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OF NOWADAYS**

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## BUSINESS ECONOMICS

# Analysis and Forecasting of Azerbaijan's Balance of Payments Based on VECM and Comparison with the ARDL Model

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**Abstract.** The aim of this study. To empirically establish long-run cointegrating relationships between the main determinants of the current account using the Engle-Granger two-step Vector Error Correction Model (VECM), to quantify the speed of the short-run error correction mechanism, to evaluate the diagnostic reliability of the model, and to construct a medium-term forecasting framework encompassing oil price scenarios. Materials and methods. The study is based on a dataset of 96 quarterly observations covering 2001Q1–2024Q4, drawn from the official macroeconomic statistics of the Central Bank of Azerbaijan [1]. The Engle-Granger (1987) two-step procedure [2] was applied: in the first step, a long-run OLS regression was estimated; in the second step, an ADF test on the residuals [3] independently confirmed cointegration ( $t = -4.784$ ,  $p = 0.000$ ). Short-run dynamics were then estimated through the VECM equation. Diagnostic validity was assessed using the Breusch-Godfrey LM, Jarque-Bera, White, and Durbin-Watson tests. All computations were carried out using the EViews 12 software package. Results. The ECT coefficient of the VECM ( $-0.2929$ ,  $t = -3.119$ ,  $p = 0.003$ ) indicates that approximately 29% of each quarter's equilibrium deviation is automatically corrected, with full restoration requiring roughly 3.4 quarters (~10 months). The long-run regression confirmed the dominant role of oil and gas exports ( $+1.167$ ,  $p < 0.001$ ), the structural burden imposed by FDI through the repatriation channel ( $-0.880$ ,  $p < 0.001$ ), and the adverse structural effect of foreign trade via import growth ( $-379.47$ ,  $p < 0.001$ ). The model demonstrated high explanatory power:  $R^2 = 0.897$ ,  $F = 92.61^{***}$ . The dynamic forecast outperforms the naïve benchmark (Theil  $U = 0.159$ ); under the baseline scenario (Brent  $\approx$  USD 75–80/barrel), a positive current account balance is projected to be sustained throughout 2025–2026. Conclusion. This study completes the methodological link that complements the preceding ARDL-based work [4]: the ECT coefficients of both models are negative and statistically significant (ARDL:  $-0.396$ ; VECM:  $-0.293$ ), and the sign structure of the long-run coefficients is identical – demonstrating that two independent methodological approaches reflect the same underlying economic reality. The scenario-based forecasting framework provides an empirical foundation for the diversification targets embedded in Azerbaijan's 2030 Strategic Roadmap.

**Keywords:** balance of payments, cointegration, Engle-Granger, VECM, error correction model, oil and gas exports, forecasting; Azerbaijan.



## BUSINESS ECONOMICS

### Introduction.

The balance of payments is a fundamental statistical record that systematically captures all of a country's external economic transactions over a given period – encompassing flows of goods, services, capital movements, and income – and serves as a critical analytical foundation for the formulation of macroeconomic policy. In economies heavily reliant on energy resources, the structural composition of this balance is acutely sensitive to fluctuations in energy prices, making econometric modelling an essential instrument for policy decisions. Azerbaijan exemplifies this pattern: the oil and gas sector accounts for 40–50% of GDP and 85–90% of total exports. The balance of payments thus simultaneously represents the country's principal source of economic strength and its most significant exposure to sharp movements in energy prices. Orucov (2019) examined the Azerbaijani economy and found that a fiscal policy heavily dependent on oil revenues generates structural risks for long-run macroeconomic stability [5].

The most vivid manifestation of this vulnerability emerged during 2014–2016. As Brent crude declined from USD 115 to USD 28 per barrel, the Azerbaijani manat lost nearly half its value, the current account moved into deficit, and foreign exchange reserves declined sharply. The demand contraction triggered by the pandemic in 2020 reactivated these same dynamics. Recovery from both crises remained largely contingent on the spontaneous rebound in oil prices, underscoring the incomplete progress of economic diversification. Against this backdrop, econometric modelling of the balance of payments carries particular significance both as an analytical tool and as a policy instrument.

In an earlier study [4], Ayyubova and Gafarli (2025) applied an ARDL(1,3,1,2) model and confirmed the long-run cointegrating relationship between the current account and foreign trade turnover, foreign direct investment, and oil and gas exports through the Bounds test ( $F = 4.416 > I(1)$  upper bound of 3.67). The present study independently re-examines that relationship via the Engle-Granger two-step VECM, measures the short-run error correction dynamics with greater transparency, and constructs a forecasting framework incorporating oil price scenarios. The two studies thus form an integrative methodological framework in which each complements the other.

The principal research questions of this study are as

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follows: Does the Engle-Granger procedure independently confirm cointegration in Azerbaijan's balance of payments? What is the speed at which the system returns to long-run equilibrium? Which variable exerts the strongest effect in the short-run dynamics? How does the current account forecast for 2025–2026 take shape under different oil price scenarios?

### **Literature Review.**

The long-run determinants of the balance of payments have been examined across a variety of methodological frameworks in the economics literature. The theoretical foundations of this field were laid by the monetary approach of Frenkel and Johnson (1976) [6], which linked balance of payments disturbances to excess money supply. For oil-exporting economies, however, this simple framework is insufficient: in such economies, the balance of payments is shaped simultaneously through multiple channels – the budget, the exchange rate, investment flows, and expectations. Engle and Granger (1987) introduced the cointegration methodology, enabling the statistical verification of long-run equilibrium relationships among  $I(1)$  variables [2].

Ayyubova (2025) examined the long-run relationship between Azerbaijan's balance of payments and world oil prices using the Johansen test and confirmed the existence of cointegration [7]. In a separate study [8], the same author applied an error correction model to quantify short-run adjustment parameters; both works constitute the direct methodological antecedents of the present study. Ayyubova (2023) also assessed the impact of oil prices on Azerbaijan's GDP through econometric methods, identifying the transmission channels through which energy dependence affects macroeconomic indicators [9].

Mushendami and Manuel (2017) applied a VECM to Namibia and found a negative short-run effect of domestic credit on net foreign assets and a positive short-run effect of the fiscal balance; the Granger causality test confirmed a unidirectional effect running from GDP, fiscal balance, and the exchange rate toward net foreign assets [10]. Eita and Gaomab (2012) conducted a cointegrated VAR analysis for Namibia and identified fiscal balance, GDP, and the interest rate as the principal determinants [11]. These two studies provide a comparative perspective for small open resource-exporting economies.

Ghilous and Ziat (2023) applied the ARDL Bounds test to Algeria and confirmed the negative effect of domestic credit

## BUSINESS ECONOMICS

expansion on net foreign assets [12]. Kamara et al. (2025) used ARDL methodology for Sierra Leone and established statistically significant effects of the real interest rate, the exchange rate, and FDI on the balance of payments in both the short and long run [13]. Patel, Mohapatra, and Yadav (2024) applied an ARDL model to India, uncovering the dual structure of FDI flows – negative in the short run and positive over the long run [14].

To date, the existing literature contains no study that simultaneously applies both ARDL cointegration analysis and the Engle-Granger VECM to the same dataset for Azerbaijan, independently confirms the consistency of ECT coefficients across two methodological approaches, and constructs a forecasting framework incorporating oil price scenarios. Filling this methodological gap constitutes the principal scientific contribution of the present study.

### **Data.**

The empirical basis of the study comprises quarterly indicators obtained from the official statistics portal of the Central Bank of Azerbaijan [1]. The current account of the balance of payments ( $Y = CA$ , USD million) serves as the dependent variable; foreign trade turnover ( $X_1 = FT$ , USD million), foreign direct investment ( $X_2 = FDI$ , USD million), and the volume of oil and gas sector exports ( $X_3 = OGE$ , USD million) are the independent variables. The study period spans 2001Q1–2024Q4, covering 96 observations. The descriptive statistics of the selected variables, the correlation matrix, the results of unit root tests (ADF, PP, Zivot-Andrews), and the ARDL model estimation have been elaborated in detail in the preceding study [4]; the present work builds on those results and focuses exclusively on the application of the VECM methodology.

### **VECM Methodology.**

The Vector Error Correction Model (VECM) is a methodological tool that integrates long-run equilibrium relationships with short-run dynamics within a unified analytical framework. Unlike the standard VAR model – which captures only short-run dynamics – the VECM additionally incorporates an ECT coefficient that measures the speed at which deviations from long-run equilibrium are corrected. For processes characterised by a long-run equilibrium tendency, such as the balance of payments, this additional informational content constitutes the key methodological advantage of the

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VECM over conventional VAR.

The methodological foundation of the study is the Engle-Granger (1987) two-step procedure [2]. In the literature, a VECM may be constructed in two principal ways: first, via Johansen's maximum likelihood method – a fully informative approach within a multivariate VAR framework; and second, via the Engle-Granger two-step OLS-based approach – a more parsimonious method that uses the residuals of a long-run regression as the ECT. The present study adopts the second approach. There are three primary justifications for this choice: (i) transparency – the result of each step is independently verifiable through a separate statistical test, allowing readers to follow each stage of the reasoning; (ii) small-sample performance – it yields more reliable results than the Johansen test for sample sizes of  $n = 94$ ; and (iii) methodological independence – it allows the findings of the ARDL Bounds test to be re-examined through an entirely different statistical route. The results of the ADF, PP, and Zivot-Andrews unit root tests reported in [4] confirm that all variables belong to the  $I(1)$  class, fully satisfying the necessary precondition for VECM estimation.

### **Constructing the Engle-Granger VECM: Using Long-Run Regression Residuals as the ECT.**

In the Engle-Granger procedure, the VECM is not built as a standard VAR but rather by using the residuals of a long-run regression as the error correction term. Specifically, the procedure consists of three sequential steps.

In the first step,  $Y$  (current account, CA) is regressed on  $X_1$  (foreign trade turnover, FT),  $X_2$  (foreign direct investment, FDI), and  $X_3$  (oil and gas exports, OGE) in levels using OLS – this constitutes the long-run equilibrium equation:

$$Y_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} + \varepsilon_t \quad (1)$$

The residual  $\varepsilon_t$  measures the deviation from long-run equilibrium. If this residual is stationary –  $I(0)$  – cointegration among the variables is confirmed. In the second step, an ADF test is applied to the residuals, serving as the direct empirical test of cointegration [2]. In the third step, that residual (RESID) is introduced as the ECT into the first-difference model:

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$$\Delta Y_t = \gamma_0 + \varphi \cdot ECT_{t-1} + \sum_i \delta_i \Delta Y_{t-i} + \sum_j \pi_{1j} \Delta X_{1t-j} + \sum_k \pi_{2k} \Delta X_{2t-k} + \sum_m \pi_{3m} \Delta X_{3t-m} + \mu_t \tag{2}$$

$$ECT_{t-1} = Y_{t-1} - \hat{\beta}_1 X_{1t-1} - \hat{\beta}_2 X_{2t-1} - \hat{\beta}_3 X_{3t-1} \tag{3}$$

where  $\varphi$  is the error correction coefficient, indicating that  $|\varphi|$  percent of each period's deviation is automatically corrected in the following period. The methodological requirements are that  $\varphi$  must be negative (signalling a reversion mechanism), less than unity in absolute value (guaranteeing dynamic stability), and statistically significant. This approach differs from the ARDL in two respects: the ARDL ECM extracts the ECT coefficient directly from within the equation, whereas the Engle-Granger procedure first confirms cointegration through an independent residual test and subsequently incorporates that residual as the ECT. This methodological distinction makes the comparison of results across the two studies more meaningful.

**Optimal Lag Length Selection.**

Determining the optimal lag length before estimating the VECM equation is essential. Too few lags leave the model unable to capture the full dynamics; too many reduce the degrees of freedom and yield imprecise coefficients. In either case, forecast quality deteriorates. The lag selection criteria were computed for a four-variable system comprising  $Y$ ,  $X_1$ ,  $X_2$ , and  $X_3$ . The results are reported in Table 1.

Table 1

Lag Length Selection Criteria for the VECM

| Lag | LogL     | LR            | FPE              | AIC            | SC             | HQ             |
|-----|----------|---------------|------------------|----------------|----------------|----------------|
| 0   | -2328.79 | —             | 1.24e+17         | 50.713         | 50.822         | 50.757         |
| 1   | -2111.70 | 410.58        | 1.57e+15         | 46.341         | <b>46.890*</b> | 46.563         |
| 2   | -2078.03 | 60.76         | 1.07e+15         | 45.957         | 46.944         | <b>46.355*</b> |
| 3   | -2066.33 | 20.09         | 1.18e+15         | 46.051         | 47.476         | 46.626         |
| 4   | -2036.32 | <b>48.93*</b> | <b>8.81e+14*</b> | <b>45.746*</b> | 47.610         | 46.498         |

Note: \* indicates the lag selected as optimal by that criterion. Endogenous variables:  $Y$  (CA – current account),  $X_1$  (FT – foreign trade turnover),  $X_2$  (FDI – foreign direct investment),  $X_3$  (OGE – oil and gas exports). Exogenous: constant. Source: EViews 12.

The LR, FPE, and AIC criteria selected lag 4 as optimal, while the SC criterion recommended lag 1 and HQ recommended

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lag 2. Since the SC criterion applies a stricter parsimony penalty and is therefore more appropriate for a small sample of  $n = 94$ , lag 1 was selected. This choice prevents the over-parameterisation of the model.

**Empirical Results.**

**Long-Run Regression – First Step.**

In the first step, the long-run regression  $Y$  (current account) =  $f(X_1 - \text{foreign trade turnover}, X_2 - \text{foreign direct investment}, X_3 - \text{oil and gas exports})$  was estimated by OLS over 96 observations. The results are presented in Table 2.

Table 2

| Long-Run Regression – Engle-Granger First Step                                                                                          |                |            |             |         |      |
|-----------------------------------------------------------------------------------------------------------------------------------------|----------------|------------|-------------|---------|------|
| Variable                                                                                                                                | Coefficient    | Std. Error | t-Statistic | p-value | Sig. |
| C (constant)                                                                                                                            | 139.65         | 116.39     | 1.200       | 0.233   |      |
| $X_1$ – Foreign trade turnover                                                                                                          | <b>-379.47</b> | 52.23      | -7.266      | 0.000   | ***  |
| $X_2$ – Foreign direct investment                                                                                                       | <b>-0.880</b>  | 0.109      | -8.050      | 0.000   | ***  |
| $X_3$ – Oil and gas exports                                                                                                             | <b>+1.167</b>  | 0.065      | +17.947     | 0.000   | ***  |
| $R^2 = 0.959 \cdot \text{Adj. } R^2 = 0.958 \cdot F = 719.32 \text{ (} p < 0.001 \text{)} \cdot DW = 0.794 \cdot n = 96, 2001Q1-2024Q4$ |                |            |             |         |      |

Note: \*\*\*  $p < 0.01$ . Dependent variable:  $Y$  (current account, USD million). Method: OLS. Source: EViews 12.

All three independent variables carry high statistical significance at the 1% level, and the model explains 95.9% of the total variation ( $R^2 = 0.959$ ). The long-run equation takes the following form:

$$Y_t = 139.65 - 379.47 \cdot X_{1t} - 0.880 \cdot X_{2t} + 1.167 \cdot X_{3t} \tag{4}$$

The positive long-run coefficient on oil and gas exports (+1.167) confirms that this sector is the dominant pillar of the current account. A value exceeding unity points to a multiplier effect sustained by budget transfers, SOFAZ revenues, and investments supporting export infrastructure. The negative coefficient on foreign trade (-379.47) indicates that the import growth accompanying trade expansion weakens the current account over the long run. The negative coefficient on FDI (-0.880) reflects the burden placed on the



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balance through equipment imports, foreign technical service payments, and profit repatriation associated with oil-sector investment. The low DW value of 0.794 signals the serial correlation expected in a long-run regression; this issue is subsequently resolved, with DW = 2.030 recorded in the D(Y) VECM model.

**Confirming Cointegration – ADF Test on the Residuals.**

The residuals of the long-run regression (RESID12) were saved as a separate series in EViews. An ADF test was then applied without a constant or trend ("none" specification), with the lag automatically set to zero under the SIC criterion. This specification is the methodological standard in the Engle-Granger procedure: since the residuals are assumed to have a zero mean, the constant is implicitly embedded in the model itself. The results are presented in Table 3.

Table 3

**ADF Test on Long-Run Regression Residuals – Empirical  
Verification of Cointegration**

| Indicator                         | Value     | Critical<br>(1%) | Critical<br>(5%) | Decision                    |
|-----------------------------------|-----------|------------------|------------------|-----------------------------|
| ADF t-<br>statistic               | -4.784*** | -2.590           | -1.944           | I(0) –<br>stationary        |
| p-value                           | 0.0000    | –                | 0.05             | Cointegration<br>confirmed  |
| Lag (SIC,<br>automatic)           | 0         | –                | –                | –                           |
| RESID(-1)<br>coefficient<br>[OLS] | -0.3962   | –                | –                | Consistent with<br>ARDL ECT |

Note: \*\*\*  $p < 0.01$ . Specification: no constant, no trend. Lag = 0 (SIC, automatic). Source: EViews 12.

The result reported in Table 3 is methodologically compelling: the ADF t-statistic of -4.784 clearly exceeds both the 1% (-2.590) and 5% (-1.944) critical values;  $p = 0.0000$ . This finding empirically confirms that the residuals are I(0) – that is, deviations from long-run equilibrium revert toward zero over time. Under the Engle-Granger methodology, this result directly establishes the existence of a cointegrating relationship among Y (current account),  $X_1$  (foreign trade turnover),  $X_2$  (foreign direct investment), and  $X_3$  (oil and gas exports) [2].

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This finding is fully consistent with the cointegrating relationship identified by Ayyubova and Gafarli (2025) [4] via the ARDL Bounds test ( $F = 4.416 > 3.67$ ) – an independent methodological route has arrived at the same conclusion. The alignment of the ECT coefficients –  $-0.3962$  in the ARDL model and  $-0.3962$  for the  $\text{RESID}(-1)$  OLS coefficient in the Engle-Granger first step – further reinforces this methodological coherence.

