen, X., Qian, W., & Chu, S. (2025). Research on the Oil Cooling Structure Design Method of Permanent Magnet Synchronous Motors for Electric Vehicles. Energies, – 18(12). – 3134 p. URL: https://doi.org/10.3390/en18123134

Ching-yu Yang. (2000). Determination of the temperature dependent thermophysical properties from temperature responses measured at medium's boundaries. International Journal of Heat and Mass Transfer – Vol. 43. – Issue 7. – April 2000. – P. 1261–1270. URL: https://doi.org/10.1016/S0017–9310(99)00142–8

submitted 16.01.2026;
accepted for publication 30.01.2026;
published 28.02.2026

Contact: dr.alexandr.minko@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 4. Materials science

DOI:10.29013/ESR-26-1.2-52-60

IMPACT OF DISORDER AND MANUFACTURING COST ON THE EFFICACY OF MECHANO-BACTERICIDAL NANOSTRUCTURES

Tina F. Meng [1]

[1] Monta Vista High School, Cupertino, California, U.S.A

Cite: *Tina F. Meng (2026). Impact of Disorder and Manufacturing Cost on the Efficacy of Mechano-Bactericidal Nanostructures. European Science Review 2026, No 1–2*. https://doi.org/10.29013/ESR-26-1.2-52-60

Abstract

This work presents a combined mathematical and simulation modeling approach to evaluating the mechano-bactericidal effect of nanostructured surfaces. We show for the first time that a mathematical expression of mechanical stress can be derived from bacterial and nanopillar properties. By applying the model in simulations, we demonstrate that the nanopillar design can be optimized to achieve higher bacteria-killing efficiency. We also show that those high-end fabricating techniques only moderately improve antibacterial efficiency at much higher cost. The study validates the mechano-bactericidal concept, provides a quantitative model for stress, and offers insights for optimizing nanostructure design.

Keyword: *Mechano-bactericidal, Nanopillar, Bacteria*

1. Introduction

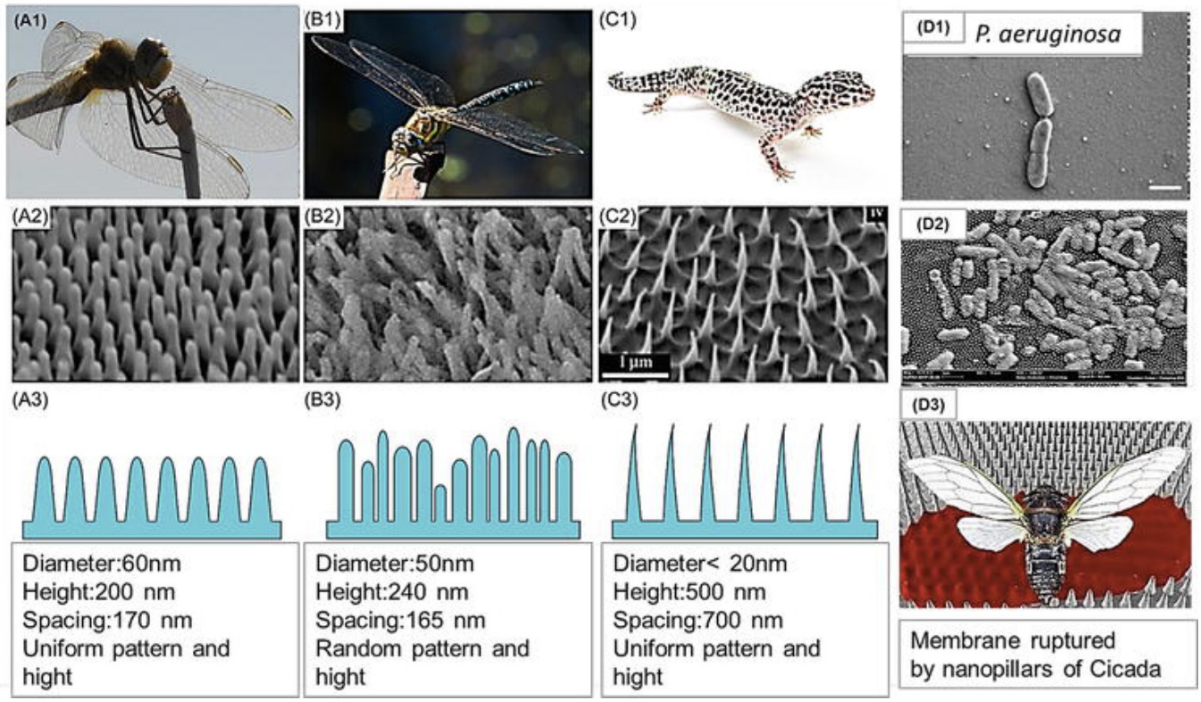
Bacterial contamination and resulting infections present a serious danger across various environments, including hospitals, the food industry, and community settings. Antibiotics are the most common treatment for bacterial infections. However, antibiotics have led to the development of bacterial resistance, making routine treatment of bacterial infections increasingly difficult. Eliminating bacteria effectively without causing bacterial resistance has become an important research topic today.

In the past decade, the use of mechano-bactericidal nanostructured surfaces has emerged as a potential alternative (Linklater 2021, Li 2021, Agbe 2024). Researchers found that the physico-mechanical interactions between such nanostructured surfaces and bacteria lead to bacterial killing or prevention of bacterial attachment, and thus are promising in circumventing bacterial infections.

This approach is inspired by nature. Researchers have found that the surfaces of cicada and dragonfly wings exhibit antibacterial properties due to their unique nanoscale pillar structure (Ivanova 2020, SHT 2013). Details of such a nanoscale pillar structure are shown in Fig. 1 (Dickson 2015). Com-

pared to bacteria incubated on flat surfaces, bacteria attached to nanopillared surfaces appeared deflated or elongated, as the pillar structure induces mechanical stress on the bacterial cell membrane. When the stress exceeds the cell membrane's elasticity, the membrane ruptures, and the bacteria die.

Figure 1. *Illustration of mechano-bactericidal surfaces in nature ((Dickson 2015)*

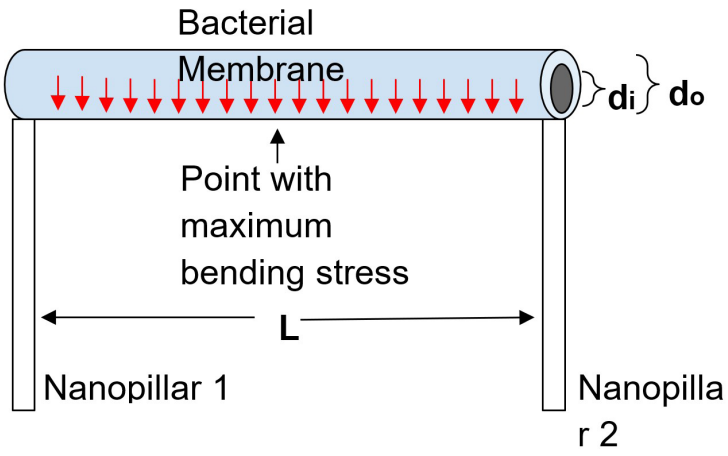


In this paper, we use both mathematical and simulation modeling to study the mechanical stress imposed by nanopillared surfaces on bacteria. We show for the first time that a mathematical expression of mechanical stress can be derived from bacterial and nanopillar properties. By applying this model in simulations, we demonstrate that the nanopillar design can be optimized to achieve the highest bacteria-killing efficiency. Furthermore, we compare the antibacterial efficiency of modern high-end and low-end nanoscale fabricating techniques, and show that those high-cost techniques provide only a moderate improvement in antibacterial efficiency.

2. Research Method

2.1 Mathematical Modeling

Figure 2. *A bacterial membrane falls onto two nanopillars*



To evaluate how nanopillars kill bacteria attached to them, we use a mechanical engineering approach to derive the bending stress imposed by the weight of a bacterial membrane on a nanopillar surface. When the bending stress exceeds the membrane's stress threshold, the membrane is considered killed.

The shape of a bacterium can be approximated as a spherocylinder, i.e., a circular tube. We use d_o and d_i to represent its outside and inside diameters, respectively. Therefore, the tube thickness is $t = \frac{d_o - d_i}{2}$. Normally, the member length is much larger than its diameter. When placed on a nanosurface with densely packed nanopillars, a membrane could land on multiple nanopillars. Between two adjacent nanopillars, as shown in Fig. 1, the membrane segment is modeled as a beam (Wikipedia 2025) in the mechanical engineering sense, supported at its ends. Due to the membrane's uniform weight distribution, it will experience bending stress along its trunk between the two supporting pillars. Clearly, the maximum bending stress occurs midway between the two pillars. Following the Euler-Bernoulli beam theory (Wikipedia 2025), such maximum bending stress is

$$\sigma_{max} = \frac{M \cdot y}{I_c}$$

Where M is the bending moment, y is the distance from the beam's neutral axis to the middle point along the dimension of the circular tube, and I_c is the centroidal moment of inertia of the beam's cross section, which is a circular tube. These two parameters, in this particular scenario of simply supported beams with uniformly distributed load, can be calculated according to (Wikipedia 2025):

$M = \frac{wL^2}{8}$ (w is the uniform weight per length unit of the membrane)

$$y = \frac{d_o - d_i}{4}$$

$$I_c = \frac{\pi}{64}(d_o^4 - d_i^4)$$

So

$$\sigma_{max} = \frac{\left(wL^2/8\right)\left(d_o - d_i\right)/4}{\left(\pi/64\right)(d_o^4 - d_i^4)} = \frac{2wL^2}{\pi(d_o^2 + d_i^2)(d_o + d_i)} \quad (1)$$

We assume $\sigma_{critical}$ is the bending stress threshold for a given bacterial type. When $\sigma_{max} \geq \sigma_{critical}$, the bacteria are considered killed. Note that while w, d_o, d_i and $\sigma_{critical}$ are all bacterial characteristics, L is the pillar-to-pillar spacing and determined by the nanosurface design.

The above mathematical model is the foundation of our analysis. Equation 1 indicates that when a bacterium is placed on a nanostructured surface, its membrane may fold onto nanopillars, resulting in high membrane stress and killing the bacterium. On the other hand, if nanopillars are too sparse, the chance of a bacterium falling onto them is low, thus a lower chance of breaking. Therefore, it is intriguing to further analyze how nanostructured surfaces impact antibacterial effectiveness.

2.2 Simulation

A computer-based simulation is conducted to further model how nanostructured surface design affects antimicrobial killing efficiency. The simulation models both nanostructured surfaces and bacteria.