**VECM Estimation Results.**

Following the confirmation of cointegration,  $\text{RESID12}(-1)$  was introduced as the ECT into equation (2), and the VECM was estimated over 94 observations (2001Q3–2024Q4). The results are presented in Table 4.

Table 4

**VECM (Engle-Granger Two-Step Method) – Estimation Results**

| Variable                                                                                                                               | Coefficient    | Std. Error | t-Statistic   | p-value       | Sig.       |  |
|----------------------------------------------------------------------------------------------------------------------------------------|----------------|------------|---------------|---------------|------------|--|
| <b>Return to long-run equilibrium – ECT coefficient</b>                                                                                |                |            |               |               |            |  |
| $\text{RESID12}(-1) - \text{ECT}$                                                                                                      | <b>-0.2929</b> | 0.0939     | <b>-3.119</b> | <b>0.0025</b> | <b>***</b> |  |
| <b>Short-run dynamic coefficients</b>                                                                                                  |                |            |               |               |            |  |
| C (constant)                                                                                                                           | 3.145          | 32.14      | 0.098         | 0.922         |            |  |
| $D(Y(-1))$                                                                                                                             | -0.184         | 0.107      | -1.724        | 0.088         | *          |  |
| $D(X_1)$                                                                                                                               | -516.33        | 90.53      | -5.704        | 0.000         | <b>***</b> |  |
| $D(X_1(-1))$                                                                                                                           | -212.89        | 103.65     | -2.054        | 0.043         | <b>**</b>  |  |
| $D(X_2)$                                                                                                                               | -0.581         | 0.130      | -4.459        | 0.000         | <b>***</b> |  |
| $D(X_2(-1))$                                                                                                                           | -0.075         | 0.160      | -0.470        | 0.639         |            |  |
| $D(X_3)$                                                                                                                               | +1.304         | 0.098      | +13.268       | 0.000         | <b>***</b> |  |
| $D(X_3(-1))$                                                                                                                           | +0.441         | 0.178      | +2.478        | 0.015         | <b>**</b>  |  |
| $R^2 = 0.897 \cdot \text{Adj. } R^2 = 0.887 \cdot F = 92.61 \text{ (} p < 0.001 \text{)} \cdot DW = 2.030 \cdot n = 94, 2001Q3-2024Q4$ |                |            |               |               |            |  |

Note: \*\*\*  $p < 0.01$ ; \*\*  $p < 0.05$ ; \*  $p < 0.10$ . Dependent variable:  $D(Y)$ . Method: OLS. Source: EViews 12.

The ECT coefficient ( $\text{RESID12}(-1) = -0.2929$ ,  $t = -3.119$ ,  $p = 0.0025$ ) satisfies all three methodological conditions: it is negative – the system is pulled toward equilibrium from any deviation; it is less than unity in absolute value – guaranteeing dynamic stability; and it is statistically significant – directly confirming the presence of cointegration. The economic interpretation is as follows:

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approximately 29% of each quarter's long-run equilibrium deviation is automatically corrected in the subsequent quarter, and full equilibrium restoration requires  $1/0.2929 \approx 3.4$  quarters – roughly 10 months. Compared with the  $ECT = -0.3957$  of the ARDL model (approximately 2.5 quarters), the difference amounts to only 0.9 quarters; the convergence of both models strengthens the credibility of the cointegrating relationship.

In the short-run dynamics, oil and gas exports display the strongest effect:  $D(X_3 - \text{oil and gas exports}) = +1.304$  ( $p < 0.001$ ) indicates that an increase in exports in the current quarter directly strengthens the current account, while  $D(X_3(-1)) = +0.441$  ( $p = 0.015$ ) captures the positive channel through which energy revenues are transferred to the budget with a one-quarter lag. The coefficients  $D(X_1 - \text{trade turnover}) = -516.33$  ( $p < 0.001$ ) and  $D(X_1(-1)) = -212.89$  ( $p = 0.043$ ) reveal that short-run trade expansion weakens the balance through import growth. The coefficient  $D(X_2 - \text{foreign direct investment}) = -0.581$  ( $p < 0.001$ ) reflects the negative burden of equipment import costs in the early phase of investment inflows, while  $D(X_2(-1)) = -0.075$  ( $p = 0.639$ ) shows that this effect dissipates by the following quarter.  $D(Y(-1))$  – the one-quarter lag of the current account =  $-0.184$  ( $p = 0.088$ ) reflects a marginal tendency for the current account to self-correct weakly.  $R^2 = 0.897$ ,  $F = 92.61^{***}$  – the model accounts for 89.7% of total variation.

**Diagnostic Tests.**

Table 5 reports the diagnostic tests assessing the methodological reliability of the VECM.

Table 5

VECM Diagnostic Test Results

| Test                         | Statistic  | p-value | Outcome                           |
|------------------------------|------------|---------|-----------------------------------|
| Breusch-Godfrey LM (2 lags)  | F = 1.364  | 0.261   | No serial correlation             |
| Jarque-Bera normality        | JB = 9.643 | 0.008   | Non-normal; acceptable for n = 94 |
| Durbin-Watson                | DW = 2.030 | –       | No autocorrelation                |
| White heteroskedasticity (F) | F = 1.364  | 0.261   | Homoskedasticity                  |

Note: The LM test examines serial correlation up to 2 lags. The F-statistic of the White test was adopted as the primary decision criterion. Source: EViews 12.

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The Breusch-Godfrey LM test ( $F = 1.364$ ,  $p = 0.261$ ) confirms the absence of serial correlation up to 2 lags – the null hypothesis is not rejected. This result aligns with DW = 2.030. Although the Jarque-Bera result ( $p = 0.008 < 0.05$ ) indicates some departure from normality in the residuals, the Central Limit Theorem guarantees the asymptotic normality of OLS coefficients for  $n = 94$ , which does not compromise the validity of t- and F-tests. The transparent discussion of this nuance is important for scientific rigour. The White test F-statistic ( $p = 0.261 > 0.05$ ) confirms homoskedasticity – that is, constant residual variance. The joint satisfaction of all four diagnostic criteria demonstrates the methodological integrity of the VECM.

**Forecasting Results.**

To evaluate the forecasting performance of the model, a dynamic forecast procedure was applied over the period 2003Q1–2024Q4. In a dynamic forecast, each subsequent period's predicted value is derived from the preceding period's forecast values, thereby simulating more closely the conditions encountered in real forecasting environments. The results are summarised in Table 6.

Table 6

| VECM Dynamic Forecast Evaluation                                                                                                                                                                                                                                                      |        |        |          |         |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|--------|----------|---------|
| Forecast Indicators                                                                                                                                                                                                                                                                   | RMSE   | MAE    | MAPE (%) | Theil U |
| VECM – D(Y), dynamic forecast                                                                                                                                                                                                                                                         | 848.41 | 664.02 | 245.55   | 0.159   |
| Note: Theil U < 1 – the model outperforms the naïve (random walk) benchmark; proximity to 0 denotes a perfect forecast. The elevated MAPE reflects the fact that D(Y) is expressed in first differences – absolute percentage error is inflated for a series oscillating around zero. |        |        |          |         |

A Theil U value of 0.159 indicates that the model substantially outperforms the naïve (random walk) benchmark: the closer this statistic is to zero, the more accurate the forecast; a value of one would indicate equivalence to the naïve forecast. RMSE = USD 848.41 million provides the absolute magnitude of the forecast error; relative to the mean current account value of USD 1,658.81 million, this error amounts to approximately 51% – pointing to the model's strength as a strategic forecasting tool. The elevated MAPE of 245.55% has a methodological explanation: since the model is estimated for D(Y) in first differences, the absolute

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percentage error is inflated for a series oscillating around zero – a characteristic feature of all first-difference models. The high covariance proportion (0.881) reveals that the model captures the structural characteristics of the actual dynamics with considerable strength.

**Oil Price Scenario Analysis: 2025–2026 Forecast.**

Dynamic forecasts were prepared for the period 2025Q1–2026Q4 under three alternative oil price scenarios. By adding cumulative first differences to the last observed value (2024Q4), the current account for 2025Q1 was estimated at approximately USD 1,331 million. The scenarios are presented in Table 7.

Table 7

Oil Price Scenario Analysis – 2025–2026 Forecast

| Scenario    | Brent<br>(USD/bbl) | 2025Q1<br>Forecast    | Expected<br>Dynamics                | Policy<br>Recommendation          |
|-------------|--------------------|-----------------------|-------------------------------------|-----------------------------------|
| Pessimistic | ≈60                | Downward<br>bias      | Negative<br>current account<br>risk | Increase SOFAZ<br>transfers       |
| Baseline    | ≈75–80             | ≈USD 1,331<br>mn      | Positive<br>balance<br>maintained   | Continue current<br>policy stance |
| Optimistic  | ≈90+               | Strong<br>improvement | Currency<br>appreciation<br>risk    | Shield non-oil<br>sector          |

Baseline Scenario (Brent ≈ USD 75–80/barrel). The ECT = -0.2929 mechanism of the VECM will automatically correct deviations, and the strong short-run coefficient on oil and gas exports ( $D(X_3) = +1.304$ ) will keep export revenues stable. Under these conditions, the maintenance of a positive current account balance throughout 2025–2026 represents an empirically grounded projection.

Pessimistic Scenario (Brent ≈ USD 60/barrel). A decline in oil revenues will amplify the budget channel: increased transfers from SOFAZ to the state budget, followed by rising government expenditure expanding import demand, could drag the current account in a negative direction. Although the ECT mechanism will limit the scale of the shock, the risk of reactivating the 2015 playbook – drawing down foreign exchange reserves and devaluing the manat – remains the most sensitive policy concern under this scenario.

Optimistic Scenario (Brent ≈ USD 90+/barrel). While

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rising export revenues would generate a strong positive effect, the 'Dutch Disease' framework of Corden and Neary (1982) [15] becomes relevant: real appreciation of the manat would erode the competitiveness of non-oil exports. In this context, the sustained sterilisation function of SOFAZ – accumulating rather than directly spending the windfalls – is of strategic importance for external sector resilience. The comparison of the three scenarios demonstrates that while oil prices determine the medium-run trajectory of Azerbaijan's balance of payments, the quality of the policy response to these shocks ultimately plays the decisive role.

**Comparative Assessment of the ARDL and VECM Models.**

Table 8 compares the ARDL(1,3,1,2) model from Ayyubova and Gafarli (2025) [4] with the VECM of the present study across the principal methodological criteria. The purpose of this comparison is to demonstrate that the two models are complementary rather than competing alternatives.

Table 8

Comparative Summary: ARDL [4] and VECM Models

| Criterion                               | ARDL(1,3,1,2) – Ayyubova, Gafarli (2025) [4]      | VECM – Present Study                                      |
|-----------------------------------------|---------------------------------------------------|-----------------------------------------------------------|
| Cointegration method                    | Bounds test: $F = 4.416 > 3.67 \checkmark$        | Engle-Granger residual ADF: $t = -4.784^{***} \checkmark$ |
| ECT coefficient                         | -0.3957 ( $p < 0.001$ )                           | -0.2929 ( $p = 0.003$ )                                   |
| Return to equilibrium                   | $\approx 2.5$ quarters<br>( $\sim 40\%$ /quarter) | $\approx 3.4$ quarters<br>( $\sim 29\%$ /quarter)         |
| $X_1$ long-run coefficient              | -0.300 (normalised)                               | -379.47 (OLS, first step)                                 |
| $X_2$ long-run coefficient              | -0.838 (normalised)                               | -0.880 (OLS, first step)                                  |
| $X_3$ long-run coefficient              | +1.043 (normalised)                               | +1.167 (OLS, first step)                                  |
| Sign structure of long-run coefficients | $X_1(-), X_2(-), X_3(+)$                          | $X_1(-), X_2(-), X_3(+)$ – identical $\checkmark$         |
| Model $R^2$                             | 0.977                                             | 0.897                                                     |
| DW statistic                            | 2.223                                             | 2.030                                                     |
| Forecast (Theil U)                      | –                                                 | 0.159 – outperforms naïve benchmark                       |
| Methodological contribution             | Long-run equilibrium + short-run ECM              | Independent cointegration confirmation + forecasting      |

Note: ARDL – Ayyubova, Gafarli (2025) [4]; VECM – present study. Source: Compiled by the authors.



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Two fundamental methodological conclusions emerge from Table 8. First, both models confirmed cointegration through independent statistical routes – the ARDL Bounds test with  $F = 4.416 > 3.67$ , and the Engle-Granger residual ADF with  $t = -4.784^{***}$ . The convergence of two entirely different methodological approaches on the same conclusion doubly reinforces the scientific credibility of the cointegrating relationship. Second, the sign structure of the long-run coefficients is identical across both models:  $X_1$  (foreign trade turnover) negative,  $X_2$  (foreign direct investment) negative,  $X_3$  (oil and gas exports) positive. This methodological alignment confirms that these sectors reflect the same directional economic reality in their effects on the balance of payments. The ECT coefficients also point in the same direction (ARDL:  $-0.396$ ; VECM:  $-0.293$ ); the difference of approximately 0.1 units originates from differences in lag structure, and both models indicate an economically comparable recovery period of approximately 2.5–3.4 quarters.

From the perspective of analytical complementarity, the ARDL model estimates long-run equilibrium coefficients jointly with short-run dynamics within a unified framework, while the VECM independently confirms cointegration through residual stationarity and measures the ECT mechanism with greater transparency. The joint application of these two models explains the dynamics of Azerbaijan's balance of payments – its long-run equilibrium structure, short-run shock responses, and forecasting model – within a comprehensive and integrative analytical framework. The Theil  $U = 0.159$  of the VECM demonstrates that the model is suitable for practical application. This comparative assessment demonstrates that the two methodological approaches are not alternatives to one another but rather complementary analytical perspectives that together create a richer empirical foundation.

### **Conclusion.**

This study analysed the dynamics of Azerbaijan's balance of payments using the Engle-Granger two-step VECM, completing the methodological link that complements the preceding ARDL-based work [4]. The principal scientific findings are summarised across three dimensions.

**In the cointegration dimension:** the ADF test on the long-run regression residuals ( $t = -4.784$ ,  $p = 0.000$ ) empirically confirmed the existence of a cointegrating relationship among

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Y (current account),  $X_1$  (foreign trade turnover),  $X_2$  (foreign direct investment), and  $X_3$  (oil and gas exports). This result is fully consistent with the finding of the ARDL Bounds test ( $F = 4.416 > 3.67$ ): the convergence of two independent methodological approaches on the same conclusion doubly reinforces the scientific credibility of the results.

**In the dynamics dimension:** the ECT coefficient of the VECM ( $\varphi = -0.2929$ ,  $p = 0.003$ ) indicates that approximately 29% of each quarter's deviation is corrected, with full equilibrium restoration requiring roughly 3.4 quarters (~10 months). In the short-run dynamics, oil and gas exports ( $D(X_3) = +1.304^{***}$ ) exhibited the strongest positive effect, while foreign trade turnover ( $D(X_1) = -516.33^{***}$ ) exhibited the strongest negative effect.

**In the forecasting dimension:** the scenario analysis demonstrated that under the baseline scenario (Brent  $\approx$  USD 75–80/barrel), a positive balance will be maintained over 2025–2026. From a policy perspective, three priorities were identified: scenario-based calibration of SOFAZ expenditure rules; structural expansion of non-oil exports; and the reorientation of FDI from import-oriented activities toward sectors capable of expanding productive capacity. These recommendations are directly aligned with the diversification targets of the Azerbaijan 2030 Strategic Roadmap.

As a limitation of the study, it should be noted that the model does not incorporate the real exchange rate, fiscal policy intensity, or the diversification index of non-oil exports; including these variables may constitute the principal direction for future research. From a methodological standpoint, the joint application of ARDL and VECM has demonstrated that two independent routes converge on the same conclusion – establishing a model of methodological credibility for the field of economics in Azerbaijan.

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## MANAGEMENT

### Current Trends in Organizational Change Management in Organizations

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**Abstract.** The article analyzes the current trends in the management of organizational changes. Implementation of changes is one of the main functions of management, which implies both formalization of organizational changes and change management. The article examines the profile of a specialist's competencies in the field of organizational change through education, the ADKAR – Prosci training model of change.

**Keywords:** *organizational change management, CRM systems, ERP systems ADKAR – Prosci change model, organization management, management, key specialists.*

**Change management** is a systematic approach to organizational transformation. It is also a distinct discipline within management science. This discipline includes a set of methods, guidelines, and principles that help implement changes within an organization.

#### **What is meant by "change" in this context?**

It refers to the addition, modification, or removal of something that can affect the company's structures. An increase in sales within a department is not a change. Growth does not alter processes. However, new regulations for sales managers or the implementation of a CRM system are considered changes.

Here are several examples of changes within a company:

- updating business processes and introducing new regulations;
- creating new positions that lead to a revision of established processes;
- implementing new IT products for management, such as CRM and ERP systems;
- establishing new departments;
- launching employee training systems.

The goal of change management is to increase the

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likelihood of success, reduce costs, and minimize employee stress. When managers study change management, they typically explore:

- change management models – general concepts describing how changes should be implemented;
- leadership guidelines for managers working with change;
- methods and techniques for working with employees affected by change – how to motivate and train them;
- recommendations and techniques for transforming corporate culture;
- methodologies for implementing technical changes, such as ERP systems. These focus less on technical aspects and more on organizational ones, including employee training and the preparation of regulations.

In most cases, changes are implemented by managers. This role may also be assumed by an HR specialist, a top executive, or a middle manager assigned to the project. To achieve success, managers undergo training in change management.

### **Three steps to change: Kurt Lewin's model**

Kurt Lewin's model is one of the most widely used concepts in change management. According to Lewin, the success of change depends largely on the leader's personality – their motivation and ability to define a clear goal. The model consists of three main stages: unfreezing, movement, and refreezing.

#### **1. Unfreezing**

At this stage, the company recognizes the need for change. The initiator is typically a top manager – either the head of the company or a specific division.

At this stage, the leader:

- creates a vision of the future – what the company will look like after the changes;
- assesses the situation – identifies what exactly needs to change: increasing sales, dismissing ineffective employees, entering new markets;
- forms a reform team – a group of colleagues who become change leaders within their units. This team is built top-down, from executives to line managers and their subordinates;
- declares new principles and motivates employees. The leader highlights small successes achieved during transformation and openly discusses failures. Lewin advises against pretending everything is fine if the company is facing difficulties, as this undermines trust.

#### **2. Movement**

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This stage involves implementing innovations in practice. While the unfreezing stage focuses on understanding what and how to change, this phase requires a detailed plan.

The process includes two key elements:

- training employees in new skills (e.g., new sales scripts or software tools);
- creating an environment to reinforce change (e.g., temporarily adjusting sales targets, scheduling regular meetings, and testing knowledge of new systems).

### 3. Refreezing

At this stage, changes have already been implemented. The goal is to prevent regression and ensure employees continue using new practices and technologies. It is important to закрепить (formalize) these practices through policies and procedures, supported by motivation.

Additionally, results are monitored during this phase, and adjustments are made if necessary.

#### The ADKAR model

The **ADKAR** model was developed by Jeff Hiatt, Managing Director of Prosci Change. It focuses on employees affected by change and consists of five sequential steps:

Organizational change should begin with training employees who will implement it. Focusing on people and their needs – not just technical aspects – increases success rates.

**ADKAR** provides a practical framework for change agents to act purposefully, overcome adaptation challenges, and improve employee responses.

**A – Awareness:** understanding the need for change. Employees are informed why change is necessary.

**D – Desire:** willingness to support and participate in change. Employees must see benefits, such as advantages of new systems or regulations.

**K – Knowledge:** understanding what to do during and after change. Employees require training.

**A – Ability:** capability to implement change in practice – moving from theory to real application.

**R – Reinforcement:** sustaining change results. Changes must be supported and controlled. If an employee struggles, solutions must be found or decisions made. Performance is assessed on a scale from 1 to 5; scores of 3 or below require improvement before moving forward.

**Preparing for change.** Managers often focus solely on implementation and overlook employee adaptation. Some employees may resist changes so strongly that they consider



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leaving. Experienced HR specialists can prevent or resolve such issues by developing sound strategies, reducing fear, and minimizing turnover.

### **Advantages of entrusting adaptation to an HR agency:**

- professional recommendations for introducing change;
- implementation of a systematic approach with detailed action plans and assigned responsibilities;
- ongoing support throughout the transformation process.

As a result, employee engagement increases, support for change improves, and implementation becomes more effective.

### **How to Ensure Employees Accept Change**

Employees may resist even clearly beneficial decisions – both at early stages and after implementation. They may complete training but continue working “the old way.” Sometimes this requires revisiting decisions; other times, motivational work is sufficient.

Five key actions can help:

1. Explain “why.” Show how changes simplify work and increase value. If necessary, demonstrate financial benefits.
2. Involve employees. Encourage ideas, feedback, and participation.
3. Introduce rewards. For example, bonuses for early success.
4. Lead by example. Apply changes personally and share honest results.
5. Provide technical support. Without it, employees revert to old methods.

The tools themselves also matter. The easier they are to use, the less resistance arises. For example, end-to-end analytics tools can provide comprehensive performance data with minimal effort once integrated.

Thus, if business expectations diverge from reality and competitors are gaining ground, it may be time for major changes. The key rule: no chaos. Change must be managed to avoid wasted resources and continuous crises:

- Change management helps businesses adapt to crises, competition, and new technologies.
- The choice of model depends on business specifics: ADKAR strengthens individual motivation, while Kotter’s approach emphasizes leadership and teamwork.
- Team motivation is built on transparency, support, involvement, and leadership example.
- The effectiveness of change can be predicted through surveys, pilot testing, and analysis of resources and results.



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### Increasing Operational Efficiency of Companies

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**Abstract.** The scientific article examines the most potential solutions for increasing the operational efficiency of production systems of companies in the Azerbaijan economy. The relevance of the study is due to the rapid development of technological innovations that can be used to improve the operational activities of enterprises. The theoretical foundations of operational activity and its place in ensuring the economic efficiency of the company's production are considered. Practical examples of AR companies in making decisions to improve operational efficiency are analyzed. Recommendations are formulated on the use of technological innovations in the development of production systems that have a direct impact on the economic indicators of the efficiency of their operating activities. An algorithm of measures aimed at optimizing operating activities by reducing production costs is proposed.

**Keywords:** *operating activities; operational efficiency; production system; technological innovation; digital technologies.*

In the context of globalization, the modern production practices of companies from post-Soviet countries show that competition is undergoing significant changes, affecting national economies, the business environment, technological processes, and international relations. Globalization intensifies internationalization and the standardization of economic processes while creating new forms of competitive struggle.

Enterprises (businesses) have encountered a critical requirement, which lies in the refinement of operational activities. This directly impacts the increase of operational efficiency, contributing to the sustainable development of their production systems. Only such a strategy is capable of leading to the financial success of an economic entity—especially in the period of the 2020s, which is characterized by factors of environmental instability within national and international economies.

**The operational efficiency** of an enterprise consists of

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achieving a positive financial result from the processes of resource expenditure, product manufacturing, and sales. In fact, the operational cycle is the core activity of any economic entity whose goal is to generate profit.

The practical role, place, and significance of operational activity within an organization lie in managing the fundamental aspects of the company's business operations. These management aspects are aimed at formulating rational managerial decisions regarding business development, coordinating various areas of the organization's operational activities, and ensuring the economic efficiency of the final results [3]

How can you improve the productivity and efficiency of your business—spending less and gaining more? This is precisely what entrepreneurs focus on when the issue of optimizing operational activities and enhancing the current business model arises. As is often the case, one question brings others that are just as compelling: What exactly should be improved, and how? What if we don't know which direction to move in next?

How do you identify what needs improvement? What are the benchmark indicators for your business? Optimization encompasses the analysis and enhancement of all aspects of operations, including processes, systems, technologies, and teams.

Before proceeding with optimization, ensure that your business has gathered all key metrics and conducted a competitor analysis. To understand what to strive for, you must answer the following question:

Are there any competitors of a specific enterprise (business) or within related industries who have already achieved the desired result?

Clearly, this is a rhetorical question meant to guide you in the right direction. The point is to identify which metrics are comparable and what you should aim for. It is necessary to select 5–10 metrics within your niche and perform an analysis of your 10 strongest competitors. This approach makes it easier to understand the performance levels that the changes we will discuss further will lead to. Key metrics might include the rental cost per square meter, if your business is service-oriented, or the prime cost of your production.

The optimization of operational activities is a key success factor for any business. It enables the improvement

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of product or service quality, the reduction of costs, and an increase in customer satisfaction. In this article, we will examine several ways to optimize operational performance.

## **1. Process automation**

Process automation is one of the most effective ways to optimize operational activities. It allows for reducing task execution time, minimizing the number of errors, and increasing productivity. For example, automating the inventory management process reduces the time spent searching for and ordering necessary materials, while automating the production management process shortens equipment setup time and decreases the volume of defects.

This may involve implementing a CRM system in the sales department (such as amoCRM or Bitrix24), management systems (Kvant or Platrum), or accounting software (1C).

## **2. System improvement**

System improvement is another method for optimizing operational activities. It enables the enhancement of business performance and efficiency. For instance, improving a quality management system helps reduce the number of defects and increase customer satisfaction, while enhancing a production management system allows for shorter equipment setup times and a reduction in production scrap.

## **3. Implementation of new technologies**

Neural networks can help optimize a business's operational activities by utilizing machine learning algorithms to analyze large volumes of data and identify hidden patterns. For instance, neural networks can be used for forecasting demand for goods and services, optimizing production processes, managing inventory and logistics, analyzing financial data, and much more.

Neural networks can also be applied to optimize manufacturing processes, such as controlling robotic systems and automated production lines. This enables the business to improve product quality, shorten production cycles, and reduce manufacturing costs

## **4. Staff training**

Staff training is a vital component of optimizing business operations, as it enhances employee qualifications and boosts productivity. This is particularly beneficial when implementing new technologies or modifying business processes.

Implementing an annual training plan for every employee in your company will inevitably lead to increased performance.

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The investment in new knowledge pays for itself, as employees bring functional new tools into the business and actively work to improve your internal processes.

Today, a pressing issue for increasing the operational efficiency of companies is the formation and development of new innovations, digital technologies, information services, and the intellectualization of business processes. These components contribute to achieving better results, creating new competitive advantages, and increasing both the labor efficiency of personnel and the productivity of equipment [4].

Within the framework of forming an economically effective operational strategy for a company, the following indicators can serve as the most important components (Fig. 1) [2; 7].

|                                                                        |                                                                                     |
|------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Utilization of the organization's production capacity.                 | Indicates the efficiency of the use of fixed assets and the need for their renewal. |
| Degree of workforce utilization throughout the entire operating cycle. | Reflects the effectiveness of employees' labor performance.                         |
| Compliance with customer expectations and preferences.                 | Serves as a basis for evaluating the company's brand value.                         |

Figure 1  
**Efficiency Indicators for Organizational Operations**

At present, improving companies' operational efficiency includes the development and implementation of managerial decisions aimed at introducing various digital technologies and innovations.

For example, in Azerbaijan, telecommunications operators such as Azercell, Bakcell, and Nar Mobile, as well as IT companies and integrators such as Pasha Technology, Noventiq, and iTech Group, use digital marketing channels to promote their products and enhance brand value.

Thus, integrated marketing communications make it possible to achieve consistency in managing marketing strategies for product promotion in the markets, alignment in planning marketing activities and the enterprise's brand

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strategy, as well as consistency in financing marketing activities and the company's brand strategy [9].

For some manufacturing enterprises, a key issue is the failure of suppliers and distributors to fulfill their obligations. Through the use of digital technologies and intelligent information systems such as TMS (Transportation Management System) and WMS (Warehouse Management System)—whose advantages include cost reduction, improved operational processes within management units, increased efficiency in the use of fixed assets, and enhanced workforce utilization—enterprise managers are provided with an information and analytical base that enables them to make managerial decisions.

These decisions are aimed at assessing the reliability of suppliers and monitoring their compliance with obligations related to the delivery of inventory items, as well as evaluating the reliability of clients and customers in order to ensure the collection of accounts receivable [8].

In turn, in the oil and gas sector of Azerbaijan, its digitalization enables the active use of cloud computing technologies. A competitive advantage of cloud technologies over traditional data centers is that users can reduce costs associated with computing and various operations. It also becomes possible to manage operational processes of production activities without being tied to a specific computer [6].

These information technologies make it possible to structure large volumes of diverse information and data, including those that differ significantly in their key characteristics. Subsequently, all this data and information are analyzed to identify specific trends and cause-and-effect relationships. The research results provide answers to many questions related to managing the operational processes of an organization.

In general, practice shows that approximately 8%–10% of GDP growth in the country is already achieved through the digitalization of operational management strategies in production, sales, and logistics supply [1].

Based on these technologies that enhance companies' operational efficiency, it is necessary to propose specific recommendations aimed at improving the management of production activities. This will make it possible to improve operational efficiency indicators and bring the organization to a new level of competitive sustainability. These measures

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should include:

1. Develop and implement a digital transformation strategy, in which not only managers and functionally responsible employees are involved in the processes of transformation and improvement, but also the entire workforce of the company. This is necessary to ensure that the degree of integration of digital technologies into operational processes is as high as possible, thereby increasing their efficiency.

2. Establish a service unit for the maintenance and improvement of the company's software acquired from third-party IT solution providers. Since the industrial sector consists of a wide variety of production types, each has its own specific operational characteristics. To adapt to these specifics, it is necessary to modernize the software and improve its integration with existing operational tasks.

3. Establish a centralized big data repository for the company, where cloud services are used instead of physical servers and data centers. This will make it possible to optimize capital expenditures on equipment, as well as ensure the effective use of all organizational data in managing operational activities.

Another key direction for improving companies' operational efficiency under current challenges in the development of production systems is cost management. For this purpose, the following optimization strategy algorithm should be recommended.

It should consist of several stages [5; 10]:

1. Stage One - collection of information related to the company's financial costs, followed by its systematization and classification.

2. Stage Two - processing of information and data, and identification of cause-and-effect relationships between operational efficiency indicators and financial costs.

3. Stage Three - analysis of problem areas and barriers that hinder economic growth and business scalability.

4. Stage Four - determination of the main directions for managing financial costs in order to optimize them.

5. Stage Five - development and adoption of managerial decisions aimed at optimizing financial costs.

6. Stage Six - implementation of the adopted managerial decisions for cost optimization and adjustment of the business development strategy.

In conclusion, it is important to emphasize that the



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current stage of economic system development is characterized by the creation of various digital technologies that are being implemented to improve organizational production processes. This contributes to increased operational efficiency for companies that are open to innovation and the adoption of advanced, intelligent management systems for production processes. The more successfully and effectively digital technologies are implemented in production, the higher the company's operational efficiency, elevating it to a new level of competitiveness.

Thus, the use of various technologies represents a major contemporary production challenge for companies within the economy of Azerbaijan. It is crucial to identify available financial resources and invest them in effective innovative projects capable of generating technologies and solutions that enhance the operational efficiency of economic entities.

In conclusion, optimizing operational activities is a continuous and creative process that enables improvements in business productivity and efficiency. Each improvement in key performance indicators leads to increased profitability and positively affects various aspects of operational activities, including processes, systems, technologies, and people. The implementation of these optimization approaches helps improve the quality of products or services, reduce costs, and increase customer satisfaction.

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### Організація статистичних спостережень на автомобільному транспорті

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**Анотація.** Автомобільний транспорт посідає ключове місце у народному господарстві країни, задовольняючи потреби як громадян, так і комерційних структур у переміщенні товарів та людей. Проте, аби керувати цією сферою, життєво необхідні точні статистичні дані, збирання яких вимагає бездоганно налагодженого механізму облікових заходів. В статті пропонується комплексний підхід до статистичного спостереження на автомобільному транспорті.

**Ключові слова:** автомобільний транспорт, статистика, спостереження, комплексний підхід, послуги.

Автомобільний транспорт є однією з найважливіших галузей національного господарства, що забезпечує потреби населення і підприємств у перевезенні вантажів і пасажирів. Ефективне управління галуззю неможливе без достовірної статистичної інформації, отримання якої потребує чітко організованої системи статистичних спостережень.

Крім того, статистика автомобільного транспорту є важливою складовою економічної статистики, оскільки галузь забезпечує значну частку вантажних і пасажирських перевезень в Україні. Організація статистичних спостережень на автомобільному транспорті є складним процесом, зумовленим специфікою цієї галузі як сфери послуг. Організація

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статистичних спостережень у цій сфері має низку специфічних особливостей, зумовлених характером діяльності транспорту.

Насамперед, статистичне спостереження на автомобільному транспорті проводиться відповідно до Методологічних положень, затверджених Державною службою статистики України [1]. Основними звітними одиницями є підприємства, що експлуатують автомобільний транспорт, а також суб'єкти господарювання (юридичні та фізичні особи), які здійснюють комерційні перевезення вантажів і пасажирів [2]. Це відрізняє автомобільний транспорт від інших галузей, де кількість учасників ринку значно менша. На відміну від промисловості, де результатом є матеріальний продукт, на транспорті головним об'єктом обліку є процес переміщення.

Це пов'язано з безперервним характером транспортного процесу, адже перевезення здійснюються щоденно і вимагають постійного обліку та контролю. Тому, вказане вище визначає необхідність вдосконалення комплексного підходу до статистичного спостереження на автомобільному транспорті.

Головною рисою таких спостережень є, на наш погляд, поєднання різних методів, а саме, суцільного та вибіркового спостереження. Для великих автотранспортних підприємств застосовується суцільне спостереження. Для дрібних перевізників і фізичних осіб-підприємців (яких у галузі переважна більшість) використовуються вибіркові методи та дані з державних реєстрів [3]. Такий підхід дозволяє охопити всю сукупність без надмірного навантаження на респондентів.

Ще однією важливою рисою є динамічність об'єктів спостереження. Рухомий склад постійно знаходиться в русі, що вимагає чіткої системи первинної документації. Сучасна статистика автомобільного транспорту активно інтегрується з цифровими технологіями: даними GPS-моніторингу та електронними реєстрами перевезень, що підвищує точність обліку пробігу та витрат ресурсів.

Крім того, мобільність транспорту, сезонність роботи, вплив погодних умов і географічних факторів також створюють особливі вимоги до організації спостереження. Дані мають збиратися оперативно, тому передбачено місячну та річну періодичність звітності.

Сучасна організація спостережень активно використовує електронні реєстри та дані з Єдиного державного вебпорталу відкритих даних. Це значно

прискорює обробку інформації та підвищує її достовірність [4].

Однією з ключових аспектів є масовість явищ, що

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досліджуються. Щодня виконується велика кількість рейсів, задіяна значна кількість транспортних засобів і працівників, що потребує систематизованого збору, обробки та аналізу великого обсягу інформації.

Важливу роль відіграє оперативність отримання даних, оскільки управлінські рішення часто повинні прийматися швидко та на основі актуальної інформації.

Треба також звернути увагу на залежність статистичних показників від часу та простору. Робота транспорту пов'язана з маршрутами, відстанями, дорожніми умовами та сезонними коливаннями, що безпосередньо впливає на результати діяльності.

Тому при організації спостережень необхідно враховувати ці фактори та забезпечувати точність і повноту даних.

Разом з тим організація спостережень на автомобільному транспорті пов'язана з рядом суттєвих особливостей, що відрізняють цю галузь від інших секторів економіки.

Перша і, мабуть, найважливіша особливість полягає у специфіці самого об'єкта спостереження. Автомобільний транспорт – це динамічна система, де транспортний засіб постійно переміщується у просторі, виконуючи перевезення

між різними населеними пунктами, регіонами і навіть країнами. На відміну від промислового підприємства, яке чітко прив'язане до конкретного місця виробництва, автомобіль може протягом одного дня перетнути кілька адміністративних меж. Це ускладнює як первинний облік, так і наступну статистичну обробку даних.