A grid is generated to simulate a nanostructured surface with pillars. Each point in the grid represents a pillar location. The point lies within a circular area of the same diameter as the pillar. The distance between neighboring grid points is the pillar-to-pillar spacing. There are many bacterial types with different geometries and sizes. *E. coli* is a commonly studied bacterial type and is used in the simulation.

All the properties of the nanostructured surface and bacterium are listed in Table 1 below.

In the simulation, 1000 bacterial samples are generated with a specified size distribution and a specified location on the grid. The location of a bacterial sample is determined by two randomized parameters: the centroid and the orientation. Once a bacterium is generated, it needs to be decided on how it interacts with the pillars. To this end, the grid and bacterial locations are used to determine

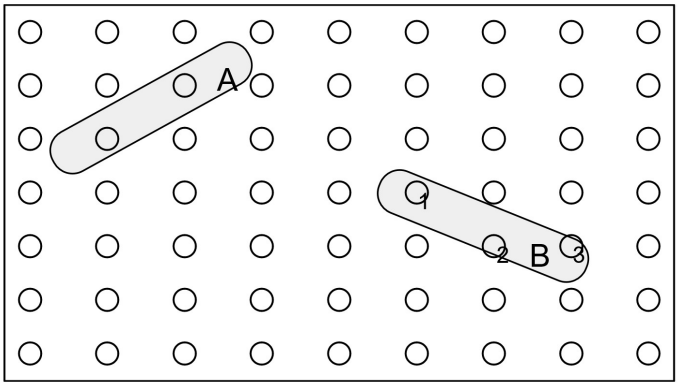
how many, if any, pillars support the bacteria (i.e., overlap with the bacteria). When deciding whether a pillar supports a bacterium, the pillar's diameter is taken into account. As long as any of the circular area of a pillar overlaps with a bacterium, the pillar is considered to support the bacterium.

Table 1. *Properties of the bacteria and the nanostructured surface used in the simulation*

	Property	Variable	Typical Values
Bacterium (*E. coli)*	Length	s	3000 nm
	Weight on unit length	w	10^{-12} gram per μm
	Outside diameter	d_o	500 nm
	Inside diameter	d_i	490 nm
	Thickness	$(d_o - d_i)/2$	5 nm
	Critical bending stress	$\sigma_{critical}$	Take a fixed value in the simulation
Nanostructured surface	Pillar diameter	d_p	36 nm [6]
	Pillar-to-pillar spacing	L	1000 nm

Fig. 3 shows two bacteria, A and B, placed on a grid. Because Bacteria A is supported by exactly 2 pillars, its σ_{max} calculation is straightforward. For Bacteria B, 3 pillars support it. In this case, the 3 pillars are first sorted along the length dimension of the bacteria. Next, the neighboring bacterial pairs with the longest distance are found, and that distance is used to calculate σ_{max}. For example, in Fig. 3, the distance between Pillars 1 and 2 is longer than that between Pillars 2 and 3. Therefore, Pillars 1 and 2 are used to calculate the force imposed on the bacterium.

Figure 3. *Simulated nano pillar array and two randomly placed bacteria*



$\sigma_{critical}$ is a bacteria-specific threshold. It's difficult to obtain from the real world. In our simulation, we use the settings in Table 1 and run it 1000 times. We then assign $\sigma_{critical}$ the 50% percentile of σ_{max}. In other words, we assume a 50% bacteria-killing rate is the baseline when the nanostructured surface uses the common settings in Table 1. We believe this doesn't affect our study, as we are more interested in the relative impact of varying surface design parameters.

3 Results Analysis

3.1 Impact of Nanostructure Geometry

The first simulation assesses how pillar geometry impacts antibacterial efficiency. Two types of pillar geometry are evaluated: pillar-to-pillar spacing and pillar diameter. As shown in Fig. 4, the optimal pillar-to-pillar spacing is neither too large nor too small relative to the bacteria's size. The insight is that when it is too small, a bacterium has

a high chance of falling onto multiple pillars, thereby reducing the inter-pillar distance and lower stress. When the distance between the nanopillars increases, the stress increases, thereafter the bacterium membrane has a high chance to break.

It is worth noting that a previous experiment (Dickson 2015) showed that smaller, more closely spaced pillars are more effective at killing bacteria. Our analysis indicates that the optimal pillar-to-pillar spacing lies between too large and too small. It is essentially relative to the bacterial size.

Figure 4. *Effect of pillar-to-pillar spacing on bacteria killing efficiency*

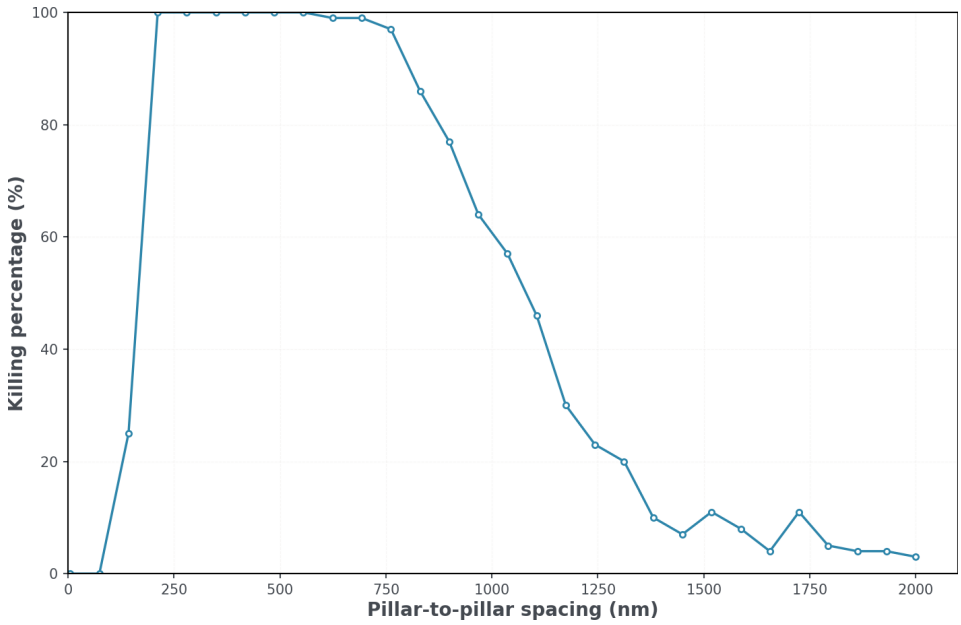
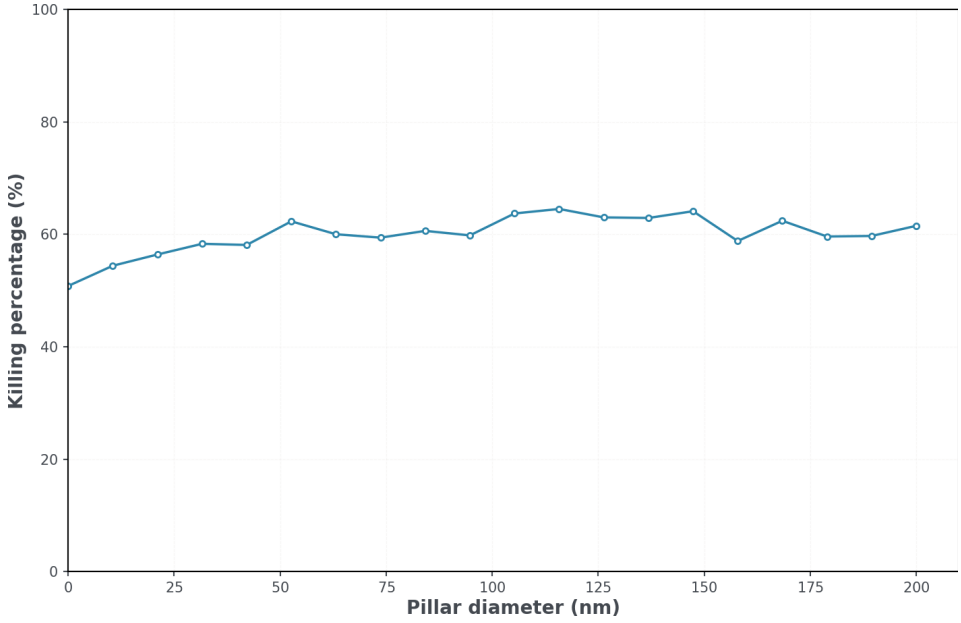


Fig. 5 shows another simulation run where the pillar diameter increases from 0 to 200 nm. The bacteria-killing efficiency has a mild increase. The insight is that when the pillar diameter is larger, the chance of a bacteria falling onto pillars is higher, as the bacteria also have a diameter. This benefits the killing efficiency. Nevertheless, the importance of pillar diameter is much less than pillar-to-pillar spacing.

Figure 5. *Effect of pillar diameter on bacteria killing efficiency*



In another two simulation runs, we vary the bacteria size while keeping the pillar design unchanged. The two bacterial sizes are Bacteria Outside Diameter (d_o) and Bacteria Length (s). As shown in Figs. 6 and 7, increasing bacteria size improves bacteria killing efficiency. The insight is that larger bacteria have a higher chance of falling onto nanopillars.