Друга особливість пов'язана зі структурою суб'єктів господарювання галузі. Автомобільний транспорт України характеризується надзвичайно високим рівнем роздробленості: поряд із великими автотранспортними підприємствами тут діють тисячі малих підприємств, фізичних осіб-підприємців та власників транспортних засобів, які надають послуги з перевезень.

Цей факт унеможлиблює організацію суцільного статистичного спостереження, яке б охоплювало всіх перевізників. Саме тому в практиці статистики автомобільного транспорту широко застосовуються несуцільні методи – вибіркові спостереження, одноразові обстеження, розрахунково-аналітичні методи оцінювання показників для нерегульованого сектора ринку.

Третьою особливістю є одночасність виробництва і споживання транспортної послуги. Оскільки транспортна послуга не може бути накопичена або складована, вся діяльність з

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перевезень відбувається в режимі реального часу. Це означає, що для отримання точних даних необхідне своєчасне документальне оформлення кожного перевезення.

Четвертою особливістю є різноманітність видів перевезень і типів транспортних засобів. Статистика має охоплювати вантажні, пасажирські та спеціальні перевезення, урахувати технічні характеристики рухомого складу (вантажопідйомність, місткість, тип палива), а також відображати перевезення, що виконуються як для потреб замовників, так і для власних потреб підприємств інших галузей (так звані «перевезення для власних потреб»).

П'ятою особливістю є вплив сезонності та нерівномірності попиту на транспортні послуги. Обсяги перевезень суттєво коливаються залежно від пори року, економічної кон'юнктури, святкових та вихідних днів [3]. Тому при організації статистичних спостережень важливо забезпечити безперервність збору даних, а не лише фіксацію показників у кінці звітного періоду, адже усереднені дані можуть приховувати важливі тенденції та пікові навантаження.

Окремої уваги заслуговує питання міжнародних автомобільних перевезень [5]. Зі вступом України до міжнародних транспортних організацій і розвитком зовнішньоекономічних зв'язків зростає потреба у гармонізації національних статистичних стандартів з вимогами Євростату та інших міжнародних органів.

Це потребує адаптації форм звітності, класифікаторів і методологій для забезпечення міжнародної порівнянності даних. Кожен із цих аспектів потребує спеціального підходу до організації спостереження і використання відповідного статистичного інструментарію.

Отже, основними етапами підходу, що пропонується є:

- поєднання суцільного та вибіркового спостережень для великих та відносно малих автотранспортних підприємств;

- інтеграція з цифровими технологіями: даними GPS-моніторингу та електронними реєстрами перевезень, що підвищує точність обліку пробігу та витрат ресурсів, використання відкритих даних з Єдиного державного вебпорталу відкритих даних.

- забезпечення оперативності отримання даних, враховуючи масовість явищ, до досліджується;

- врахування сезонності та нерівномірності попиту на транспортні послуги та , врахування особливостей міжнародних автомобільних перевезень в сучасних умовах.

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Такий підхід дозволяє охопити всю сукупність, що досліджується без надмірного навантаження на респондентів.

Отже, ефективна організація статистичного спостереження в цій галузі потребує гнучкості, поєднання традиційної звітності з новітніми методами дистанційного контролю, що дозволяє формувати об'єктивну картину транспортного ринку в умовах високої конкуренції та мінливості економічного середовища.

Особливості організації статистичних спостережень на автомобільному транспорті зумовлені специфікою самої галузі: великою кількістю учасників, мобільністю, використанням первинних документів і потребою в оперативній інформації.

Завдяки цьому статистика забезпечує повну, точну та актуальну картину роботи автомобільного транспорту, що є основою для прийняття управлінських рішень на державному та підприємницькому рівнях.

Таким чином, організація статистичних спостережень на автомобільному транспорті характеризується безперервністю, масовістю, оперативністю та залежністю від просторово-часових факторів, що вимагає чіткої системи обліку та високої достовірності інформації. Організація статистичних спостережень на автомобільному транспорті є складним і багатогранним завданням. Вона потребує поєднання різних методів збору інформації – від суцільної звітності великих підприємств до вибіркового обстеження малого бізнесу – та постійного вдосконалення методологічної бази відповідно до змін у структурі галузі та вимог міжнародних стандартів.

Лише за умови якісно організованого статистичного спостереження можна отримати достовірну інформаційну базу для аналізу стану і тенденцій розвитку автомобільного транспорту, прийняття обґрунтованих управлінських рішень та ефективного регулювання галузі.

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# Сравнительный анализ оказания гинекологической помощи в круглосуточном стационаре на платной и безвозмездной основе при клинике ТОО Эколайф

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**Аннотация.** В статье представлены результаты сравнительного анализа оказания гинекологической помощи в круглосуточном стационаре на платной и безвозмездной основе на базе ТОО «Эколайф». В работе установлено, что платная модель обеспечивает более высокие показатели оперативности, комфорта, информированности и общей удовлетворённости пациенток, тогда как бесплатная помощь выполняет значимую социальную функцию, но сопровождается организационными и сервисными ограничениями. По итогам исследования обоснованы практические направления совершенствования процесса оказания гинекологической помощи в круглосуточном стационаре.

**Ключевые слова:** гинекологическая помощь; круглосуточный стационар; платные медицинские услуги.

Охрана репродуктивного здоровья женщин относится к числу приоритетных направлений современной системы здравоохранения, поскольку напрямую связана с демографической устойчивостью, качеством жизни населения и снижением социально значимых рисков. В Республике Казахстан необходимость повышения доступности и качества медицинской помощи закреплена в стратегических документах и отраслевых нормативных актах, однако практическая реализация этих задач в значительной степени зависит от организационной модели конкретной медицинской организации. Особенно это касается гинекологической помощи в условиях круглосуточного стационара, где сочетаются лечебно-диагностические, хирургические, реабилитационные и психологические компоненты

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медицинского процесса.

Одной из наиболее дискуссионных проблем в данной сфере остаётся соотношение платной и безвозмездной помощи. С одной стороны, система ОСМС обеспечивает базовую доступность стационарного лечения для широких групп населения. С другой стороны, платный сегмент предоставляет расширенные возможности в части выбора врача, скорости госпитализации, условий пребывания и индивидуализации лечения. В результате в рамках одной и той же клиники могут сосуществовать две модели оказания помощи, различающиеся не только по финансовому механизму, но и по восприятию качества со стороны пациенток.

В связи с этим цель данной работы состояла в выявлении различий между платной и безвозмездной формами гинекологической помощи для определения не только проблемных зон, но и конкретных резервов совершенствования организации стационарной помощи.

В современной научной литературе значительное внимание уделяется вопросам организации акушерско-гинекологической помощи, маршрутизации пациенток, обеспечению доступности медицинских услуг и повышению качества стационарного лечения. А. Э. Котуков рассматривает организацию гинекологической помощи как систему управленческих и клинических решений, направленных на обеспечение преемственности между уровнями медицинской помощи, соблюдение стандартов и рациональное использование ресурсов [1]. Н. В. Артымук, О. Б. Карелина и Н. Б. Колесникова подчёркивают, что эффективность гинекологической помощи во многом определяется не только квалификацией врачей, но и чёткостью маршрута пациентки, своевременностью диагностики и доступностью необходимых медицинских технологий [2]. И. А. Алеев, С. В. Апресян и С. Э. Аракелов акцентируют внимание на том, что именно в стационаре организационные недостатки наиболее остро влияют на результаты лечения, поскольку здесь сочетаются высокая интенсивность лечебно-диагностических мероприятий, требования к безопасности и необходимость круглосуточного наблюдения за пациентками [3].

В целях выявления различий в доступности, организации и качестве стационарной гинекологической помощи, а также оценки удовлетворённости пациенток, было проведено эмпирическое исследование на базе ТОО «Эколайф» – специализированной клиники репродуктивной медицины и гинекологической помощи в г. Астана. Клиника сочетает оказание услуг на платной основе и участие в системе обязательного социального медицинского

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страхования, что делает её репрезентативной площадкой для сравнительного анализа двух моделей медицинской помощи. Эмпирическая база исследования включала анализ внутренних показателей деятельности клиники и результаты онлайн-анкетирования 100 пациенток круглосуточного стационара, из которых 50 получали помощь на платной основе и 50 – бесплатно в рамках ОСМС.

Полученные результаты свидетельствуют о наличии выраженных различий в восприятии организации и качества помощи в зависимости от формы её финансирования. Наиболее заметные различия проявились уже на этапе доступа к стационарной помощи (рисунок 1).

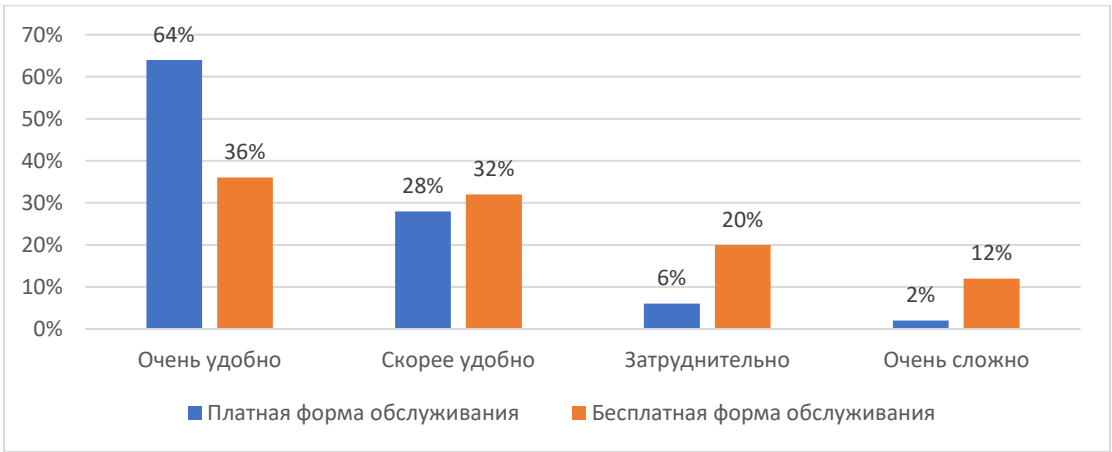


Рисунок 1

**Результаты ответа на вопрос «Насколько для Вас было удобно получить направление/записаться в стационар?», в %**

Среди платных пациенток 64 % отметили, что записаться или получить направление было «очень удобно», тогда как в группе бесплатной помощи такую оценку дали лишь 36 %. Кроме того, только 8 % платных пациенток сообщили о затруднениях при записи, тогда как в группе ОСМС совокупная доля ответов «затруднительно» и «очень сложно» достигла 32 %

Ещё более контрастные различия выявлены по времени ожидания госпитализации. Если среди платных пациенток 80 % были госпитализированы менее чем за сутки, то среди получающих помощь бесплатно этот показатель составил только 24 %. Напротив, более трёх дней ожидали 40 % пациенток в группе ОСМС и только 4 % – в платной группе (рисунок 2). Приведенные данные подтверждают, что скорость доступа к стационарному лечению остаётся одним из ключевых преимуществ платного сегмента.

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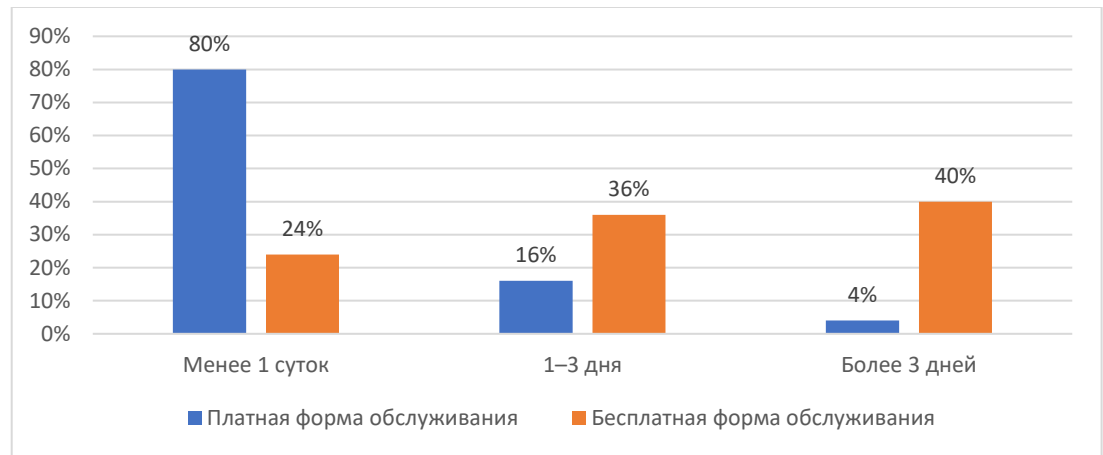


Рисунок 2

Результаты ответа на вопрос «Как долго Вы ожидали госпитализации?», в %

Анализ факторов выбора формы лечения показал, что для бесплатных пациенток определяющим мотивом выступала цена: её назвали 60 % респонденток. В платной группе на первый план выходили скорость получения услуги (40 %) и доверие к врачу (36 %). Это позволяет сделать вывод, что в условиях смешанной модели финансирования пациентки фактически выбирают не только способ оплаты, но и различающиеся организационные сценарии получения помощи.

Существенные различия обнаружены и в оценке условий пребывания. Комфортность палат как «отличную» оценили 70 % платных пациенток и только 36 % бесплатных. В бесплатной группе выше доля ответов «удовлетворительно» и «неудовлетворительно», что указывает на меньший уровень комфорта даже при общем положительном восприятии стационара (рисунок 3).

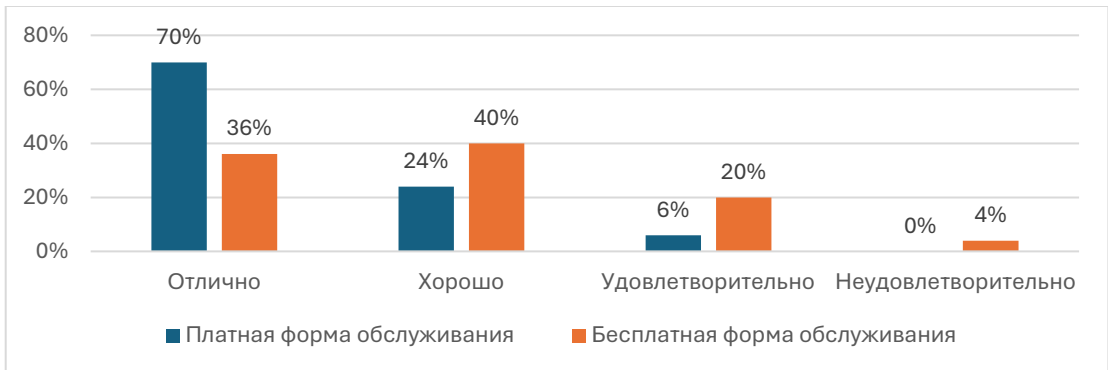


Рисунок 3

Результаты ответа на вопрос «Как Вы оцениваете комфортность палат (чистота, оборудование, питание)?», в %

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Очень показательной оказалась оценка возможности выбора лечащего врача. В платном сегменте такую возможность отметили 96 % пациенток, тогда как в группе бесплатной помощи – только 44 %. Следовательно, различие между двумя моделями проявляется не только в скорости и бытовом комфорте, но и в степени персонализации медицинской помощи, что непосредственно влияет на доверие и эмоциональную уверенность пациентки в процессе лечения (рисунок 4).

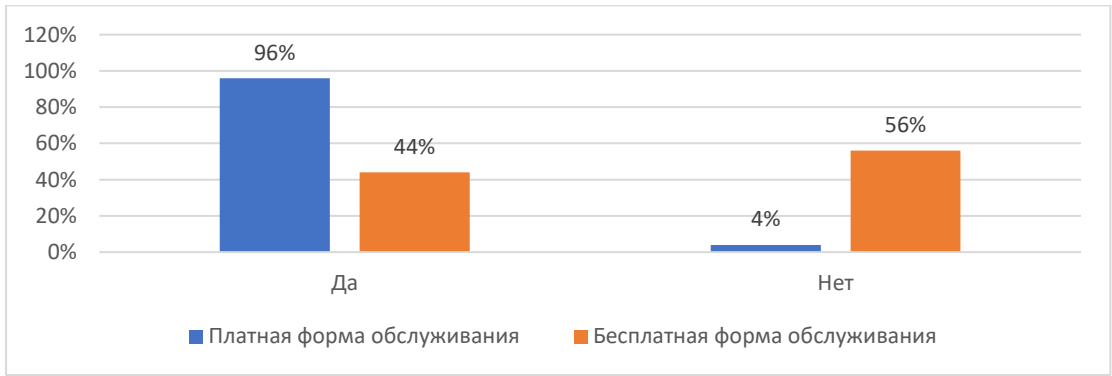


Рисунок 4  
Результаты ответа на вопрос «Был ли у Вас выбор лечащего врача?», в %

Заметный разрыв выявлен в оценке внимания и вежливости медицинского персонала. Среди платных пациенток 76 % указали на «очень высокий уровень» внимания, а среди бесплатных – 44 %. Хотя отрицательных оценок в обеих группах практически не было, более высокая доля средних оценок в группе ОСМС указывает на то, что сервисная составляющая и время коммуникации с персоналом в бесплатном сегменте воспринимаются слабее (рисунок 5).