Figure 6. *Effect of Bacteria Outside Diameter on Bacteria Killing Efficiency*

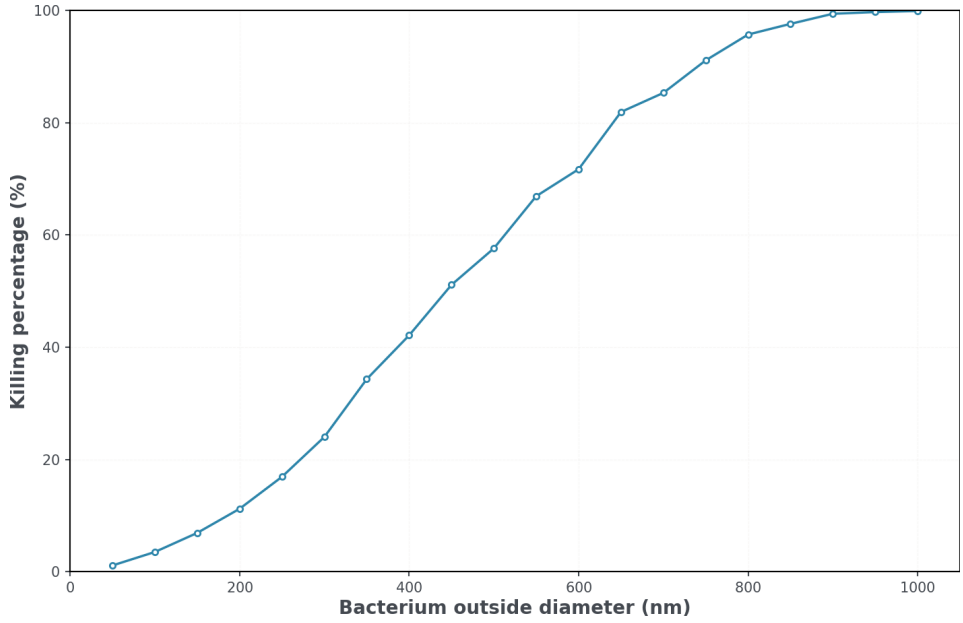
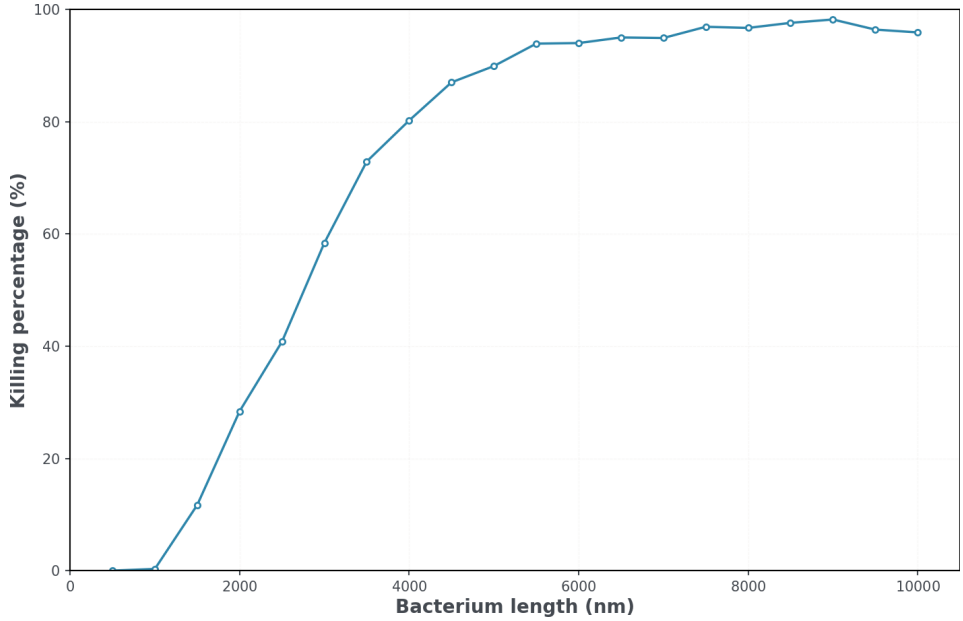


Figure 7. *Effect of Bacteria Length on Bacteria Killing Efficiency*



3.2 Impact of Disorder and Manufacturing Cost

In previous simulations, the nanostructure is assumed in perfect order, i.e, each pillar position is precise, and all pillars exist. In reality, nanostructure is fabricated by expensive machines. Due to fabrication errors, the nanostructure could be imperfect. For example, there are three popular techniques in the industry for fabricating nanostructures: E-beam Lithography (Zhu 2024), Nanoimprint Lithography (NIL) (Dhull 2024), and Self-Assembly Method. They have different levels of cost and fabrication quality, as shown in Table 2.

Table 2. *Three popular nanostructure fabricating techniques*

Fabricating Technique	Disorder Level	Non-Uniformity	Defect Density	Cost
E-beam Lithography	Very Low	< 5 nm	< 0.1 defects/μm²	High
Nanoimprint Lithography (NIL)	Moderate	5–15 nm	0.5–5 defects/ μm²	Moderate
Self-Assembly Method	High	20–50 nm	> 10 defects/μm²	Low

As Table 2 shows, every fabricating technique introduces errors: either the pillars are displaced, not uniformly distributed, or in defect. In this section, we simulate how an imperfect nanostructure affects the bacteria-killing efficiency. Three types of errors are considered in the simulation:

Pillar Dislocation: A pillar is dislocated from its original location. This is modeled by introducing a Gaussian noise to the pillar location. The standard deviation of the Gaussian noise is used to control the magnitude of the Pillar Dislocation

Defect Density: A pillar has a defect. This is modeled by introducing Defect Density that describes statistically, on average, how many pillars in an area have defects, thus not being fabricated

Regional Defect Percentage: An entire region of pillars has defects. This is modeled by dividing the entire pillar array into 10×10 regions, and each region has a probability that all the pillars within are not fabricated. This probability is called the Regional Defect Percentage.

Figures 8–10 show that increasing any of the three error types decreases the bacteria-killing efficiency. Nevertheless, we observe that within the error range of the three fabricating techniques in Table 2, the bacteria-killing efficiency does not appear to differ significantly. For example, Defect Density is the most clearly defined error type in Table 2. As shown in Fig. 9, the bacteria-killing efficiency only decreases from 60% to 50% when switching from E-beam Lithography, the most expensive fabrication technique, to the Self-Assembly Method, the least expensive one. This observation suggests that low-cost fabrication techniques may be preferred when mechanical stress is the primary anti-bacterial factor.

We have also simulated the scenario with multiple error types. As shown in Fig. 11, both Pillar Dislocation and Defect Density. The figure shows that multiple error types have compound effects: when the magnitudes of both error types increase, the bacteria-killing efficiency decreases more significantly than when only one error type increases.

Figure 8. *Effect of pillar displacement on bacteria killing efficiency*

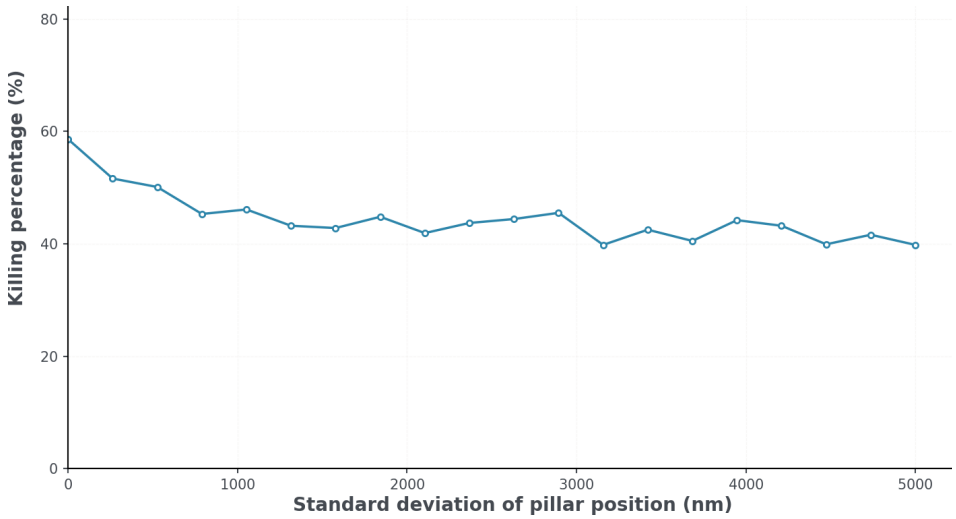


Figure 9. *Effect of individual pillar defect on bacteria killing efficiency*

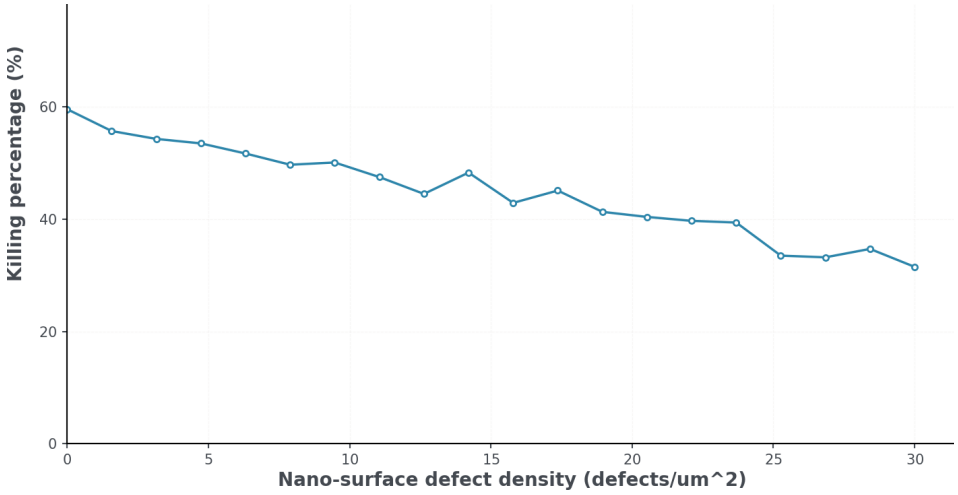


Figure 10. *Effect of a block of pillar defect on bacteria killing efficiency*

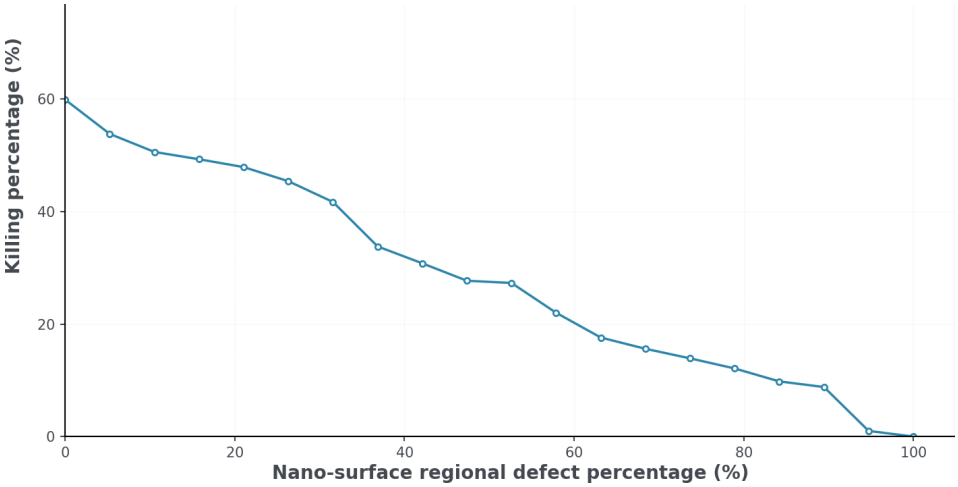
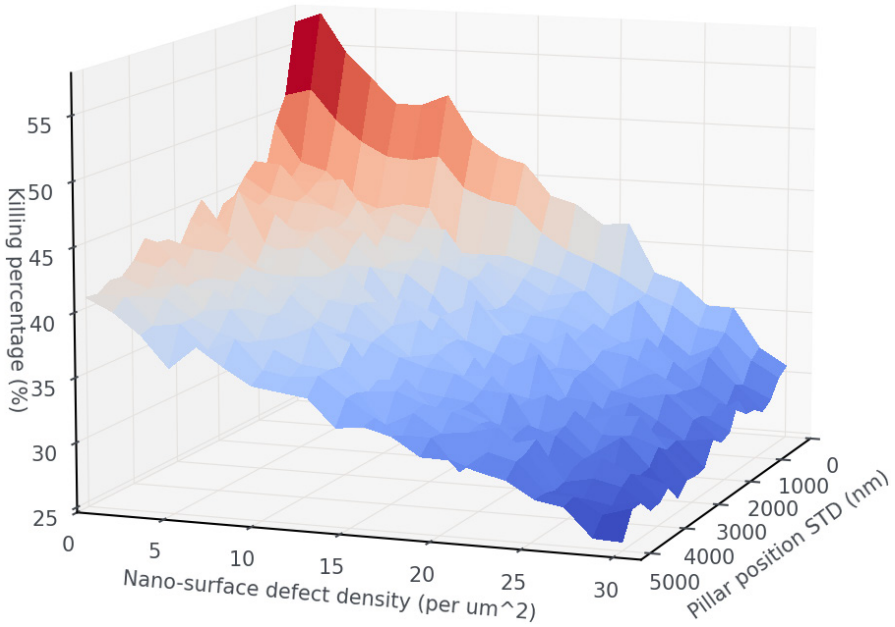


Figure 11. *Effect of co-existence of pillar dislocation and defect on bacteria killing efficiency*



Conclusion

This study proposes both a mathematical and a simulation model to explain the effectiveness of nanopillared surfaces in killing bacteria. We use a mechanical engineering approach to derive an analytical expression of the maximum stress imposed by nanopillars on bacterial membranes. The stress is compared to a critical stress threshold to determine whether the bacteria are killed by nanopillars. We further develop a simulation model to evaluate the interaction between bacteria and nanopillars. The results show that the pillar distribution and size must fall within a specific range to optimize the bacteria-killing efficiency. We further evaluate how existing nanoscale fabrication techniques, with varying costs and quality levels, affect antibacterial effectiveness. The results show that although higher-end fabricating techniques yield higher bacterial-killing efficiency, the gain is marginal compared to most cost-effective fabricating techniques.

References

Linklater, D.P., Baulin, V.A., Juodkazis. (2021). Mechano-bactericidal actions of nanostructured surfaces. Nat Rev Microbiol (19, 8–22). Retrieved from: https://doi.org/10.1038/s41579–020–0414-z

Yi Zhang et. Al. (2023). A smart coating with integrated physical antimicrobial and strain-mapping functionalities for orthopedic implants. Science advances (9). Retrieved from: https://www.science.org/doi/10.1126/sciadv.adg7397

Li W., Thian E. S., Wang M., Wang Z., Ren L. (2021). Surface Design for Antibacterial Materials: From Fundamentals to Advanced Strategies. Adv Sci (Weinh).

Dickson, Mary & Liang, Elena & Rodriguez, Luis & Vollereaux, Nicolas & Yee, Albert. (2015). Nanopatterned polymer surfaces with bactericidal properties. Biointerphases

Ivanova E. P., Linklater D. P., Werner M., Baulin V. A., Xu X., Vrancken N., Rubanov S., Hanssen E., Wandiyanto J., Truong V. K., Elbourne A., Maclaughlin S., Juodkazis S., & Crawford R. J. (2020). The multi-faceted mechano-bactericidal mechanism of nanostructured surfaces, Proc. Natl. Acad. Sci. U.S.A (117 (23)). Retrieved from: https://www.pnas.org/doi/full/10.1073/pnas.1916680117

Kenneth Alambra and Nicholas Swanson. (2025). Beam deflection formulas. Retrieved from: https://www.omnicalculator.com/construction/beam-deflection

Wikipedia (2025). Beam (structure). Retrieved from: https://en.wikipedia.org/wiki/Beam_

Wikipedia (2025). Euler–Bernoulli beam theory. Retrieved from: https://en.wikipedia.org/wiki/Euler%E2%80%93Bernoulli_beam_theory

Agbe and S. Kwofie. (2024). Recent Advances in Mechano-Bactericidal Nanostructured Surfaces for Biomedical Implants and Frequently Touched Surface Applications, Nanotechnology and Nanomaterials. Intech Open.

Bandara C. D. et al (2017). Bactericidal effects of natural nanotopography of dragonfly wing on Escherichia coli. ACS Applied Materials & Interfaces – (9(8)).

Zhu, C., Ekinci, H., Pan, A. et al (2024). Electron beam lithography on nonplanar and irregular surfaces. Microsyst Nanoeng – (10).

Nidhi Dhull (2024). Nanoimprint Lithography: Methods and Material Requirements. Retrieved from: https://www.azonano.com/article.aspx? ArticleID=6755

Nguyen S. H.T., Webb H. K., Hasan J., Tobin M. J., Crawford R. J., Ivanova E. P. (2013). Dual role of outer epicuticular lipids in determining the wettability of dragonfly wings. Colloid Surf B Biointerfaces – (106).

submitted 15.01.2026;
accepted for publication 01.02.2026;
published 28.02.2026

Contact: Tina.fanting.m@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 5. Medicine

DOI:10.29013/ESR-26-1.2-61-66

THE EFFECT OF NAIL EXTENSIONS ON THE HEALTH OF THE NAIL PLATE: DAMAGE MECHANISMS AND PREVENTION METHODS

Saduova Tolkyn [1]

[1] Independent research, Astana, Kazakhstan

Cite: *Saduova Tolkyn (2026). The Effect of Nail Extensions on the Health of the Nail Plate: Damage Mechanisms and Prevention Methods. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-61-66

Abstract

This article examines in detail the effect of various nail extension techniques on the condition of the natural nail plate. Attention is paid to both chemical and mechanical factors that can harm the nail. The processes occurring with the nail under the influence of primers, monomers, gels and acrylates, as well as the effects of prolonged wearing of artificial coatings, are analyzed. Special attention is paid to changes in the structure of keratin, dehydration of the nail, thinning and delamination of the plate, impaired microcirculation and possible fungal complications that may occur if proper working techniques are not followed. The article provides up-to-date data on the causes of nail damage during sawdust, aggressive preparation of the nail plate, and the use of non-sterile tools. In addition, the authors propose scientifically based prevention methods gentle nail preparation techniques; selection of hypoallergenic materials; proper nail care between treatments; determination of optimal correction intervals; and ways to restore nails after removing artificial coating.

Keywords: *nail extensions, nail plate, nail damage, gel, acrylic, dehydration, thinning of the nail, allergy to materials, prevention, and nail restoration*

Relevance of the study

With the increasing popularity of nail extension and strengthening procedures, more and more people are faced with damage to the nail plate of varying degrees. Although modeling techniques such as gel, acrylic, and polygel extensions have become very common, the potential health risks of natural nails remain unnoticed by both beauty industry professionals and clients.

Chemicals contained in nail extension materials, as well as mechanical effects during coating removal, ultraviolet radiation, non-compliance with safety regulations and insufficient qualifications of artisans can cause thinning of the nail plate, matrix injuries, allergic reactions and the development of microbial complications. The relevance of the study is due to an increase in the number of complaints about the deterioration of nails

after regular use of artificial coatings, as well as the lack of systematic data on the mechanisms of their damage and effective preventive measures.

The purpose of the study

To investigate the main causes of damage to natural nails with various extension methods and develop the most effective prevention methods to minimize the risk of structural, chemical and biomechanical changes in the nail plate.

Materials and research methods

The study used modern scientific publications on dermatology, cosmetology and materials science, as well as the results of practical observations of nail service masters. The methodology of the work included a comparative analysis of the chemical composition of gel, acrylic and polygel systems. Their effect on the keratin structure and the level of dehydration of the nail plate was evaluated. In addition, mechanical aspects were considered: the degree of abrasive action during sawdust, the effect of hardware manicure, the features of surface preparation and coating removal.

The study used methods of visual analysis of the condition of nails both before and after prolonged wearing of artificial materials. In addition, the frequency of allergic and microbial complications was analyzed. Preventive technologies such as gentle treatment methods, hypoallergenic materials, optimization of the correction regime and recommendations for nail restoration were also studied.

The results of the study

The history of studying the effect of artificial coatings on natural nails is closely related to the development of the modeling industry, which originated in the middle of the XX century.

The first steps towards artificial nail lengthening were taken in the 1950s and 1960s, when beauty artists began using dental acrylates. At that time, the main attention of scientists was focused on the chemical composition of materials, since acrylic monomers often caused severe allergic reactions and skin irritation. This prompted dermatologists to study for the first time the systemic effects of monomers such as methyl methacrylate on the nail plate and surrounding tissues.