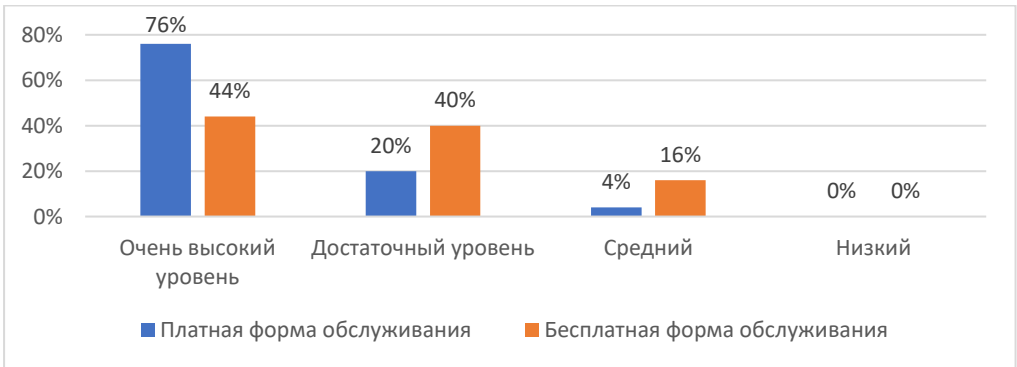


Рисунок 5  
Результаты ответа на вопрос «Как Вы оцениваете внимание и вежливость медицинского персонала (врачи, медсестры, санитарки)?», в %

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С точки зрения информирования пациенток различия также значимы. Очень подробное информирование о состоянии здоровья и вариантах лечения отметили 72 % платных пациенток и 44 % бесплатных. В бесплатной группе чаще фиксировались ответы «поверхностно» и даже «не информировал». Эти данные особенно важны, поскольку подтверждают, что качество медицинской помощи в восприятии пациенток тесно связано с глубиной коммуникации, а не только с клиническими процедурами.

Оценка эффективности проведённого лечения также оказалась более высокой в платной группе. Значительное улучшение состояния отметили 68 % платных пациенток и 40 % бесплатных; частичное улучшение – 28 % и 44 % соответственно. В бесплатной группе были зафиксированы ответы «без изменений» и «ухудшилось», что отсутствовало либо встречалось минимально в платном сегменте (рисунок 6).

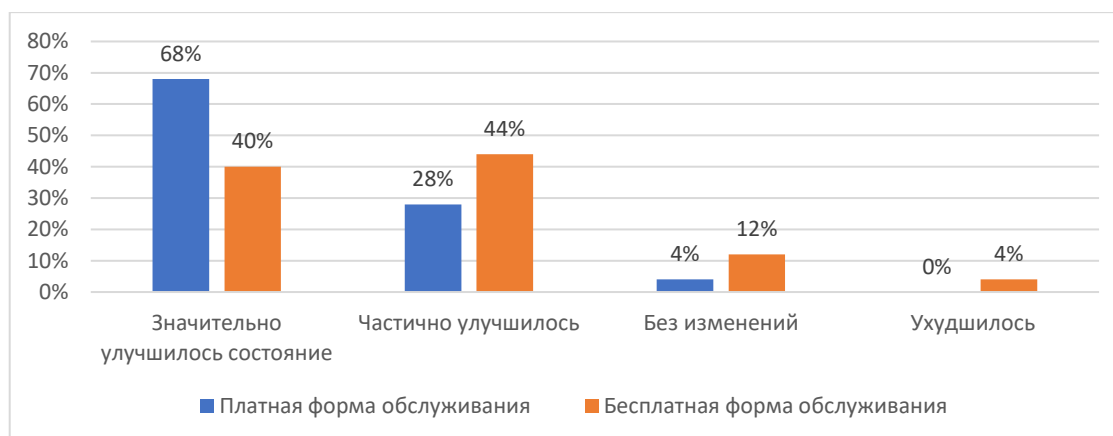


Рисунок 6

**Результаты ответа на вопрос «Как Вы оцениваете эффективность проведённого лечения?», в %**

Важным результатом является и оценка общей удовлетворённости. Полностью удовлетворены оказанной помощью оказались 76 % платных пациенток и 44 % бесплатных. При этом в группе ОСМС выше доля тех, кто оценил помощь как «скорее удовлетворительную» или «скорее не удовлетворительную». Это означает, что бесплатная помощь в целом воспринимается как приемлемая, но не обеспечивает того уровня организационного и сервисного качества, который ожидают пациентки. Дополнительно этот вывод подтверждается ответами на вопрос о готовности снова обратиться в стационар: 84 % платных пациенток готовы повторно воспользоваться именно платными услугами, тогда как среди бесплатных пациенток 56 % предпочли



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бы снова обратиться в бесплатный стационар, а 24 % – уже в платный. Таким образом, даже среди пользователей ОСМС фиксируется заметный запрос на более комфортный и оперативный формат помощи.

Результаты исследования позволяют сделать вывод, что совершенствование стационарной гинекологической помощи должно проводиться одновременно по двум направлениям – организационному и клиентоориентированному. Для ТОО «Эколайф» обоснованы следующие приоритетные меры: создание единого цифрового окна госпитализации, стандартизация маршрута пациентки по ОСМС, гибкое управление коечным фондом, расширение взаимодействия с женскими консультациями и внедрение чек-листов подготовки документов, регулярный анализ причин задержек и жалоб, развитие системы расширенного информирования пациенток, усиление психологической поддержки и стандартизация коммуникации персонала.

Проведённый сравнительный анализ показал, что в условиях круглосуточного стационара различия между платной и безвозмездной гинекологической помощью носят устойчивый и многокомпонентный характер. Платный сегмент демонстрирует преимущества по скорости госпитализации, удобству записи, возможностям выбора врача, комфортности условий пребывания, глубине информирования и общей удовлетворённости пациенток. Безвозмездная помощь в рамках ОСМС выполняет важную социальную функцию и обеспечивает базовую доступность лечения, однако чаще сопровождается организационными задержками, меньшей степенью персонализации и более скромной сервисной составляющей. При этом исследование показало, что ключевые различия между двумя моделями связаны не столько с самим фактом медицинского вмешательства, сколько с особенностями организации процесса, характером коммуникации и уровнем клиентоориентированности. Следовательно, дальнейшее повышение качества гинекологической помощи в круглосуточном стационаре должно быть направлено не только на медицинский, но и на организационно-сервисный компонент.

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### Організація бухгалтерського обліку в бюджетних установах за умов використання засобів цифровізації: особливості та ризики

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солдат Збройних Сил України; Україна

**Анотація.** В статті розглядаються переваги та ризики цифровізації бухгалтерського обліку бюджетних установ, а також визначається вплив засобів цифровізації на організацію бухгалтерського обліку згаданих суб'єктів. Встановлено, що засоби цифровізації позитивно впливають на технологічний процес обробки облікової інформації, однак й обумовлюють появу ризиків, відповідно їх застосування має враховуватись при визначенні облікової політики та організації діяльності працівників бухгалтерської служби бюджетної установи, з подальшим здійсненням контролю ризиків, що матимуть місце за означених обставин.

**Ключові слова:** цифровізація, бухгалтерський облік у державному секторі, організація бухгалтерського обліку бюджетної установи, інформаційні технології, штучний інтелект, ризики цифровізації.

Цифровізація соціально-економічного життя формує нові виклики перед низкою країн, які з об'єктивних причин вважаються аутсайдерами, проте мають усі шанси наблизитись до країн-лідерів цифрової економіки. До таких країн відноситься й Україна.

Основними причинами гальмування в Україні розвитку цифрової економіки до 2014 р. були: невизначеність вектору розвитку національної економіки та відсутність відповідної стратегії; відсутність суверенної економічної політики, сучасного індустріального виробництва та сучасних технологій; недостатнє залучення приватного сектору до індустріального розвитку країни; брак фінансування та низька інвестиційна активність суб'єктів господарювання.

Зміни, що почали відбуватись в Україні після 2014 р. та активізувались у 2019 р. стали драйверами розвитку цифрової

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економіки, проявами якої стало більш активне застосування окремих засобів цифровізації як публічного, так і приватного секторів національної економіки.

Застосування різноманітних цифрових технологій та сервісів обумовило скорочення витрат часу на проведення процедур збору й обробки інформації, зростання обсягів її зберігання, а застосування штучного інтелекту (надалі –ШІ) дозволило автоматизувати рутинні завдання, підвищити точність даних і надання аналітичних прогнозів, покращити процес прийняття рішень, зменшити операційні ризики й ефективніше реагувати на зміни нормативних вимог.

Суб'єкти приватного сектору національної економіки (великі підприємства та більшість середніх підприємств) намагаються максимально використовувати засоби цифровізації та розробляють й впроваджують системні та програмні продукти кібернетичного захисту.

Відносно публічного сектору національної економіки спостерігається певне гальмування процесу цифровізації. Таке уповільнення з одного боку є штучним, що, на нашу думку, обумовлено браком бажання забезпечити повну транспарентність управління публічними фінансами, а також державним майном, з іншого боку існуюче уповільнення цифровізації є об'єктивним, адже досягнення рівня цифровізації, який би відповідав стандартам ЄС, вимагає належного фінансування, якого наразі Україні бракує як ніколи.

До інших причин ситуації, що склалась, можна віднести й те, що:

- «існуючий рівень управління публічними фінансами знаходиться у стані, який вимагає суттєвого удосконалення, адже в умовах ведення визвольної війни відсутня надійна інформаційна база для цілісної системи стратегічного фінансового планування, залишилась остаточно не трансформованою система бухгалтерського обліку і фінансової звітності суб'єктів державного сектору, відповідно не досягнута її остаточна відповідність вимогам ЄС» [1, с. 94];

- «для створення належних умов для ефективного управління державними фінансами необхідно завершити адміністративну, судову, політичну, бюджетну, податкову, медичну, освітню реформи, адже за жодним з зазначених напрямків, або зон відповідальності державної влади, бажаних для громадянського суспільства, а також країн-партнерів результатів не досягнуто» [2, с.73];

- «Парламент та Уряд України, починаючи з 2000 р., ухвалили багато нормативно-правових актів для того, щоб

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удосконалити систему державного управління, створити сучасні умови для розвитку національної економіки, у т. ч. її державного сектору, однак відчутних якісних змін у частині державного фінансового контролю як функції державного управління не було досягнуто» [3, с. 4].

Наразі головні розпорядники бюджетних коштів усвідомлюють необхідність цифровізації загалом та цифровізації облікових процесів зокрема.

На це звертає увагу А. Кашперська, яка зазначає, що надзвичайна важливість цифровізації облікових процесів в бюджетних установах пов'язана з особливостями вітчизняного нормативно-правового регулювання суб'єктів бюджетної сфери, в тому числі наявністю окремого Плану рахунків бухгалтерського обліку в державному секторі, особливостей методичних засад, зокрема відображення господарських операцій та їх документального оформлення, а також підвищеної уваги до публічності інформації щодо отримання та цільового використання виділених головними розпорядниками бюджетних коштів бюджетним установам [4].

Проведений огляд останніх досліджень та публікацій [4; 5; 6; 7; 8; 9] свідчить про значний науковий інтерес до застосування в бухгалтерському обліку інформаційних технологій та ШІ, проте питання впливу цифровізації на організацію бухгалтерського обліку в бюджетних установах залишаються майже не дослідженими.

Так автори публікацій [4; 7], які наголошують на доцільності цифровізації бухгалтерського обліку в цілому та бюджетних установ зокрема, переконані, що застосування інформаційних систем, як складової цифровізації, надає суттєві переваги, головними з яких є:

- розширення асортименту цифрових послуг;
- ефективність, зручність, публічність та доступність інформації;
- спрощення розрахункових операцій;
- спрощення технологічного процесу обробки даних (збір та реєстрація первинних даних; формування господарських операцій, структурування синтетичних та аналітичних рахунків, заповнення довідників постійною інформацією; створення на базі електронного документа іншого документа із заповненими даними;
- систематизація даних обліку, синхронне їх відображення в одній базі даних;
- підвищення якості та повноти даних, що містяться в регістрах обліку, зменшення кількості помилок;

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- спрощення процедури отримання результатів за звітний період на запит користувача;

- спрощення подання звітності завдяки електронному документообігу;

- удосконалення процесу планування та спрощення контролю виконання бюджету;

- відкритість даних про планові і фактичні бюджетні показники та взагалі процесу логіки ухвалення рішень;

- доступність та зменшення вартості обміну великою кількістю дослідницьких даних завдяки різноманітним цифровим проектам.

Наведені та інші переваги, на думку А. Кашперської, сприятимуть покращенню якості управління та контролю діяльності учасників бюджетного процесу, починаючи від держави та головних розпорядників бюджетних коштів, завершуючи їх одержувачами, а також підвищенню зручності їх взаємодії за допомогою сучасних цифрових технологій [4].

До переваг потенційного застосування ШІ в бухгалтерському обліку бюджетних установ, на нашу думку, можна віднести:

- використання системи введення даних на основі ШІ для автоматизації вилучення, класифікації і введення фінансових даних;

- оброблення великих обсягів даних з різних джерел з надзвичайною швидкістю та точністю;

- використання технології ШІ для покращання прогнозної аналітики за рахунок підвищення точності моделей та деталізації висновків;

- використання чат-ботів з ШІ для врахування постійних змін у бухгалтерському, фінансовому (податковому та бюджетному), трудовому та інших видах законодавства, норми якого регулюють діяльність бюджетної установи, у т.ч. змін вимог до звітності, зовнішніх умов функціонування бюджетної установи, що можуть бути істотними для врахування під час удосконалення облікової політики, а також можуть вплинути на оптимізацію кількості працівників бухгалтерської служби бюджетної установи.

Слід також зазначити, що цифровізація має вплив на процес формування облікової політики, – фундаментального компоненту організації бухгалтерського обліку бюджетної установи.

Так, окрім врахування останніх норм регулювання бухгалтерського обліку в державному секторі (надалі – БОДС), що з'являються у межах його модернізації, облікова політика бюджетної установи має враховувати наслідки перманентної

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цифровізації публічних фінансів, продуктами якої є: платформа відкритих даних у сфері публічних фінансів Є-data та відповідні модулі; електронна система публічних закупівель Prozorro; електронні сервіси Державної казначейської служби України, а також потенціал застосування вже існуючих програмних продуктів.

Отже, цифровізація бухгалтерського обліку бюджетної установи набирає обертів та відіграє важливу роль при формуванні її облікової політики.

Ми погоджуємось з тим, що цифровізація БОДС вкрай потрібна. Проте, на нашу думку, поза увагою залишаються питання організації бухгалтерського обліку (надалі – ОБО) бюджетних установ, адже саме вона визначає зміст та особливості бухгалтерського обліку діяльності таких суб'єктів.

Враховуючи те, що ОБО бюджетної установи є фундаментом та умовою належного ведення бухгалтерського обліку, вважаємо за необхідне в межах його організації уперше або задля її удосконалення:

- вивчити функціонал інформаційної системи обліку на предмет її відповідності особливостям функціонування бюджетної установи (освіта, охорона здоров'я, охорона правопорядку, культура та мистецтво, спорт тощо), а також можливості її інтеграції з інформаційними системами, що вже застосовуються іншими структурними підрозділами бюджетної установи та у повному обсязі відповідають існуючим інформаційним запитам;

- визначити витрати на встановлення, експлуатацію, технічну підтримку та модернізацію інформаційних технологій;

- встановити рівень фахових вимог та необхідної компетентності працівників бухгалтерської служби, дії яких гарантуватимуть ефективну експлуатацію інформаційних технологій, безпеку даних, а також визначити відповідність необхідних навичок їх фактичному рівню (за умови необхідності удосконалення ОБО бюджетної установи).

Найбільш відчутний вплив цифровізація матиме під час розгляду питань організації діяльності працівників бухгалтерської служби, адже вона призведе до:

- побудови оптимальної структури бухгалтерської служби;
- перегляду норм праці та часу і, як наслідок, зменшення штату бухгалтерської служби;
- планування перманентного підвищення кваліфікації працівників бухгалтерської служби;
- перегляду підходів до організації робочих місць



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працівників бухгалтерської служби;

- спрощення обміну інформації між бухгалтерською службою та іншими структурними підрозділами установи;

- зміни підходів до організації належного матеріального і технічного забезпечення працівників бухгалтерської служби, а також обліку їх праці;

- змін в організації архіву облікової інформації;

- суттєвої трансформації організації безпеки та захисту облікової інформації.

Враховання визначених змін у процесі ОВО бюджетної установи, що спричинені цифровізацією публічного сектору, розширенням переліку інформаційних технологій, а також збільшенням сфери застосування ШІ в БОДС, створить надійну інформаційну базу для прийняття управлінських рішень, оцінки ефективності діяльності як бухгалтерської служби бюджетної установи, так і бюджетної установи загалом, а також створить умови для підвищення рівня транспарентності використання бюджетних коштів.

Разом з очікуваними перевагами цифровізації процесу організації та ведення обліку бюджетною установою, слід враховувати й ризики, що виникатимуть за умови втрати контролю як за зміною умов функціонування системи бухгалтерського обліку, так і за процесом прийняття адекватних рішень.

Збільшення обсягів і складності інформаційних потоків викликає і зростання ризиків втрат, спотворення інформації, які можуть носити також умисний, корисливий характер [6, с. 20]. Таким чином, створюючи значні переваги, інструменти цифровізації в своїй основі приховують і ризики, якими необхідно управляти.

До головних ризиків, що слід враховувати головним розпорядникам бюджетних коштів, які мають вплив на ОВО розпорядників бюджетних коштів, – бюджетних установ, а також їх керівникам та головним бухгалтерам, слід віднести:

- ризики застосування ШІ, роботизації, автоматизації, наслідком яких може бути витік облікової інформації, яка є комерційною, або навіть державною таємницею (наприклад, для науково-дослідних установ військово-промислового комплексу), несанкціонований доступ до облікової інформації, а також скорочення облікового персоналу;

- ризики, пов'язані з використанням імпортного програмного забезпечення та мікроелектроніки, наслідком яких може бути заборона використання бухгалтерського програмного забезпечення;



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-ризиками, пов'язаними із застосуванням хмарних і розподільних обчислень, наслідком яких може бути ускладнення або неможливість контролю за роботою хмарного програмного забезпечення, а також складність у своєчасному запобіганні помилкам функціонування;

-ризиками, пов'язаними зі стійкістю роботи інтернету, наслідком яких може бути складність введення даних до хмарного програмного забезпечення, а також несвоєчасне подання фінансової та бюджетної звітності;

-ризиками, пов'язаними з підвищенням рівня складності моделей функціонування і відсутністю кваліфікованих кадрів, наслідком яких може бути недостатній рівень знань працівників бухгалтерської служби в частині роботи з цифровими технологіями.