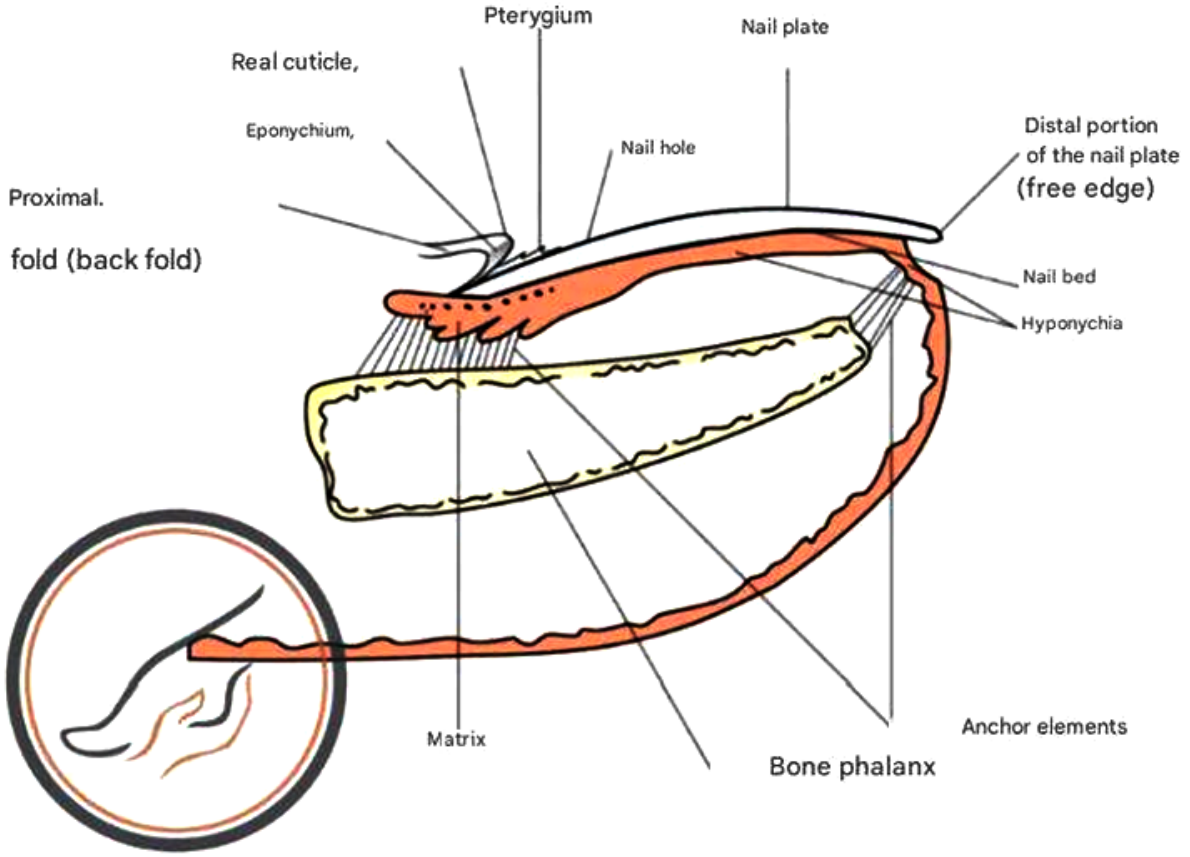
In the 1970s and 1980s, with the expansion of the use of acrylic nails, research began to focus on mechanical damage: thinning of the nail, violation of the surface layer of keratin, increased fragility and the risk of infection. Dermatologists began to notice that some people's nails peel off after using such products, chemical burns and fungal infections occur. In this regard, the first restrictions were imposed on the use of the most aggressive components.

In the 1990s, new gel technologies emerged, which led to a surge in scientific research. The attention of scientists has shifted to the study of photoinitiators, the interaction of gels with ultraviolet radiation and the effects of dehydration of the nail during the preparation of its surface. Potential allergens were identified among the components of gels and photo-cured systems, and the effect of overheating during polymerization on the structure of the nail matrix was investigated. During this period, the first systematic reviews appeared on microbiological complications that can occur due to improper application and removal of coatings (Kondalova I. A., Kushnaryova M. A., 2022).

Since the 2000s, research has become more multifaceted. Scientists have begun to study the biomechanical properties of the nail plate, its reaction to prolonged wearing of coatings and the changes that occur during regular extension and removal procedures. Special attention was paid to the issues of sanitary and hygienic safety, sterilization of instruments and prevention of microbiological risks. A comparison was made of various modeling methods – acrylic, gel and biogel – in terms of their effect on the keratin structure.

In recent decades, the focus has been on damage prevention, the development of hypoallergenic materials and the creation of gentle technologies for the preparation of the nail plate. Research has begun to take into account not only chemical and mechanical factors, but also the individual characteristics of the nail plate, as well as the professional skills of the artisans and the impact of improper self-care (Fig. 1).

Figure 1. *Diagram of the nail structure*



Modern research reveals a complex mechanism of negative effects on nails, starting with microcracks, thinning, and ending with immune reactions and deterioration of regeneration. Due to this, scientifically based prevention methods have been developed, which include minimizing sawdust, using safe formulations, and following optimal correction regimens.

This gave rise to a modern scientific basis that allows us to understand how various nail extension technologies affect the condition of nails and what measures can minimize the risk of damage while maintaining an aesthetic appearance (Birzhankyzy B. I., 2022).

It is important to note that modern scientific research and clinical observations indicate that prolonged wearing of acrylic, gel and polygel systems can lead to damage to the nail plate. This occurs under the influence of a combination of chemical, mechanical and microbiological factors. One of the most common examples is thinning of the nail after repeated extension and removal, especially if the sawdust process was aggressive. Regular grinding of the nail surface leads to damage to the keratin layers, which reduces the strength and makes it more vulnerable to delamination (Dinani N., George S., 2019). In practice, dermatologists often encounter cases when, after 6-12 months of continuous wearing of artificial nails, clients encounter increased fragility, soreness and slow plate growth. This may be due to microtrauma of the matrix (Table 1).

Another modern example is allergic contact dermatitis, which occurs due to unpolymerized monomers found in gels and acrylics. In recent years, the number of complaints related to allergies to acrylates such as HEMA and di-HEMA has increased significantly. Clients complain of itching and redness of the skin around the nails, and in more severe cases, peeling of the nail plate. It has been proven that such reactions most often occur when using low-quality materials or when the polymerization mode in the lamp is incorrect. As a result, some of the monomers remain active and penetrate the skin, causing irritation and inflammation.

Currently, a common type of nail damage is “green nail”, a bacterial infection caused by

Pseudomonas aeruginosa. It occurs when a moist, airtight cavity forms between an artificial material and a natural nail, creating ideal conditions for bacterial growth. Such problems often arise due to violations in modeling techniques, too rare corrections, or when clients try to fix a broken nail on their own. In such cases, the nails acquire a characteristic greenish tint, and without timely treatment, the infection can penetrate deeper into the nail bed.

Table 1. *The effect of nail extensions on the health of the nail plate*

№	Positive impact	Negative impact
1	*The aesthetic side* The extended nails look very neat and can be decorated with a variety of designs.	*Damage to natural nails* The process of removing nail extensions can damage the top layer of the natural nail plate.
2	*Protection* Extensions can become a reliable barrier that protects your natural nails from mechanical damage and breakage.	*Infections* Improper application or removal of nail polish can lead to the penetration of bacteria or fungi under the nail plate.
3	*Alignment and strengthening of the nail plate* Nail extensions allow you to give them the desired shape, strengthen the structure and prevent possible deformations that may occur due to mechanical stress.	*Allergic reactions* Some of the materials used for extensions can cause allergic reactions or skin irritation.
4	*Support during the recovery period after illnesses* After hypovitaminosis, hormonal changes or long-term diseases, nails can become very brittle. Artificial material not only facilitates the rehabilitation process, but also prevents new injuries.	*Chemicals* The gels, acrylics and other substances used in the build-up process can be toxic with prolonged exposure.

Mechanical damage includes detachments, cracks, and deformations of the nail plate, which can occur due to nails that are too long or incorrectly modeled. Recently, traumatologists and dermatologists have increasingly encountered situations where excessive length or unsuccessful modeling of an artificial nail leads to the separation of the natural nail upon impact. This can cause severe pain, bleeding, and prolonged disruption of nail plate growth.

Modern prevention methods are aimed at minimizing these risks. One of the key approaches is the gentle preparation of the nail plate, without aggressive cutting. For clients with sensitive skin, it is recommended to use hypoallergenic formulations without HEMA. It is also important to strictly observe polymerization modes and use lamps of sufficient power to avoid the presence of unpolymerized monomers. From the point of view of hygiene, prevention includes thorough antiseptic treatment of nails before applying the material and mandatory corrections every 3-4 weeks. This prevents the formation of pockets where bacteria can multiply.

In addition, experts advise clients to take breaks between extensions, use nourishing cuticle oils, as well as strengthening agents based on keratin or biotin. It is important to avoid removing the coating yourself, as this can lead to injury to the nail plate. These measures will help significantly reduce the risk of damage and maintain the health of natural nails, even with frequent use of artificial coatings.

However, it is worth noting that in modern practice, nail extensions are often accompanied by some problems. They can be related to both materials and technology violations.

One of the most common problems is the thinning and weakening of the nail plate. This is due to regular aggressive sawdust, which

disrupts the upper keratin layers of the nail and makes it more brittle and painful.

Another common problem is allergic contact dermatitis, which can be caused by acrylates in gels and acrylic formulations. This is especially common when using products with HEMA and when there is insufficient polymerization in the lamp. Clients may experience itching, redness, burning, and even detachment of the nail plate. In recent years, this problem has become more common.

A bacterial lesion known as a "green nail" represents a separate category of problems. It occurs due to the formation of air pockets between the natural nail and the artificial coating, which creates favorable conditions for the reproduction of Pseudomonas aeruginosa. The main causes of problems are poor preparation of the plate, non-compliance with the technology of applying the material, peeling, increased humidity and contact with water without the use of protective equipment, as well as insufficient sterility of instruments. Gradually, the bacterial colony spreads under the coating, weakening the structure of the nail. This can lead to its delamination, brittleness and prolonged recovery after removal of the affected area.

For prevention, it is important to thoroughly degrease and dry nails, use materials with good adhesion, completely remove detachments, keep clean and avoid contact with water after the procedure. If a green spot appears on the nail, the coating must be removed to ensure that the nail is dry. Then you should consult a specialist who will assess the extent of the lesion and give recommendations on proper nail care.

An equally serious problem is mechanical damage: detachment, cracks, deformations and partial separation of the natural nail. These phenomena are especially common with long artificial nails, irregular architecture, or shock loads. The situation is aggravated by non-compliance with sanitary standards, the use of substandard materials, irregular corrections and self-removal of the coating. All this significantly increases the risk of injury and infection.

We are convinced that effective elimination of the negative consequences that may occur after nail extensions is possible only with an integrated approach. This approach should include proper technique, choice of safe materials, and proper care.

To prevent thinning and weakening of the nail plate, it is important to minimize aggressive sawdust. To do this, work at low milling speeds and remove the old coating in layers without affecting the artificial material. The use of soft buffs and the refusal to completely wear off the upper keratin layers will help maintain the strength of natural nails and avoid painful sensations.

It is important to choose high-quality materials with a minimum content of HEMA and other aggressive monomers, as they often cause allergic contact dermatitis. Careful polymerization in a lamp of sufficient power reduces the risk of gel not leaking, which can cause burning and allergic reactions.

To avoid bacterial complications, it is necessary to ensure complete adhesion of the material to the nail plate, eliminating the formation of air bubbles. The master must strictly observe all sanitary standards, disinfect tools and carefully prepare the nail plate for coating, avoiding waterlogging and dust formation. If a green spot does appear, the artificial material should be completely removed, treated with an antiseptic and given time to recover until the natural color returns completely.