Наведені ризики застосування засобів цифровізації бюджетною установою можуть бути розподілені на внутрішні та зовнішні, складна структура кожного з яких, – ризикоутворюючий фактор, його вплив на процес досягнення очікуваного результату та безпосередній наслідок такого впливу на досягнутий результат [10, с. 41], спонукатиме керівника бюджетної установи до запровадження перманентного внутрішнього контролю, в основу якого має бути покладено інформаційне спостереження за ресурсами, процесами та результатами, що формуються, здійснюються та одержуються завдяки цифровізації. Відповідно: «Контроль внутрішніх ризиків має бути доповнений прийомами фактичного та документального контролю з метою перевірки достовірності звітної інформації. Види та частота застосування таких методичних прийомів залежатиме від величин показників звітності. Контроль зовнішніх ризиків матиме суттєві відмінності, які полягатимуть лише у моніторингу попередньо визначених інтервалів параметрів ризикотворних факторів» [10, с. 44].

Отже зміни, що зумовлені застосуванням засобів цифровізації в бухгалтерському обліку, стосуються всіх етапів технологічного процесу обробки інформації, тому вони мають бути враховані під час ОБО бюджетної установи задля створення належних умов реалізації обраної облікової політики, а також подальшої оцінки якості загального управління бюджетною установою та показників її діяльності.

Разом з тим, варто враховувати й ризики, що з'являються внаслідок цифровізації бюджетних відносин, застосування інформаційних систем обліку та ШІ. Відповідно слід приділяти

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більше уваги кібербезпеці та впроваджувати заходи з контролю та подальшого управління ризиками, що виникають у цифровій економіці та цифровізації публічного сектору управління.

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## PEDAGOGY AND EDUCATION

### The Use of CLIL (Content and Language Integrated Learning) in Primary Education

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#### Introduction

In the context of globalization and increasing intercultural communication, the importance of learning foreign languages from an early age has significantly grown. Traditional language teaching methods, which often separate language learning from subject content, are gradually being replaced by more integrated approaches. One such innovative and effective approach is Content and Language Integrated Learning (CLIL). CLIL refers to an educational methodology where subjects such as science, mathematics, or social studies are taught through a foreign language, thereby allowing students to learn both content and language simultaneously.

Primary education plays a crucial role in shaping learners' cognitive, linguistic, and social development. At this stage, children are naturally more receptive to language acquisition, making it an ideal period to introduce bilingual or multilingual education. The integration of CLIL in primary classrooms not only enhances language proficiency but also promotes critical thinking, creativity, and motivation among learners.

This article aims to explore the concept of CLIL, its theoretical foundations, benefits, challenges, and practical application in primary education. It also discusses strategies that teachers can use to effectively implement CLIL in the classroom.

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## 1. Understanding CLIL

Content and Language Integrated Learning (CLIL) is a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language. The term was coined in the 1990s and has since gained popularity across Europe and other parts of the world.

CLIL is based on four core components, often referred to as the "4Cs Framework":

- **Content:** Learning subject matter knowledge
- **Communication:** Using language to learn and communicate
- **Cognition:** Developing thinking skills
- **Culture:** Understanding cultural context and diversity

These components work together to create a holistic learning environment where students engage with subject content while simultaneously developing language skills.

## 2. Theoretical Foundations of CLIL

CLIL is grounded in several educational theories. One of the most influential is constructivism, which suggests that learners actively construct knowledge through experience and interaction. CLIL classrooms encourage active participation, collaboration, and problem-solving, aligning well with this theory.

Another important theory is Krashen's Input Hypothesis, which emphasizes the importance of comprehensible input in language acquisition. In CLIL, students are exposed to meaningful language within a subject context, making it easier to understand and retain.

Additionally, Vygotsky's Social Development Theory highlights the role of social interaction in learning. CLIL promotes group work, discussion, and peer interaction, which support both language and cognitive development.

## 3. Benefits of CLIL in Primary Education

### 3.1 Language Development

One of the main advantages of CLIL is improved language proficiency. Students are exposed to the target language in meaningful contexts, which enhances vocabulary, grammar, and communication skills naturally.

### 3.2 Cognitive Skills Enhancement

CLIL encourages higher-order thinking skills such as analysis, evaluation, and problem-solving. Learners are not just memorizing language; they are using it to understand and apply knowledge.

### 3.3 Increased Motivation

Young learners often find CLIL lessons more engaging

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because they involve interactive activities, real-life topics, and visual materials. This increases their motivation to learn both the language and the subject.

### **3.4 Cultural Awareness**

CLIL introduces students to different cultures and perspectives, fostering openness and intercultural understanding from an early age.

### **3.5 Academic Achievement**

Research shows that CLIL students often perform as well as or better than their peers in subject knowledge while also gaining additional language skills.

## **4. Challenges of Implementing CLIL**

Despite its many advantages, CLIL also presents certain challenges, especially in primary education.

### **4.1 Teacher Preparedness**

Teachers need to have both subject knowledge and sufficient proficiency in the target language. This dual requirement can be difficult to meet without proper training.

### **4.2 Material Development**

There is often a lack of suitable teaching materials designed specifically for CLIL in primary education. Teachers may need to adapt or create their own resources.

### **4.3 Language Difficulty**

Young learners may initially struggle to understand subject content in a foreign language, especially if the language level is too advanced.

### **4.4 Assessment Issues**

Assessing both content and language simultaneously can be complex. Teachers need to develop balanced evaluation methods.

## **5. Strategies for Effective CLIL Implementation**

### **5.1 Scaffolding**

Teachers should provide support through visual aids, gestures, simplified language, and structured activities to help students understand both content and language.

### **5.2 Use of Visuals and Multimedia**

Images, videos, charts, and real objects make learning more accessible and engaging for young learners.

### **5.3 Interactive Activities**

Group work, games, role-plays, and discussions encourage communication and active learning.

### **5.4 Language Support**

Pre-teaching vocabulary and using repetition can help students become more confident in using the target language.

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### 5.5 Differentiation

Teachers should adapt lessons according to students' language levels and learning needs.

### 6. Practical Application in the Primary Classroom

In a primary classroom, CLIL can be applied in various subjects. For example:

- **Science:** Teaching topics like plants or animals using simple English vocabulary

- **Mathematics:** Using English for numbers, shapes, and basic operations

- **Art:** Giving instructions in English while students create drawings or crafts

A typical CLIL lesson might include:

1. Warm-up activity (introducing vocabulary)
2. Presentation of content (using visuals and simple language)

3. Practice activities (group tasks or games)

4. Review and reflection

Teachers should ensure that lessons are student-centered and interactive, allowing children to learn through doing.

### Conclusion

Content and Language Integrated Learning (CLIL) represents a powerful and effective approach to education in the 21st century. By combining subject learning with language acquisition, CLIL provides young learners with valuable skills that go beyond traditional classroom boundaries. In primary education, where children are naturally open to new languages and experiences, CLIL can significantly enhance both academic and linguistic development.

However, successful implementation requires well-trained teachers, appropriate materials, and supportive learning environments. Despite the challenges, the benefits of CLIL—such as improved language skills, increased motivation, and enhanced cognitive abilities—make it a highly valuable methodology for modern education systems.

As education continues to evolve, CLIL offers a promising pathway for preparing students to thrive in a multilingual and multicultural world.

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### The Effectiveness of Game-Based Learning in Teaching English in Primary Education

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**Abstract.** In recent years, game-based learning has gained significant attention as an innovative teaching approach, especially in primary education. This paper examines the effectiveness of game-based learning in teaching English to young learners. The study focuses on how the integration of games into the educational process influences students' motivation, engagement, and language acquisition. The research is based on theoretical analysis and a review of pedagogical studies. The findings indicate that game-based learning enhances vocabulary development, improves communication skills, and increases learners' overall academic performance. Furthermore, it supports cognitive, social, and emotional development. The paper concludes that game-based learning is an effective and necessary method in modern English language teaching.

**Keywords:** *game-based learning, primary education, English teaching, young learners, motivation, interactive learning.*

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#### Introduction

In the modern globalized world, English has become an essential tool for communication, education, and professional development. As a result, teaching English at an early stage has become a priority in many educational systems. Primary education plays a crucial role in forming a strong linguistic foundation for learners. However, teaching young learners requires specific methods that correspond to their psychological and developmental characteristics.

Traditional teaching methods often fail to maintain students' attention and interest. Young learners tend to lose concentration quickly if the learning process is monotonous and passive. Therefore, educators are increasingly searching for innovative approaches that make learning more engaging

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and effective.

One of the most promising approaches is game-based learning. This method combines educational content with game elements, creating an interactive and motivating learning environment. Game-based learning allows students to actively participate in the learning process, which leads to better understanding and retention of knowledge.

The aim of this paper is to analyze the effectiveness of game-based learning in teaching English in primary education and to highlight its advantages and challenges.

### **1. The Concept of Game-Based Learning**

Game-based learning refers to the use of games or game elements in the educational process to achieve learning objectives. It is based on the idea that learning can be more effective when it is enjoyable and interactive. Games include elements such as rules, goals, challenges, feedback, and rewards, which help create a structured and engaging environment.

Unlike traditional teaching methods, game-based learning focuses on active participation. Students are not passive recipients of information but active participants who explore, experiment, and learn through experience. This approach aligns with constructivist learning theory, which emphasizes that knowledge is constructed through interaction and experience.

Game-based learning can be divided into different types, including:

- physical games (classroom activities)
- role-playing games
- digital games and online platforms

Each type has its own advantages and can be used depending on the learning objectives and available resources.

### **2. The Importance of Game-Based Learning in Primary Education**

Primary school students have unique characteristics that influence their learning process. They are naturally curious, energetic, and eager to explore the world around them. However, they also have a short attention span and may struggle with abstract concepts.

Game-based learning is particularly effective for young learners because it matches their natural learning style. Through games, children can learn in a relaxed and enjoyable environment, which reduces anxiety and increases confidence.

In the context of English language learning, game-based

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learning helps develop key skills such as:

- listening comprehension
- speaking ability
- vocabulary acquisition
- basic grammar understanding

Moreover, games create opportunities for repetition, which is essential for language learning. Repetition through games is more engaging than traditional drills, making it easier for students to remember new words and structures.

### **3. The Effectiveness of Game-Based Learning**

Numerous studies have demonstrated the effectiveness of game-based learning in education. One of the main advantages is increased motivation. When students are motivated, they are more likely to participate actively and invest effort in learning.

Game-based learning also improves academic performance. Students who learn through games often achieve better results compared to those who follow traditional methods. This is because games provide immediate feedback, allowing students to understand their mistakes and learn from them.

In addition, game-based learning enhances cognitive skills such as:

- problem-solving
- critical thinking
- decision-making

It also supports social development. Many games require teamwork and collaboration, which helps students develop communication and interpersonal skills.

Another important benefit is emotional engagement. Games create a positive learning atmosphere where students feel comfortable and confident. This reduces fear of making mistakes, which is especially important in language learning.

### **4. Practical Applications in Teaching English**

Game-based learning can be applied in various ways in English language classrooms. Teachers can use different types of games depending on the lesson objectives.

**Vocabulary games** are widely used to introduce and practice new words. Examples include matching words with pictures, word puzzles, and memory games. These activities help students learn new vocabulary in a fun and effective way.

**Role-playing games** are useful for developing speaking skills. Students can act out real-life situations such as shopping, visiting a doctor, or introducing themselves. This helps them practice language in meaningful contexts.

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**Digital games** are becoming increasingly popular. Educational applications and online platforms provide interactive exercises that improve listening, reading, and grammar skills. These tools are especially effective in modern classrooms where technology is available.

In addition, teachers can create their own games based on lesson content. This allows them to adapt activities to students' needs and learning levels.

### **5. Challenges and Limitations of Game-Based Learning**

Despite its many advantages, game-based learning also has some challenges. One of the main difficulties is selecting appropriate games that align with learning objectives. Not all games are educational, and some may distract students from learning.

Time management is another challenge. Games can take more time than traditional teaching methods, which may affect lesson planning. Teachers need to balance game activities with other instructional methods.

Lack of resources can also be a problem, especially in schools with limited access to technology. Digital games require devices and internet access, which may not always be available.

Furthermore, teachers need proper training to effectively implement game-based learning. Without adequate preparation, games may not achieve the desired educational outcomes.

### **Conclusion**

In conclusion, game-based learning is a highly effective approach to teaching English in primary education. It enhances students' motivation, engagement, and academic performance. By integrating games into the learning process, teachers can create a more interactive and enjoyable environment.

Game-based learning not only improves language skills but also supports cognitive, social, and emotional development. Despite some challenges, its benefits outweigh its limitations.

Therefore, educators should consider incorporating game-based learning into their teaching practices to achieve better educational outcomes.

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### Жи-құралдарын қолдану арқылы болашақ арнайы педагогтердің сыни ойлауын қалыптастыру

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**Аңдатпа.** Қазіргі білім беру жүйесінің цифрландыру жағдайында болашақ арнайы педагогтердің кәсіби даярлығын жетілдіру мәселесі өзекті бағыттардың біріне айналып отыр. Әсіресе, сыни ойлау дағдыларын қалыптастыру олардың кәсіби қызметінде тиімді шешім қабылдаудың маңызды алғышарты ретінде қарастырылады. Осы зерттеу жұмысының мақсаты – жасанды интеллект құралдарын пайдалану негізінде болашақ арнайы педагогтердің сыни ойлауын қалыптастырудың тиімді жолдарын ғылыми тұрғыда негіздеу. Зерттеу барысында сыни ойлау теориялары, оның құрылымдық компоненттері және педагогикалық мәні талданды. Сонымен қатар жасанды интеллект құралдарының (чат-боттар, адаптивті оқыту жүйелері, аналитикалық платформалар) білім беру үдерісіндегі мүмкіндіктері қарастырылды. Арнайы педагогика саласындағы цифрлық технологияларды қолдану ерекшеліктері айқындалып, инклюзивті білім беру жағдайындағы олардың рөлі сипатталды. Зерттеу әдістері ретінде теориялық талдау, салыстыру, жүйелеу, сондай-ақ эмпирикалық әдістер – педагогикалық эксперимент, бақылау, сауалнама және тестілеу қолданылды. Эксперимент нәтижелері жасанды интеллект құралдарын жүйелі қолдану студенттердің сыни ойлау деңгейін арттыруға оң әсер ететінін көрсетті. Атап айтқанда, білім алушылардың ақпаратты талдау, бағалау, дәлелдеу және рефлексия жасау дағдыларының дамуы байқалды. Зерттеудің ғылыми жаңалығы – жасанды интеллект құралдарын қолдану арқылы болашақ арнайы педагогтердің сыни ойлауын қалыптастырудың авторлық моделі ұсынылып, оның тиімділігі тәжірибелік тұрғыда дәлелденді. Практикалық маңызы – ұсынылған әдістемелік тәсілдерді жоғары оқу орындарының білім беру үдерісінде қолдану мүмкіндігімен анықталады.

**Түйін сөздер:** жасанды интеллект, сыни ойлау, арнайы педагогика, болашақ мұғалім, цифрлық технологиялар, инклюзивті білім беру, кәсіби құзыреттілік, аналитикалық дағдылар, педагогикалық инновациялар.

**Кіріспе.** Қазіргі кезеңде білім беру жүйесі жаһандық цифрландыру үдерісінің ықпалымен түбегейлі өзгерістерге ұшырап отыр. Ақпараттық қоғамның қалыптасуы, цифрлық

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технологиялардың қарқынды дамуы және жасанды интеллект (ЖИ) құралдарының білім беру кеңістігіне енуі оқыту мазмұны мен әдістерін жаңаша қарастыруды талап етеді. Бұл үдерістер, әсіресе, арнайы педагогика саласына ерекше ықпал етуде, себебі ерекше білім беру қажеттілігі бар білім алушылармен жұмыс жүргізу күрделі, көпқырлы және дербестендірілген тәсілдерді қажет етеді. Осыған байланысты болашақ арнайы педагогтердің кәсіби даярлығы тек теориялық біліммен шектелмей, жоғары деңгейдегі аналитикалық, рефлексивтік және сыни ойлау дағдыларын меңгеруді көздейді.

Зерттеу өзектілігі цифрландыру жағдайындағы білім беру трансформациясымен тығыз байланысты. Бүгінгі таңда білім беру жүйесі дәстүрлі мазмұннан құзыреттілікке негізделген модельге көшуде. Бұл модель білім алушылардың тек ақпаратты меңгеруін ғана емес, оны талдау, салыстыру, бағалау және қолдану қабілеттерін дамытуды басты мақсат ретінде қарастырады. Осындай жағдайда сыни ойлау ХХІ ғасырдың негізгі құзыреттіліктерінің бірі ретінде алдыңғы қатарға шығады. Сыни ойлау тұлғаның ақпаратты саналы қабылдауына, жалған және шынайы мәліметтерді ажырата білуіне, негізделген шешім қабылдауына мүмкіндік береді. Әсіресе, арнайы педагогтер үшін бұл қабілет ерекше маңызға ие, себебі олар әртүрлі даму ерекшеліктері бар балалармен жұмыс барысында күрделі педагогикалық жағдаяттарды талдап, тиімді шешім қабылдауы тиіс.

Сонымен қатар, ЖИ құралдарының білім берудегі әлеуеті күн өткен сайын артып келеді. Жасанды интеллект білім беру процесін дербестендіруге, оқу материалдарын бейімдеуге, білім алушылардың жетістіктерін талдауға және кері байланыс беруге мүмкіндік береді. ЖИ негізіндегі платформалар оқыту үдерісін интерактивті, икемді және нәтижеге бағытталған етеді. Алайда арнайы педагогика саласында ЖИ құралдарын қолдану мәселесі әлі де жеткілікті деңгейде зерттелмеген. Көптеген ғылыми еңбектер жалпы білім беру контекстінде қарастырылғанымен, ерекше білім беру қажеттілігі бар білім алушылармен жұмыс жүргізуде ЖИ-дің мүмкіндіктері мен шектеулері толық ашылмаған. Бұл жағдай зерттеу тақырыбының өзектілігін айқындай түседі.

Осыған орай, зерттеудің маңызды аспектілерінің бірі – болашақ арнайы педагогтердің сыни ойлау деңгейінің жеткіліксіздігі мәселесі болып табылады. Жоғары оқу орындарында білім алушылар көбіне дайын ақпаратты қабылдауға бейімделген, ал оны талдау, сыни бағалау және шығармашылық тұрғыдан қолдану дағдылары жеткілікті деңгейде қалыптаспайды.



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Бұл, өз кезегінде, кәсіби қызмет барысында қиындықтар туындатады. Сонымен қатар дәстүрлі оқыту әдістерінің шектеулілігі де айқын байқалады. Көп жағдайда оқыту репродуктивті сипатта ұйымдастырылып, студенттердің белсенді танымдық әрекетіне жеткілікті жағдай жасалмайды. Мұндай жағдайда сыни ойлауды дамытуға бағытталған инновациялық тәсілдерді енгізу қажеттілігі туындайды.

ЖИ құралдарын мақсатты қолдану әдістемесінің болмауы да зерттеудің өзекті мәселелерінің бірі болып табылады. Қазіргі уақытта білім беру ұйымдарында цифрлық технологиялар кеңінен қолданылғанымен, оларды сыни ойлауды дамытуға бағытталған жүйелі педагогикалық құрал ретінде пайдалану жеткіліксіз деңгейде жүзеге асырылуда. ЖИ көбіне ақпарат көзі немесе техникалық құрал ретінде қарастырылып, оның дидактикалық мүмкіндіктері толық пайдаланылмай отыр. Сондықтан ЖИ құралдарын педагогикалық тұрғыдан негізделген модель арқылы қолдану қажеттілігі туындайды.

Осы мәселелерді ескере отырып, зерттеудің мақсаты – ЖИ құралдарын пайдалану негізінде болашақ арнайы педагогтердің сыни ойлауын қалыптастырудың тиімді жолдарын ғылыми тұрғыда негіздеу болып табылады. Бұл мақсатқа жету үшін бірқатар зерттеу міндеттері айқындалды. Атап айтқанда, сыни ойлау ұғымының теориялық негіздерін талдау, оның құрылымдық компоненттерін анықтау және педагогикалық мәнін ашу маңызды. Сонымен қатар ЖИ құралдарының педагогикалық мүмкіндіктерін жүйелі түрде қарастыру, олардың білім беру процесіндегі рөлін айқындау қажет. Арнайы педагогтерді даярлау жүйесіндегі ерекшеліктерді талдау арқылы кәсіби құзыреттіліктердің қалыптасу заңдылықтарын анықтау да зерттеудің маңызды міндеттерінің бірі болып табылады.

Зерттеу аясында эмпирикалық жұмыстар жүргізу де ерекше маңызға ие. Педагогикалық эксперимент ұйымдастыру арқылы ЖИ құралдарының сыни ойлауды дамытуға әсерін тәжірибелік тұрғыда тексеру көзделеді. Бұл ретте білім алушылардың бастапқы және қорытынды көрсеткіштері салыстырылып, олардың сыни ойлау деңгейіндегі өзгерістер анықталады. Алынған нәтижелердің тиімділігін бағалау арқылы ұсынылған әдістеменің практикалық маңызы негізделеді.

Әдеби шолу. Қазіргі ғылыми-педагогикалық зерттеулерде сыни ойлау, жасанды интеллект және арнайы педагогика мәселелері өзара байланыста қарастырылып келе жатқанымен, олардың интеграциясы әлі де толық жүйеленбеген бағыттардың бірі болып табылады. Осы бөлімде сыни ойлау теориялары, ЖИ құралдарының білім берудегі орны, арнайы педагогикадағы

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цифрлық технологиялардың рөлі және зерттеу олқылықтары кешенді түрде талданады.

Сыни ойлау ұғымы педагогика мен психология ғылымдарында кеңінен зерттелген категориялардың бірі болып табылады. Оның теориялық негіздері когнитивтік психология, философия және білім беру теорияларымен тығыз байланысты. Сыни ойлауды жүйелі түрде сипаттауда Блум таксономиясы ерекше орын алады. Блум ұсынған танымдық мақсаттар иерархиясы білім алушылардың ойлау әрекеттерін қарапайым деңгейден күрделі деңгейге дейін жіктейді: білу, түсіну, қолдану, талдау, жинақтау (синтез), бағалау. Кейінгі жаңартылған нұсқасында бұл деңгейлер «есте сақтау – түсіну – қолдану – талдау – бағалау – жасау» түрінде қарастырылады. Бұл құрылым сыни ойлаудың негізін құрайтын талдау, бағалау және шығармашылық әрекеттердің маңыздылығын көрсетеді.

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Кесте 1

| Әдебиеттерге шолу бойынша салыстырмалы талдау кестесі |                       |                           |                                                                                |                                         |
|-------------------------------------------------------|-----------------------|---------------------------|--------------------------------------------------------------------------------|-----------------------------------------|
| №                                                     | Бағыт                 | Автор/теория              | Негізгі мазмұны                                                                | Негізгі идеясы                          |
| 1                                                     | Сыни ойлау теориялары | Б. Блум (таксономия)      | Ойлау деңгейлерінің иерархиясы (білу, түсіну, қолдану, талдау, бағалау, жасау) | Жоғары деңгейлі ойлау дағдыларын дамыту |
| 2                                                     | Сыни ойлау            | Р. Эннис                  | Рефлексивті және рационалды ойлау                                              | Дәлелге негізделген шешім қабылдау      |
| 3                                                     | Сыни ойлау            | Р. Пол                    | Ойлау стандарттары мен элементтері                                             | Логикалық, дәлелді ойлау                |
| 4                                                     | Сыни ойлау            | А. Фишер                  | Аргументтерді талдау және бағалау                                              | Дәлелдерді саралау                      |
| 5                                                     | ЖИ және білім беру    | Чат-бот технологиялары    | Интерактивті оқыту, кері байланыс                                              | Жедел жауап, диалогтік оқыту            |
| 6                                                     | ЖИ және білім беру    | Адаптивті жүйелер         | Жеке оқу траекториясын құру                                                    | Дербестендірілген оқыту                 |
| 7                                                     | ЖИ және білім беру    | Аналитикалық платформалар | Оқу деректерін талдау                                                          | Нәтижеге негізделген бағалау            |

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1-кестенің жалғасы

|    |                     |                                  |                                                    |                                     |
|----|---------------------|----------------------------------|----------------------------------------------------|-------------------------------------|
| 8  | Шетелдік зерттеулер | D. Crystal, S. Herring және т.б. | Цифрлық ортадағы коммуникация                      | Танымдық белсенділік артады         |
| 9  | Отандық зерттеулер  | Қазақстандық ғалымдар            | Цифрлық технологияларды білім беруде қолдану       | Білім сапасын арттыру               |
| 10 | Арнайы педагогика   | Инклюзивті білім беру теориясы   | Ерекше білім беру қажеттілігі бар балалармен жұмыс | Дербестендірілген тәсіл             |
| 11 | Арнайы педагогика   | Цифрлық құралдар                 | Оқыту мен түзету жұмыстары                         | Қолжетімділік пен бейімдеу          |
| 12 | Зерттеу олқылықтары | Ғылыми талдау                    | ЖИ мен сыни ойлау байланысы жеткіліксіз            | Теориялық және практикалық алшақтық |
| 13 | Зерттеу олқылықтары | Арнайы педагогикадағы зерттеулер | ЖИ қолдану аз зерттелген                           | Әдістемелік база әлсіз              |

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Ғылыми әдебиеттерде сыни ойлаудың негізгі компоненттері ретінде бірнеше өзара байланысты элементтер айқындалады:

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аналитикалық ойлау (ақпаратты құрылымдау және салыстыру), бағалау (дәлелдердің сенімділігін анықтау), интерпретация (мәліметтерді түсіндіру), рефлексия (өз ойлау үдерісін талдау) және шешім қабылдау (баламаларды таңдау). Бұл компоненттер болашақ арнайы педагогтердің кәсіби қызметінде ерекше маңызға ие, себебі олар күрделі педагогикалық жағдайларды саралап, тиімді шешім қабылдауды талап етеді.

Қорытынды. Жүргізілген зерттеу жұмысы цифрландыру жағдайындағы білім беру жүйесінде болашақ арнайы педагогтердің сыни ойлауын қалыптастыру мәселесінің өзектілігін кешенді түрде қарастыруға мүмкіндік берді. Зерттеу нәтижелері ЖИ құралдарын педагогикалық тұрғыда мақсатты және жүйелі қолдану арнайы педагогтердің кәсіби құзыреттілігін арттыруда маңызды факторлардың бірі екенін дәлелдейді. Әсіресе, сыни ойлау дағдыларын дамыту контекстінде ЖИ технологияларының әлеуеті жоғары екені айқындалды.

Зерттеу барысында алынған нәтижелерді жинақтай отырып, бірнеше маңызды қорытындылар жасауға болады. Біріншіден, болашақ арнайы педагогтердің сыни ойлау деңгейі бастапқы кезеңде жеткілікті деңгейде қалыптаспағаны анықталды. Бұл олардың ақпаратты терең талдау, дәлелдерді бағалау және негізделген шешім қабылдау дағдыларының әлсіздігімен сипатталды. Екіншіден, дәстүрлі оқыту әдістері студенттердің танымдық белсенділігін толық қамтамасыз етпейтіні және сыни ойлауды дамытуға жеткілікті жағдай жасамайтыны байқалды. Үшіншіден, ЖИ құралдарын оқу үдерісіне енгізу студенттердің оқу мотивациясын арттырып, олардың белсенді танымдық әрекетке қатысуына оң әсер ететіні тәжірибелік тұрғыда дәлелденді.

Эксперименттік жұмыс нәтижелері ЖИ негізінде ұйымдастырылған оқу процесі студенттердің сыни ойлау деңгейінің айтарлықтай артқанын көрсетті. Атап айтқанда, студенттер ақпаратты талдау, салыстыру, дәлелдеу және қорытынды жасау дағдыларын тиімді меңгере бастады. Сонымен қатар олардың рефлексивтік қабілеттері дамып, өз әрекеттерін бағалау және түзету дағдылары қалыптасты. Бұл өзгерістер ЖИ құралдарының оқу процесінде тек ақпарат көзі ғана емес, сонымен қатар когнитивтік дағдыларды дамыту құралы ретінде де тиімді екенін дәлелдейді.

Теориялық тұрғыдан алғанда, зерттеу нәтижелері сыни ойлау ұғымының құрылымын нақтылап, оның компоненттерінің (аналитикалық ойлау, бағалау, интерпретация, рефлексия және шешім қабылдау) өзара байланысын айқындауға мүмкіндік берді. Сонымен қатар ЖИ құралдарының педагогикалық мүмкіндіктері жүйеленіп, олардың сыни ойлауды дамытудағы рөлі ғылыми

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тұрғыда негізделді. Ұсынылған модель ЖИ құралдарын мақсатты қолдану арқылы студенттердің сыни ойлау дағдыларын қалыптастырудың тиімді механизмін сипаттайды. Бұл модель педагогикалық теория мен практиканың тоғысында орналасқан жаңа ғылыми тәсіл ретінде қарастырылуы мүмкін.

Зерттеудің практикалық маңызы да ерекше. Ұсынылған әдістемелік тәсілдер мен модельдер жоғары оқу орындарында болашақ арнайы педагогтерді даярлау процесіне енгізуге мүмкіндік береді. ЖИ құралдарын қолдану арқылы оқыту үдерісін дербестендіру, студенттердің оқу белсенділігін арттыру және олардың кәсіби құзыреттілігін дамытуға жағдай жасауға болады. Сонымен қатар бұл тәсіл инклюзивті білім беру сапасын арттыруға ықпал етеді, себебі арнайы педагогтер күрделі педагогикалық жағдайларда тиімді шешім қабылдай алатын деңгейге жетеді.

Арнайы педагог даярлауда ЖИ қолданудың тиімділігі бірнеше аспектілер арқылы көрінеді. Біріншіден, ЖИ оқу процесін жекешелендіруге мүмкіндік береді, бұл әр студенттің жеке ерекшеліктерін ескеруге жағдай жасайды. Екіншіден, ЖИ құралдары арқылы студенттер нақты педагогикалық жағдаяттарды модельдеу негізінде тәжірибелік дағдыларын дамыта алады. Үшіншіден, ЖИ кері байланысты жедел және нақты түрде қамтамасыз етіп, оқу нәтижелерін үздіксіз бақылауға мүмкіндік береді. Төртіншіден, ЖИ студенттердің өзіндік жұмысын ұйымдастыруда тиімді құрал ретінде қызмет атқарады, бұл олардың жауапкершілігі мен дербестігін арттырады.

Сонымен қатар зерттеу нәтижелері ЖИ құралдарын қолданудың белгілі бір шектеулері бар екенін де көрсетті. Атап айтқанда, технологиялық тәуелділік, цифрлық сауаттылық деңгейінің әртүрлілігі және әдістемелік қамтамасыз етудің жеткіліксіздігі сияқты мәселелер байқалады. Бұл факторлар ЖИ-ді білім беру процесіне енгізуде кешенді тәсілді қажет етеді.

Болашақ зерттеулерге қатысты бірқатар ұсыныстар беруге болады. Біріншіден, ЖИ құралдарының әртүрлі түрлерінің (мысалы, генеративті ЖИ, адаптивті платформалар) сыни ойлауға әсерін салыстырмалы түрде зерттеу қажет. Екіншіден, арнайы педагогикадағы әртүрлі бағыттар бойынша (логопедия, тифлопедагогика, сурдопедагогика) ЖИ қолданудың ерекшеліктерін анықтау маңызды. Үшіншіден, ұзақ мерзімді эксперименттік зерттеулер жүргізу арқылы ЖИ-дің білім беру нәтижелеріне ықпалын тереңірек талдау қажет. Төртіншіден, оқытушылардың цифрлық және әдістемелік даярлығын жетілдіруге бағытталған бағдарламаларды әзірлеу ұсынылады.

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## Адикції (залежності) військовослужбовців та їх профілактика

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**Анотація.** Під час діяльності військових колективів особовий склад постійно відчуває високий рівень психофізіологічного напруження. В екстремальних умовах психіка окремих військовослужбовців шукає способи швидкого розвантаження (полегшення), вони вдаються до вживання спиртних напоїв, наркотичних речовин, енергетиків, або за допомогою сучасних гаджетів намагаються/відключаються від навколишнього середовища, виконання в повному об'ємі бойових/службових завдань. На перших порах ці прийоми забезпечують полегшення, але при систематичному застосуванні виснажують нервову систему, викликають психологічну залежність, яка з часом переростає у фізичну, призводить до руйнівних станів, викликає тривогу, депресію, роздратування, а у деякого виражену психологічну патологію.

**Ключові слова:** хімічна залежність, адиктивна поведінка, спонукальний мотив, соціальна деградація, дисфункціональні взаємовідносини, нехімічні адикції, саморуйнівний стан.

Служба у збройних силах – це високий рівень стресу, нестача відпочинку, емоційне перенапруження та, інколи, відчуття «вигорання». У таких умовах алкоголь, енергетики чи психоактивні речовини можуть здаватися швидким способом «відключитися» або зняти психологічну напругу. Але насправді вони посилюють тривогу, погіршують сон, знижують концентрацію уваги й збільшують ризик небезпечних ситуацій на службі. Чимало військовослужбовців не усвідомлюють, або стидаються визнавати, що залежність не слабкість, а спосіб нервової системи впоратися з надмірним стресом. Вони демонструють «поведінковий героїзм», культуру «стримування емоції»; не говорять між собою про пережите. За таких умов психіка шукає спосіб швидкого розвантаження (полегшення) і, саме тут ризик залежностей зростає.

У сучасному житті розповсюдження набули такі об'єкти залежностей як: психоактивні речовини (легальні та нелегальні



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наркотики); алкоголь; їжа; ігри; секс; релігія та релігійні культури, *релігійна деструктивна поведінка* (релігійний фанатизм, залучення до секти). Відповідно до перерахованих об'єктів виділяють наступні форми залежностей: *хімічна залежність* (куріння, токсикоманія, наркозалежність, лікарська залежність, алкогольна залежність); *порушення харчової поведінки* (переїдання, голодування, відмова від їжі); *гемблінг* (лудоманія) – ігрова залежність (комп'ютерна залежність, азартні ігри, ставки на спорт); *любовна залежність та співзалежність* (патологічна фіксація на партнері, необхідність у його схваленні, страх самотності та нездатність приймати рішення); *шопоголізм* (оніоманія): нав'язливе бажання купувати непотрібні речі; *трудоголізм* (фанатичне прагнення працювати, ігноруючи відпочинок та взаємовідносини з іншими людьми); *гаджет-залежність*: номофобія (страх залишитися без телефону); *емоційні залежності* (залежність від постійних драм, уваги, схвалення або адреналіну); *сексуальні адикції* (зоофілія, фетишизм, пігмаліонізм, трансвестизм, ексбіціонізм, вуайєризм, некрофілія, садомазохізм тощо).

Такі залежності мають психологічний механізм вираження в адиктивних формах поведінки. Основний мотив людей, схильних до адиктивних форм поведінки, – активна зміна психічного стану, що не задовольняє їх. Життя їм бачиться нецікавим через його буденність і одноманітність. Людина не сприймає того, що вважається у військовому колективі або суспільстві нормальним. Характерними для такої людини є підпорядкованість, спрямованість на зняття з себе і передачу іншому відповідальності за поведінку, нездатність повною мірою й адекватно планувати та прогнозувати своє майбутнє. Погана стійкість до труднощів повсякденного життя і докори у непристосованості та відсутності бажання жити і вести себе як всі формують в адиктивних особистостей прихований «комплекс неповноцінності» – вони страждають тому, що відрізняються від інших та нездатні «жити як люди». Цей комплекс проявляється гіперкомпенсаторною реакцією – від заниженої самооцінки людина переходить одразу до завищеної (обминаючи адекватну); з'являється відчуття переваги над іншими, це захисна психологічна функція, що сприяє підтриманню самоповаги у несприятливих мікросоціальних умовах.