Mechanical damage can be prevented if the artificial nail architecture is done correctly, the optimal length is chosen, and recommendations for hand loads are followed. In case of cracks or peeling, it is important to contact the master in a timely manner, rather than trying to remove the coating yourself, so as not to damage the natural nail.

An important aspect of prevention is the proper removal of the coating. It is recommended to carry out the procedure under the supervision of a master using a milling cutter or special liquids, as self-removal can lead to injury to the nail plate. If signs of damage appear, it is recommended to take breaks between procedures. Firming oils and creams containing vitamin E and nutritional components will help speed up the restoration of the nail plate. If all these measures are followed, the risks can be significantly reduced and the nails can remain healthy even with frequent extensions.

Conclusions

The health of natural nails with regular extensions directly depends on following the correct technique of the procedure, using safe materials and ensuring proper care. Most problems, such as plate thinning, allergic reactions, detachment, or bacterial complications, are not the inevitable consequences of build-up, but arise from violations of technology or improper handling of the coating.

With the work of an experienced artisan, the use of high-quality materials and careful attitude towards the client, nail extensions remain a safe and comfortable procedure. It is important to remember that prevention is always better than treatment, so regular corrections; careful removal of coating and supportive home care will help keep your nails strong and healthy even with prolonged wearing of artificial material.

References

Birzhankyzy B. I. Modern practice of using innovative technologies in nail strengthening // Current research. 2022. – No. 36 (115).

Kondalova I. A., Kushnaryova M. A. On the problem of nail extensions // Advances in modern natural science. 2013. – No. 9. – P. 49–49.

Dinani N., George S. Nail cosmetics: a dermatological perspective // Clinical and experimental dermatology. 2019. – Vol. 44. – No. 6. – P. 599–605.

submitted 12.02.2026;
accepted for publication 27.02.2026;
published 28.02.2026

Contact: saduova1212@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 6. Pedagogy

DOI:10.29013/ESR-26-1.2-67-70

SUFISM IN XVI–XVII CENTURIES CENTRAL ASIA: DOCTRINAL FOUNDATIONS AND PEDAGOGICAL INTERPRETATION

Nusratov Anvar Nematjonovich [1]

[1] Professor of the Department of "Pedagogical Education" of the Bukhara State Pedagogical Institute, PhD

Cite: *Nusratov, A.N. (2026). Sufism in XVI–XVII Centuries Central Asia: Doctrinal Foundations and Pedagogical Interpretation. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-67-70

Abstract

This article examines Sufism in Central Asia during the XVI–XVII centuries as a historically grounded system of moral and pedagogical formation. Moving beyond purely theological interpretations, the study analyzes Sufi traditions as non-formal educational models that played a significant role in ethical education and social regulation. Using a qualitative historical–pedagogical methodology, the research draws on classical Sufi texts, historical sources, and contemporary scholarly studies, including works by Central Asian and Uzbek researchers.

The findings indicate that Sufi pedagogy was primarily oriented toward character formation, moral self-discipline, and experiential learning. Central to this educational system was the mentorship-based *murshid–murid* relationship, which functioned as an individualized pedagogical model emphasizing continuous moral guidance and self-reflection. Unlike madrasa-based education, Sufi instruction integrated ethical training into everyday social and professional life, extending its educational influence to diverse social groups.

The study argues that Sufi pedagogy represents an indigenous and holistic model of moral education that anticipated key principles of modern learner-centered and character-based educational approaches. Recognizing the pedagogical dimensions of Sufism contributes to a deeper understanding of the history of education in Central Asia and offers insights for contemporary discussions on moral and holistic education.

Keywords: Sufism; Central Asia; XVI–XVII centuries; Naqshbandiyya; Spiritual Education; Moral Pedagogy; Murshid–Murid Relationship; Informal Education

Introduction

During the XVI–XVII centuries, Central Asia was a major center of Islamic intellectual and cultural life where religious thought, social practice, and educational traditions closely interacted. In this context, Sufism functioned not only as a mystical doctrine but also as a comprehensive system of moral

and educational formation. Sufi orders, particularly the Naqshbandiyya, played an important role in shaping ethical norms and informal pedagogical practices within Central Asian societies (De Weese, 2016).

Unlike madrasa-based education, which emphasized jurisprudence (*fiqh*) and theology (*kalam*), Sufi education focused on inner transformation, character formation, and mentorship-based learning. Central to this system was the *murshid–murid* relationship, which functioned as a structured pedagogical model grounded in moral supervision and gradual personal development (Knysh, 2017). During periods of political instability and social change, Sufi pedagogy provided moral continuity and stability. Ethical values such as humility, self-restraint, and social responsibility were transmitted through lived practice rather than formal instruction, allowing Sufism to function as a complementary educational system accessible to broader social groups (Bertels, 1965).

This article aims to analyze the doctrinal foundations of Sufism in XVI–XVII century Central Asia and to interpret its pedagogical significance within the broader history of non-formal education.

Literature Review

Research on Central Asian Sufism has primarily focused on historical, philosophical, and socio-cultural dimensions, while its pedagogical aspects have often remained implicit. Existing literature can be grouped into historical studies of Sufi orders, analyses of Sufi ethical concepts, and pedagogical interpretations of Sufi practices.

Historical scholarship emphasizes the social and educational roles of Sufi orders, noting that Sufi lodges functioned as centers of moral education where knowledge was transmitted through personal example and communal practice rather than formal curricula (DeWeese, 2016). Philosophical studies examine concepts such as *tazkiya al-nafs*, *riyāḍa*, and *ṣuḥba*, which form the epistemological basis of Sufi pedagogy and emphasize experiential and lifelong ethical development under spiritual guidance (Knysh, 2017).

More recent scholarship interprets the *murshid–murid* relationship as an early mentorship-based pedagogical model characterized by individualized guidance and moral accountability (Bertels, 1965). Despite these contributions, focused analysis of Sufism as a pedagogical system in the specific context of XVI–XVII century Central Asia remains limited. This study addresses this gap by integrating historical and pedagogical perspectives.

Methodology

This study employs a qualitative historical–pedagogical research design to examine the educational dimensions of Sufism in Central Asia during the XVI–XVII centuries. The research is grounded in an interpretive historical approach that enables contextual analysis of Sufi teachings within their socio-cultural, religious, and intellectual environments. This approach is particularly suitable for the study of non-formal educational systems such as Sufi pedagogy, which operated outside institutional schooling while exerting significant influence on ethical education and social conduct (DeWeese, 2016; Bertels, 1965).

From a pedagogical perspective, classical Sufi concepts—including *tazkiya al-nafs* (self-purification), *riyāḍa* (spiritual discipline), and *ṣuḥba* (companionship)—are interpreted as educational mechanisms aimed at character formation and moral development. Uzbek scholars emphasize that these concepts reflect a coherent educational philosophy centered on cultivating the "perfect human being" (*insān al-kāmil*), corresponding to contemporary theories of holistic and character-based education (Komilov, 2009; Niyozmetov, 2018).

The study is based on systematic analysis of both primary and secondary sources. Primary sources include classical Sufi texts, doctrinal treatises, and hagiographical works circulated in Central Asia during the XVI–XVII centuries, providing insight into Sufi educational ideals and ethical norms (Bertels, 1965; Knysh, 2017). Secondary sources comprise contemporary studies in Islamic studies, history, philosophy, and pedagogy, with particular attention to Uzbek scholarship examining Sufism as a cultural and educational phenomenon (Komilov, 2009; Abduqodirov, 2020).

Qualitative content analysis identifies recurring pedagogical themes such as moral self-regulation, mentorship-based learning, experiential education, and ethical accountability, which are interpreted through pedagogical theory (Niyozmetov, 2018; DeWeese, 2016). Comparative analysis contrasts Sufi educational practices with madrasa-based education, highlighting Sufism as an alternative and complementary educational model within Central Asian society (Komilov, 2009; Bertels, 1965).

Reliability is ensured through data triangulation, while validity is strengthened by the consistent application of pedagogical concepts to historical material (Knysh, 2017; Abduqodirov, 2020). As a historical and textual study, ethical considerations are limited to accurate citation, faithful representation of sources, and avoidance of anachronistic interpretations, ensuring respect for the conceptual integrity of Sufi teachings (DeWeese, 2016; Komilov, 2009).

Naqshbandiyya Order and Pedagogical Practice in XVI–XVII Centuries Central Asia

During the XVI–XVII centuries, the Naqshbandiyya order emerged as one of the most influential Sufi traditions in Central Asia, significantly shaping spiritual life, social organization, and moral education. Unlike Sufi orders that emphasized ascetic withdrawal, the Naqshbandiyya promoted active social engagement combined with spiritual discipline. This balance between inner purification and outward responsibility formed the pedagogical foundation of Naqshbandi education (Komilov, 2009; DeWeese, 2016).

A key pedagogical principle of the Naqshbandiyya was *"dil ba yār, dast ba kār"* (the heart with God, the hand at work), which expressed a holistic educational philosophy integrating spiritual awareness with practical and social activity. This principle encouraged learners to develop ethical consciousness while fulfilling professional and communal responsibilities and has been interpreted by Uzbek scholars as an early model of integrative education combining moral formation with social competence (Komilov, 2009; Abduqodirov, 2020).

The core instructional mechanism of Naqshbandi pedagogy was the *murshid–murid* relationship, functioning as a mentorship-based educational model. Education was individualized and grounded in continuous moral guidance and personal example rather than formal curricula. The *murshid* served as teacher and moral exemplar, while the *murid* engaged in sustained self-discipline and ethical self-reflection (Knysh, 2017; Bertels, 1965). This structure closely corresponds to modern learner-centered pedagogical approaches emphasizing formative learning outcomes (Niyozmetov, 2018).

Naqshbandi education relied primarily on experiential learning through daily activities, communal interaction, and spiritual practices such as silent *dhikr*, ethical self-monitoring (*muhāsaba*), and companionship (*ṣuḥba*). These practices functioned as pedagogical tools for cultivating moral awareness and ethical responsibility and align with contemporary models of reflective and experiential learning (Knysh, 2017; DeWeese, 2016).

Naqshbandi communities often operated as informal educational spaces accessible to diverse social groups, facilitating the diffusion of ethical norms beyond elite circles. Ethical formation remained the primary goal of Naqshbandi pedagogy, with virtues such as humility, patience, self-restraint, honesty, and social responsibility cultivated through sustained practice. This character-oriented approach represents an indigenous model of moral education integrating spirituality, social engagement, and personal accountability (Komilov, 2009; Abduqodirov, 2020).

Conclusion

This study demonstrates that Sufism in Central Asia during the XVI–XVII centuries functioned as a coherent system of moral and pedagogical formation. Sufi traditions, particularly within the Naqshbandiyya order, provided mentorship-based, experiential, and character-oriented education that complemented formal religious institutions. Sufi pedagogy emphasized internal transformation, ethical discipline, and the integration of education with everyday life. Uzbek scholars highlight that such approaches align with contemporary models of moral and value-oriented education, in which ethical competence is developed through sustained

practice and social engagement (Ismailov, 2016; Qodirov, 2019).

The inclusive and community-based nature of Sufi education contributed to social cohesion during periods of political instability and offers valuable historical insights for modern discussions on character education, mentorship, and holistic learning.

References

Abduqodirov, A. (2020). Markaziy Osiyoda tasavvuf va ma'naviy tarbiya masalalari. *O'zbekiston ijtimoiy-gumanitar fanlari axborotnomasi*, – 4. – P. 33–41.

Bertels, E. E. (1965). *Sufizm i sufijskaya literatura*. Moscow: Nauka.

DeWeese, D. (2016). *Sufism in Central Asia: New Perspectives on Sufi Traditions*. Leiden: Brill.

Ismailov, Z. (2016). *Ma'naviy tarbiya nazariyasi va amaliyoti*. – Tashkent: O'zbekiston.

Karimov, S. (2017). Ta'limda ijtimoiy muhit va shaxs kamoloti. *Pedagogik ta'lim*, – 3. – P. 28–35.

Knysh, A. (2017). *Sufism: An Introduction to the Mystical Tradition of Islam*. Cambridge: Cambridge University Press.

Komilov, N. (2009). *Tasavvuf*. – Tashkent: Movarounnahr.

Niyozmetov, R. (2018). Tasavvuf ta'limotining ma'naviy-axloqiy asoslari. *Sharq falsafasi*, – 2. – P. 45–52.

Qodirov, M. (2019). Tajribaga asoslangan ta'lim va axloqiy kompetensiyalar rivoji. *Zamonaviy ta'lim*, – 2. – P. 41–47.

submitted 27.01.2026;
accepted for publication 11.02.2026;
published 28.02.2026

Contact: nvrnusratov@gmail.com

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 7. Philology and linguistics

DOI:10.29013/ESR-26-1.2-71-73

THE MYSTICAL DEVINE EPIPHANY MANIFESTATION OF THE ALBANIAN BAYTAJIES THROUGH THE ARABIC-OTTOMAN LETTERS

Muhamed Mustafi [1]

[1] PhD of Philology Full Prof. of Albanian and Methodology of Language Faculty of Islamic Sciences, Skopje, N. Macedonia

Cite: *Muhamed Mustafi (2026). The Mystical Devine Epiphany Manifestation of the Albanian Baytajies through the Arabic-Ottoman Letters. European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-71-73

Abstract

The issue of the manifestation of the divine epiphany in the mystical thoughts of the Baytajies is crucial and has a deep esoteric meaning because it was part of their life, which developed through this principle. The Baytajean mystical thoughts derive from the worldview of the divine epiphanic appearance in every natural phenomenon, and for this reason, they followed with full attention every natural movement, expressing that there lies the precision and divine manifestation. The Baytajies believed that the divine epiphany is considered the best and most serious guardian in protecting society and nature from negative phenomena and that any negative behavior in the world negatively affects this manifestation and causes social consequences, which will create chaos in the social order and will disrupt the relationship between the Creator and the creatures.

Keywords: *Mysticism, Epiphany, Manifestation, Divine, Albanian, Baytajies*

Introduction

The constellation of Albanian writers, known as bejtexjinj, are known for using the Arabic-Ottoman script in their artistic writings. The influence of the then literary culture on the formal weaves of their poems and within their poetic verses has made us clearly notice mystical thoughts alongside various religious, social and cultural thoughts.

Islamic mysticism has been part of the lives of those who have experienced this specific state and have expressed such feelings in prose and poetry, and since the influence on our territories has been very visible during the Ottoman rule, it has been natural that this constellation of Baytajean writers also wrote about mystical worldviews, experiences and perceptions, but in Arabo-Ottoman script.

Devine Epiphany Manifestation of the Baytajies

In the world of soufisme, the principle of epiphany occupies an important place in thinking about creation and the manifesta-

tion of divine majesty in His creatures, and this manifestation is related to the creation of the universe and its various forms. This epiphanic manifestation has an infinite nature because it belongs to the creative divine Majesty.

The being of God is unknown but the act of creation makes it visible in this world. The distinction between His beings and attributes is conceptual because there is no ontological distinction between them. (William, 1983:42)

The argument put forward on its account derives its power from the thesis that confirms that the truth of any cognitive act is, in fact, quite different from what the scholar with an esoteric orientation believes.

Even in the case of normal perception of an external sensory object, it cannot be said that the mind has a vision of the form that would be in external matter. Sensory cognition does not consist of this because its object is not such a form. The matter observed by the senses is only a manifestation of the symbolic form. The real form is seen if the manifestation is observed from within, and that it is reached by starting from the spiritual knowledge. (Henry Corbin, 1997:67)

Guta describes this real form of vision in these words:

(God) has made His force shown,
He has decorated the heavens with stars,
and He has placed the lamps in order... (Guta: 35)

The external creative phenomenon must be in complete harmony with the internal spiritual phenomenon because, if there were no coexistence between them, then nothing would be harmonious and there would be no compatibility between the Creator and the created.

And this creation must be in complete harmony with the creator. So, the essence of God, as I said before, is identical with His creative attributes, and this identity is illustrated very beautifully in the words of Zenel Bastar:

I am the sun, I am the moon
I am the star, I am the rainbow
I am the day, I am the night! (Jorgo Bulo, 3/1999:32)

This epiphanic manifestation is presented by the mystic's great love for God and by the great energy that is formed between man and God.

The mystic accepts such a manifestation through love and feels a unity that is realized through this powerful love that arises from within under the influence of the outside.

The mystic is aware that what is seen is difficult to understand and that the true divine being cannot be seen through them. So, what is seen is the visible creative epiphanic form but not the essence of God. In this context, the Anonymous of Vushtria says:

Everything we have is perishable,
The face of the truth is eternal,
What you see is Him,
Can't you see it, or did I not tell you? (Hajdar Salihu, 1987:118)

The Baytajean mystics were inspired not only by nature but also by man himself, and this initiates the well-known mystical principle that 'everything invisible of God [was] invisible in his human form.' (Henrry Corbin, 1997:70)

According to Baba Salihi, God also exists within nature:

God is in man
And his own face. (Baba Salihi, 2–3/1999:129)

So, man has the face of God, and in this context, he further continues and says: 'God gave man his face by creating him with three capitals: the first is thought, the second is the soul, the third is the human face.

The human face is the secret power that benefits sanctification. Everything that is created from this unique reality returns to its essence.' (Ibidem)

Since creation was realized because God wanted to manifest himself in this world, then we will see that this manifestation in man will be considered true because such an epiphanic manifestation also exists in man himself.

Dervish Hasani describes this divine epiphanic manifestation in man as follows:

I am The truth,
I have found myself in myself! (Hajdar Salihu, 1987:167)

The divine epiphanic manifestation is not only observed in nature and in the human body but also in the human heart.

Material manifestation is seen with the senses of sight, while the heart sees what can-

not be seen with the eyes. This is what makes a person see when 'God lights a spark in the heart!' (Montgomery, 1963:134)

The manifestation within the heart of the divine spark is clearly appreciated in the words of Sheikh Mala:

Oh my God, my Lord
Revive our hearts by seeing you
Light up our hearts, I saw all the prophets
Show us the way, oh Guide! (Hajdar Salihu, 1987: 387, 389).

According to mystical experience, the man who sees the divine manifestation everywhere in the world, even within himself, does not see any other thing, and in this way he convinces himself that, since every creature is an epiphanic phenomenon, he lives within the truth, and that there is no distance between him and the divine being.

The mystic who experiences this experience to such a high degree, declares and says what Dervish Salihu also says:

I am united with the Truth! (Ibidem:255).

This precious treasure that is observed in the external and internal world is the source of inspiration for the testimonies of the mystical ascetics for a high achievement in their contemplative Sufi life and in their deep metaphysical Sufi thinking.

Conclusion

The study of such mystical thoughts of the mystics cannot bring any expected exact scientific result because the entire mystical experience is considered individual and the inner mystical feelings are very difficult to describe in words in a perfect way. Such experiences are a mirror of the reflection of a deep spiritual state, which can be truly understood only if experienced and only if man passes the gradual stages of the rise of inner purity to the highest stage which in the mystical notion is called «The Perfect Man» (Al-Insan Al-Qamil). This specific state makes man see the divine epiphanic mystical manifestation everywhere and in everyone and it is precisely for this experience that the mystical authors wrote.

Albanian poets experienced mystical feelings with spirit and writings just as the famous German poet Goethe experienced them, but unfortunately, they did not gain Goethe's international authority because the communist elite prevented them and caused their works to be covered with thick dust. I hope that the dust from their works will be erased and that they will enjoy the deserved authority in Albanian and World literature just as the German Goethe enjoys because they have a common and identical source of mystical inspiration.

References

Baba Rexhepi. (1995). Misticizma islame dhe Bektashizma, ribotoi Kryegjyshata Botërore Bektashiane, – Tiranë.
Corbin, Henry. (1997). Historia e filozofise islame, Logos-A, Shkup.
Guta, Mulla Vesel Xheladin. Perendia me frymëzoi, Focus, Shkup.
Hajdar Salihu. (1987). Poezia e bejtexhinjve, Prishtinë.
Jorgo Bulo. (1999). Zenel Bastari dhe poezia e bejtexhinjve, Perla, Tiranë, – 3/1999.
Kur'ani i Madhërishëm. (2006). (Përktheu kuptimet e tij nga gjuha arabe Prof. Hasan I. Nahi), përgatiti për botim: Instituti Shqiptar i Mendimit dhe i Qytetërimit Islam (AIITC); – Tiranë.
Montgomery W. Watt. (1971). Muslim intellectual, University press, Edinburgh.
William C. Chittick. (1983). The sufi path of love, State University of New York press.

submitted 12.02.2026;
accepted for publication 26.02.2026;
published 28.02.2026

Contact: meti@t.mk

European Science Review 2026,
No 1–2
ISSN 2310-5577

PREMIER Publishing
ppublishing.org

Section 8. Study of art and cultural studies

DOI:10.29013/ESR-26-1.2-74-77

CHANGES IN THE GLOBAL CONTEXT OF TRADITIONAL PATTERNS DESIGN (COMPARATIVE ANALYSIS)

Mahliyo Xoliqova [1]

[1] PhD., National institute Fine arts and Design after named Kamoliddin Behzod, department of Dizayn, Toshkent, Uzbekistan

Cite: *Mahliyo Xoliqova (2026). Changes in the Global Context of Traditional Patterns Design (Comparative Analysis). European Science Review 2026, No 1–2.* https://doi.org/10.29013/ESR-26-1.2-74-77

Abstract

This article analyzes the changes occurring in the design of traditional ikat fabrics in a global context based on color, technique, and cultural-semantic aspects. The research objects selected are India's Patola, Malaysia's Pua Kumbu, Indonesia's Geringsing, Japan's Kasuri, and Uzbekistan's Atlas fabrics. The article conducts a comparative analysis of the coloristic system, resist dyeing technique, pattern composition, and semantic load of these fabrics. According to the research results, Southeast Asian ikats (Pua Kumbu, Geringsing) have a more ritual-protective and cosmological color system, while the Indian Patola stands out with its high-contrast and complex symmetrical color composition. Uzbekistan's atlas has actively adapted to global fashion processes with its colorful expressiveness and free composition, while Japanese kasuri demonstrates aesthetic simplicity based on minimalism and indigo dominance. In the process of globalization, traditional ikat fabrics are undergoing transformation through technological modernization, the use of synthetic dyes, and adaptation to market demands. At the same time, their regional identity and color-semantic system are preserved. The research reveals the interpretation of traditional ikat fabrics in modern design and the interconnection between cultural heritage and fashion.

Keywords: *abrband, ikat, Patola, Pua Kumbu, Geringsing, Kasuri, atlas, global transformation, traditional textiles*

Introduction

The word "ikat" was introduced into the European Weaving Dictionary by Professor A. R. Hein in 1880. The word was adopted into the Dutch lexicon as ikatten and into the English language as ikat, meaning both the process and the finished fabric. All warp ikats have common as well as regional characteristics. While there are clear similarities in style, technique and decoration, they are all linked to the historical and cultural origins of the community. Factors such as geo-

graphical location (remote), topography (difficult) and old local cultural elements (strict) serve to preserve the culture of the community or cultural elements such as its unique weaving techniques. Over the years, Ikat has been known by various names such as Kasuri in Japan, Patola, Bandhini, Pagudubandhu, Budhabus, Chitki, Bandha in India, Asb in the Arab world, Matmee in Laos, Mudmee in Thailand and Atlas in Uzbekistan.

First, although the weaving process used for Ikat fabrics varies from country to country according to different national cultures, lifestyles, colors, patterns, and usage methods, they are all Ikat-dyed fabrics. Therefore, they are all considered valuable items that symbolize a certain social status and are used as gifts for special occasions such as weddings. Second, the shape of the pattern is different. Indian Patola has clear outlines and regular patterns, while Japanese Kasuri patterns are mainly inspired by ideas of folk life. Indonesian Ikat fabrics incorporate the influence of local tribes, and the Atlas fabrics of Uzbekistan and China are influenced by bright colors and pattern designs inspired by geography, religion, and national culture, including plants, musical instruments, and geometric shapes. Finally, the patterns and colors of Xinjiang Atlas fabrics show strong ethnic characteristics. Unlike Uzbek fabrics, which are largely influenced by Islam, human and animal motifs are not found in Xinjiang Atlas patterns, which consist mainly of long lines, repeated in a neat and orderly manner.

Materials and Methods

Gerard Pieter Rouffaer was a Dutch ethnographer and colonial researcher who studied the culture, trade, and traditional crafts of the Dutch East Indies (now Indonesia). He was associated with the Leiden School and is considered one of the first systematic scientific descriptions of Indonesian textiles. His work, Ikat's, Tjinde's, Patola's en Chiné's, was written in the early 20th century and provides a historical and typological analysis of Southeast Asian textiles. Rouffaer scientifically explains the ikat technique: the pre-dyed yarn, the formation of the pattern during the weaving process, and the existence of warp, weft, and double ikat in Indonesia.

Nian S. Djoemena (full name Rahmaniar Soerianata Djoemena) is an Indonesian researcher and writer specializing in traditional weaving and batik. He is considered one of the leading experts on Indonesian textile art, his work documents the symbolism, techniques and cultural significance of local fabrics. In 2015, his book Kain Tenun Minangkabau: Narasi Masyarakatnya, which focuses on Minangkabau textiles and their social significance, was published. This work continues his approach to textiles as a vehicle of collective memory and identity. N. S. Juemena's work is an integral part of the scholarly documentation of traditional Indonesian textiles and has made a significant contribution to the preservation and reinterpretation of the country's craft traditions.

Results and Discussion

According to the study, the fabric called ikat is named differently according to the region, and each region is defined based on its name. Features of Patola double ikat (Gujarat), Telia Rumal ikats in India: Patola (the word comes from the Sanskrit word "patt" (patta), meaning: silk fabric, precious fabric, patterned silk) is given the same pattern to both tanda and arkok threads before weaving. Regional pattern differences: In Orissa, simple warp patterns are distinguished, while Telia Rumaln is distinguished by oil-treated fibers. The Indonesian art of geringsing double ikat is created using special traditional patterns. This ikat is a complex technique used only in the village of Tenganan. Geringsing (derived from the Balinese words gering – disease, sing – absence or non-existence, meaning disease-free, protector from calamity.) is uniform in color between red, reddish brown, eggshell color and dark blue/black/brown designs. There are two main patterns or Tumpal, similar to some batik designs, which leave a central panel. The pattern can be made of vertically oriented geometric and abstract floral patterns, which are repeated across the central area.

The Japanese word kasuri is derived from the English verb kasureru, meaning "to blur". This technique can occur accidentally by weavers using unevenly dyed defective yarns, resulting in unexpected patterns.

One of the earliest known examples of silk kasuri is found in the Hōryūji collection of the Tokyo National Museum, known as Taishi Kando (sometimes called Kanto Nishiki). The material was imported from China in the 6th and 7th centuries AD and was probably used for Buddhist ceremonial flags. Okinawa, in the southernmost part of Japan, is a region consisting of many small islands that formed the independent Ryukyu Kingdom. Kasuri has been woven on these islands since the 14th century from ramie and banana fibers, and later from cotton and silk. It only became widespread on the Japanese mainland in the late 17th century. Although cotton is a native Japanese plant, seeds were introduced from China in the early 16th century. During the Edo period, from the mid-18th century, due to economic growth, ordinary people were allowed to wear cotton clothing. In terms of color, blue kasuri (Kon gasuri) was popular, with white applied on an indigo blue background. White kasuri (Shiro gasuri) was made with blue indigo on a white background. Okinawa (formerly known as Ryukyu) Each island of Okinawa has its own unique kasuri material, which has been produced for centuries, and there are at least 300 different traditional patterns on these islands. It has a minimalist and aesthetically balanced composition.

In Malaysia, there is Pua Kumbu, which is woven by the Iban people of Sarawak. It is mainly warp ikat woven, with red-brown, indigo, and black natural colors prevailing. The patterns represent mythological beings, ancestral spirits, and cosmological images. It is associated with ceremonial and social status. The knowledge in traditionally weaving the Pua Kumbu was mainly reserved to certain class of woman in the long house. The chosen motif was dependent on illustration that appeared in their dream, where they believe that this was a sign or omen. The rules of weaving motif were also explained. There were three significance motifs with its own hidden meaning found in Pua Kumbu; the ular (snake), antu engkeramba and baya (crocodile) which became the belief of the Iban people.

Conclusion

Ikat is divided into three types according to weaving: Patola and Geringsing fabrics are mainly produced in double ikat technique, Pua Kumbu in warp ikat technique, Kasuri in weft ikat technique (in some cases it is also made in warp ikat technique), and Atlas fabric is produced in warp and weft ikat technique. Pattern types: Geringsing and Patola are complex geometric, Pua Kumbu cosmological symbols, Atlas is a mixture of colors, geometric and plant patterns, and Kasuri is a blurred depiction. By composition and color types: Patola and geringsing are strictly symmetrical, Red (lacquer paint), green, yellow, black and white contrast, colors are clearly arranged, often four or five complex combinations, Kasuri is simplified, blue, black and white, the color palette is minimal, aesthetic-minimalist, pua kumbu is red-brown dominant, dark indigo colors are close to earth colors, low contrast, colors have a spiritual and ceremonial meaning, atlas is free, rhythmic, colorful, with a “cloudy” mixing effect, dynamic, expressive, market-oriented. In a global context, ikat fabrics reflect the process of transition from the historical roots of traditional techniques to current fashion and market mechanisms. Although these traditions differ in technique, pattern semantics and cultural contribution, they are all based on common principles such as resistive dyeing, patterned design and preservation of cultural identity.

References

Djoemena, Nian S. Kain tenun Minangkabau: narasi masyarakatnya. 2015y. ISBN:9786027151406. URL: https://catalogue.nla.gov.au/catalog/6928159

Lifeng Wang, Younhee Lee. Characteristics of the traditional Atlas fabrics of the Xinjiang Uygur Minority Ethnic Group, China. – The Research Journal of the Costume Cult... (The Costume Culture Association). –Vol. 28. – Iss: 2. – 30 Apr 2020. – P. 199–214.

URL: https://www.academia.edu/130046183/Rouffaer_1902_About_Ikats_Cindes_Patolas_and_Chines.

Gillow, J. (1993). Traditional Indian Textiles. London: Thames and Hudson.
Gillow, J., & Sentance, B. (2001). World Textiles. London: Thames & Hudson Ltd.
URL: https://en.wikipedia.org/wiki/Geringsing
Jun Tomita, Noriko Tomita. Japanese of Kasuri. 1983y. ISBN 9781032642819
Alexander, Chelum and Anna, Durin and Lim, Hamizan and Mohd Jefri, Samaroon. (2018). *The Iban Textiles*. Journal of Borneo-Kal imantan, – 4 (1). – P. 1–7. ISSN 2289-2583

submitted 13.02.2026;
accepted for publication 27.02.2026;
published 28.02.2026

Contact: xmahliyoa@gmail.com

Contents