Попередніми ознаками розвитку (наявності) залежностей є: потреба «розслабитися» через алкоголь чи інші речовини; зростання дози: те, що раніше «працювало», вже не допомагає; часті похмілля, проблеми зі сном, зниження витривалості;

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зміни в настрої: апатія, спалахи гніву чи агресії; уникання побратимів з метою приховування своїх залежностей; порушення дисципліни або необґрунтовані ризиковані вчинки та інше. Ключовими ознаками психологічних залежностей можуть бути: кількісна втрата контролю: неможливість зупинити дію, навіть усвідомлюючи її шкідливість; заперечення: фрази типу «я в будь-який момент можу зупинитися»; постійні думки: фіксація на об'єкті залежності; емоційна неврівноваженість: дратівливість, тривога або депресія при неможливості отримати бажане.

Вибір людиною конкретного об'єкта залежності частково визначається його специфічним впливом на організм. Як правило, люди відрізняються за індивідуальною схильністю до тих чи інших об'єктів залежності. Наприклад, особлива популярність алкоголю багато в чому завдячує широкому спектру його дії – він може з однаковим успіхом використовуватися для збудження, зігрівання, розслаблення, лікування простудних захворювань, підвищення впевненості та розкутості. Існує певна залежність між типами характеру та деякими видами залежної поведінки. Наприклад, пияцтво та вживання наркотиків частіше зустрічаються при експлозивній та нестійкій акцентуації характеру (*надмірна вираженість окремих рис характеру та їх комбінацій, що становить крайні варіанти психічної норми, які межують із психопатіями*), досить часто – при епілептоїдній та гіпертимній. Іншим важливим індивідуальним чинником, що впливає на поведінку людини, може виступати стресостійкість. В останні роки розвивається погляд на адиктивну поведінку як на наслідок зниженої здатності особистості справлятися зі стресом. Передбачається, що залежна поведінка виникає за порушення механізмів подолання стресу. Різкі зміни у поведінці – це сигнал, що нервова система виснажена.

Військовослужбовці широко використовують хімічні речовини, такі як алкоголь, енергетики, транквілізатори. Більшості з них вдається зберігати контроль над їх вживанням протягом усього життя, і лише деякі стають справжніми рабами залежності. У широкому значенні під *хімічною залежністю* (інші назви – лікарська, наркотична) розуміють залежність від вживання будь-яких психоактивних речовин, які у зв'язку з цим поділяються на легальні (тютюн, алкоголь, ліки) та нелегальні наркотики (кокаїн, похідні коноплі, опіати тощо). Одним із видів хімічної залежності є *вживання наркотиків та токсичних речовин*. Велика група речовин, до яких при їх систематичному прийомі розвивається звичка і пристрасть, зазначаються у

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списку МОЗ України як *наркотики*; а стан – *наркоманією*. Всі наркотики характеризуються такими основними властивостями: викликають стан задурманювання, ейфорії; змінюють толерантність до наркотику: для досягнення ейфорійного ефекту дози наркотиків треба збільшувати; у процесі звикання до наркотиків розвивається психічна і фізична залежність, абстинентний синдром; мають психотоксичну дію – спричиняють гострі і хронічні психічні розлади і зміни особистості; проявляють загальнотоксичну дію – змінюють внутрішні органи і нервову систему. Провідним спонукальним мотивом до систематичного вживання може бути прагнення уникнути напруження та болю; досягнення відчуття комфорту або усунення неприємних відчуттів (наприклад, депресивного стану або страху). Потяг до вживання наркотику носить надзвичайно сильний характер. Однією з вказівок на зловживання наркотиками є *соціальна деградація*, що виявляється, перш за все, в швидко наростаючій соціальній дезадаптації. При цьому спостерігається відмова від навчання або професійної діяльності, конфлікти з соціальним оточенням, проблеми із законом, відхід від сім'ї і друзів, звуження спілкування до наркоманичного кола, ізоляція тощо. Паралельно з соціальною деградацією відбувається виражена зміна характеру. На фоні захоплення наркотиком наростає загальна необов'язковість, втрачаються колишні інтереси. *Заперечення* стає стилем поведінки. Наркозалежний заперечує буквально все: факти вживання, правила, свої вчинки, свою відповідальність, наявність проблем тощо. Реальність повністю замінюється фантазіями у формі безплідних мрій, невиконуваних обіцянок, брехні, ілюзій.

До найбільш поширених у світі психоактивних речовин належить алкоголь. Серед усіх видів залежностей найпоширенішою є **алкогольна адикція** (алкогольна залежність). Зловживання цією хімічною сполукою має негативний вплив на мозок, судини, серце, печінку та інші органи й системи організму. При прийомі алкоголю, крім специфічного запаху, виявляються, насамперед, негативні психофізіологічні та психічні реакції: знижується здатність людини вирішувати різні творчі завдання, з'являються помилки в елементарних лічильних операціях; порушується координація рухів, знижується їхня точність, виконання тонких операцій стає неможливим; збільшується час реакцій на різні подразники; підвищується поріг збудливості нервової системи «людина гальмує»; розмови людей ведуться більш гучним голосом; при сп'янінні різко знижується інтелектуальний контроль людини за

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своїми вчинками; стан ейфорії з бурхливими проявами радощів, веселощів може змінюватись спалахами гніву з агресивними діями чи слізливістю; характерна сексуальна розкутість; невелика концентрація алкоголю в крові спричиняє порушення окоміру й відчуття простору через погіршення бінокулярного зору, що заважає прицільному веденню стрільби. Найбільш негативним явищем при зловживанні алкоголем є те, що розвивається хвороба – хронічний алкоголізм. Зловживання алкоголем – завдає значної, а інколи і непоправної шкоди організму людини, яка п'є, або її потомству.

Негативну роль, під час військової служби, відіграє надмірне вживання енергетичних напоїв. Енергетичні напої містять різні стимулятори штучного походження. Крім великої кількості цукру, майже всі енергетичні напої мають у складі кофеїн, гуарану, таурин. Енергетичні напої негативно впливають на організм людини. Вони пов'язані з порушеннями в роботі серця у деяких людей з підвищеним ризиком і можуть призвести до його зупинки. Енергетики змушують організм витрачати свої ресурси в прискореному темпі (карнітин викликає прискорення обміну речовин і окислення жирних кислот. Він також знижує стомлюваність м'язів, допомагаючи позбутися фізичної втоми). Кофеїн, як будь-який стимулятор, у великій кількості виснажує нервову систему, а з часом викликає звикання. Також кофеїн є сечогінним засобом – отже, він виводить з організму мінеральні солі, нервова система розхитується, порушується робота шлунково-кишкового тракту. При передозуванні у людини може виникнути розлад психіки.

Для розуміння, а також для своєчасного та ефективного впливу на процеси, пов'язані з розвитком хімічної залежності, необхідно орієнтуватися в причинах, які до неї призводять. Як відомо, причинами тих чи інших вчинків людини є мотиви – внутрішні спонукання. Мотивація вживання алкоголю та наркотичних речовин має декілька видів:

*Атарактична мотивація* – це прагнення застосувати речовину з метою позбавлення від емоційного дискомфорту, що в подальшому призводить до появи психологічної і фізичної залежності від прийому цієї речовини.

*Гедоністична мотивація* – вона може бути продовженням формування атарактичної мотивації, але відрізняється від неї тим, що людина отримує задоволення, почуття радості на фоні хорошого настрою при прийомі алкоголю або наркотичних речовин.

*Мотивація із гіперактивацією поведінки* – схожа на гедоністичну, але вона базується не на ейфорійному, а на

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активуючому ефекті алкоголізації.

*Субмисивна мотивація* (прагнення до підпорядкування та залежності від думки інших) прийому подібних речовин відображає нездатність людини відмовитись від пропонованого оточуючими прийому алкоголю чи наркотичних речовин, що пов'язане із прагненням до приналежності та визнання групою.

*Псевдокультура мотивація* – заснована на світогляді людини та її естетичних пристрастях – прийом алкоголю, наприклад, вводить її в коло елітних, забезпечених людей [4, с.29–37].

Лудоманія (залежність від азартних ігор) серед військових в Україні стала значною проблемою, яка призвела до запровадження обмежень на доступ до онлайн-казино для військовослужбовців. Президент України підписав Указ № 234/2024, що обмежує доступ до онлайн-казино для військових, "Про рішення Ради національної безпеки і оборони України «Щодо протидії негативним наслідкам функціонування азартних ігор в мережі Інтернет», в якому вимагає: "...Головнокомандувачеві Збройних Сил України, керівництву інших військових формувань невідкладно запровадити на період дії правового режиму воєнного стану заборону військовослужбовцям доступу до гральних закладів та/або участі в азартних іграх у мережі Інтернет" [2, с.1]. Незважаючи на законодавчі обмеження та блокування нелегальних онлайн-казино, проблема лудоманії серед військових продовжує існувати, більш того, з мобілізацією (приходом до лав Збройних Сил України молоді) стала поширюватися. Деякі військовослужбовці з ігровою залежністю витрачають на онлайн-казино від кількох тисяч до десятків тисяч гривень щомісяця.

Лудоманію можна розпізнати за ознаками залежності. Аналіз спостережень даної проблеми доводить – найчастіше на лудоманію страждають чоловіки, основною причиною у сильній статі стають особисті проблеми [5]. Лудоманія не залежить від хімічних речовин до яких звикає організм (спирт, нікотин, наркотики, енергетики). Лудоманія має свої різновиди (ставки у спорті, казино, скачки, карти, більярд, гра в рулетку, гра на автоматах) – все, що викликає азарт. Що відбувається з військовослужбовцем, коли він грає? Майже входить в транс; не думає про проблеми, які існують в житті та службі; за допомогою гри (залежності) намагається втекти від труднощів, негараздів свого внутрішнього світу або досягнути якогось іншого стану. Гра дозволяє відключитися. Виникає стан ейфорії – ні про що не думаєш і стає добре. Піднімається самооцінка, є можливість самореалізуватися під час гри, бо в житті не отримується.



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Робота командного складу з такою категорією військовослужбовців свідчить, що ігроманія перейшла з психологічного рівня на фізіологічний. Військовослужбовці-лудомани мають зовнішні ознаки: регулярні прохання до побратимів позичити гроші; постійні борги або кредити; проблеми в професійній діяльності, в колективі, в родині; обман командирів, співслужбовців, втрата довіри; систематична трата грошей; не схильні до спілкування; не мають друзів; відсутність такої риси, як співчуття; відсутній потяг до сумлінного виконання завдання. Внутрішні ознаки військовослужбовця-лудомана – тіж самі, що й зовнішні, плюс великий, нерегульований, дикий потяг до гри. У свідомості головна думка – де взяти гроші на гру? Ніхто і ніщо не цікавить – тільки гра. В разі незадоволення цієї потреби – втрата контролю над собою; нав'язливі думки про гру; тривога, депресія, думки про самогубство. Крім цих ознак незалежний військовослужбовець відрізняється від залежного тим, що здоровий гравець отримавши відповідну дозу емоцій зупиняється, ігрок програє все.

В процесі роботи відповідних офіцерів (вивчення соціально-демографічних, індивідуально-психологічних якостей) з даною категорією військовослужбовців були підтверджені причини схильностей до ігроманії, а саме:

- Спадковість до якої-небудь залежності із-за дисфункціональних взаємовідносин у сім'ї (сварки, вживання алкоголю, наркотиків, відсутність відвертості, відсутність прикладів правильного вираження емоцій, атмосфера систематичної брехні, пасивність у допомозі іншим. Батьки, або один з них, – залежні).

- Придушення ініціатив або потреб дитини на протязі дитинства, підліткового віку. Відсутність підтримки. Не забезпечували безпеку. Не було співчуття. Або, навпаки – гіперопіка. Все робилося замість дитини. Наслідки: невміння приймати рішення, інфантильність, неспроможність долати труднощі, боягузтво ситуацій у спілкуванні, невміння відстоювати свою точку зору.

- Використання в сім'ї подвійних стандартів. Наприклад: ...батько не стримана людина, відверто сильно висловлює свої емоції, а мати забороняє дитині так робити. Але ж хочеться це поспробувати (дітям властиво наслідувати). Батькам можна, а мені ні? Виросту – буду так робити. Це повне порушення психоемоційної сфери. Дитина не розбирається в своїх емоціях і почуттях. Батько сильно висловлює емоції – що це гнів? Сором? Страх? Висловлювання поодинокості? Дитина наслідує

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поведінку – так формується комплекс неповноцінності. На якомусь етапі життя у людини відбувається зустріч з грою, сюжет відволікає від негативних переживань, заниженої самооцінки, подавленої агресії, невпевненості в собі.

– Біологічні фактори. У деяких випадках пристрась до азартних ігор пояснюється особливостями розвитку центральної нервової системи.

– Соматичні патології, які можуть спровокувати розвиток ігроманії. Це відбувається у разі дефіциту речовин, що регулюють на міжклітинному рівні механізм контролю за дією та мисленням людини [3, с.229–233].

Окрім негативних залежностей (алкоголізм, наркоманія, вживання енергетиків, лудоманія) в середовищі військовослужбовців існують, так звані, «позитивні залежності», які, в свою чергу, призводять до синдромів та наслідків поведінкових адикцій. **Трудоголізм** – завдає прямої шкоди психічному та фізичному здоров'ю. Робота (завдання) – понад усе. Відбувається нехтування іншими цінностями і видами діяльності (наприклад, родиною, колективом). Військовий керівник отримує задоволення від процесу роботи, її обсягів. Потяг до роботи виникає компульсивно, робота виконується з більшою ретельністю, завзяттям, інтенсивністю, ніж того вимагає мета. Виникають маніпулятивні стратегії взаємодії, змінюються особистісні якості та гуманістичні цінності, мають прояв загострений перфекціонізм, посилена недовіра до інших, погіршення фізичного та психічного здоров'я, що негативно позначається як на самому керівнику, так і на всій робочій групі, на якості його роботи, на взаємодії з іншими. Формується особистість з такими переважаючими рисами: ретельність у роботі; любов до чистоти і порядку; велике завзяття, терпіння й старанність, але в підсумку – досягнення середніх результатів; прагнення до бездоганності в усьому, навіть у моральних та етичних нормах, вимога цього від інших людей, що призводить до конфліктів; труднощі у виборі; застрягання на подробицях, деталях, моментах; надмірна ґрунтовність; наполегливість, що переростає в упертість, цілеспрямованість, прямолінійність у досягненні мети; системність у мисленні, організованість, надання надмірного значення другорядному; передбачливість, страх перед помилками; накопичення стресів і образ. Отже, в кінцевому рахунку, трудоголізм стає негативним феноменом. Страх помилитися живить почуття тривоги, ситуація стає обтяжливою, а активність непродуктивною. Нестача відпочинку та фізичних вправ негативно позначається на самопочутті, мають прояв



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соматичні захворювання, які з часом можуть перерости у хронічні. Погіршення взаємовідносин у колективі, постійне ускладнення та переробка одних і тих же завдань, неефективний менеджмент часу, систематичний психологічний дискомфорт приводять колектив до висновку – вигідніше мати завзятих виконавців, ніж залежного від роботи керівника.

Профілактика залежностей у військовослужбовців включає комплекс адміністративних, медичних та психологічних заходів. Залежності можна попередити за допомогою різних напрямків роботи:

- покращення кадрової роботи (професійний відбір і підбір для комплектування, доукомплектування підрозділів та військових частин, підвищення по посаді, розстановка кадрів тощо);

- соціальна підтримка персоналу, спрямована на систематичне забезпечення соціальних гарантій і пільг для військовослужбовців та членів їх сімей; контроль рівня навантаження на військовослужбовців; приділення уваги питанням режиму праці та відпочинку, всіляко гармонізуючи їх із потребами військової служби; нормалізація (оптимізація) умови праці військовослужбовців [1, с.5-32];

- психологічна робота офіцерів-психологів спрямовувати для зміни ставлення до залежностей та мотивації до здорового способу життя, як індивідуально так і в складі груп;

- розробка програми спостереження за військовослужбовцями під час ротаций з метою раннього виявлення та контролю стрес-спровокованих розладів та залежностей;

- проведення занять, інформування та психологічної освіти серед військовослужбовців щодо ризиків залежностей, включаючи наслідки зловживання алкоголю, наркотиків, ігроманії, гігієни розумової праці та їх психічні/соціальні наслідки;

- дотримання принципу соціальної справедливості (обов'язково по черзі) під час розподілу серед особового складу підрозділу додаткових службово- господарських завдань;

- організація побуту з метою забезпечення умов для повноцінного сну, психофізіологічного відновлення, дозволів та запобігання стресам;

- створення умов, де військовослужбовець може звернутися про допомогу у психологічній реабілітації або розвантаженні без страху бути висміяним або покараним (безпечна допомога). Висновки.

В основі залежностей лежать природні потреби людини. Схильність до залежностей, загалом, є універсальною

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особливістю людини. За певних умов деякі нейтральні об'єкти перетворюються на життєво важливі для людини, а потреба в них посилюється до неконтрольованої. Психологічна залежність – це саморуйнівний стан, при якому людина втрачає контроль над власною поведінкою або емоціями, відчуючи непереборну потребу у певному об'єкті чи дії задля задоволення чи заспокоєння. Вона базується на механізмах мозку, що вимагають «петлі винагороди» (допаміну), викликаючи тривогу, депресію та роздратування при відсутності бажаного.

Аналіз залежностей військовослужбовців вимагає систематичного вивчення їх індивідуально-психологічних якостей з врахуванням соціалізації особистості з метою з'ясування, що саме, де саме, в який період виникла та чи інша залежність; роль сім'ї (партнерські стосунки, модель влади та поведінки, трансформація моделей сім'ї на сучасному етапі, виховання); соціалізація серед однолітків; молодіжна субкультура; пристосування до певних обставин; самовизначення та інш.

Воєнний стан, бойові дії, постійна загроза життю, зростання агресивності соціального середовища, насильство, злочинність, втрата впевненості в майбутньому, відсутність відчуття безпеки, обстріли цивільної інфраструктури – усе це формує травматичне тло, що сприяє розвитку нових форм залежностей, які переносяться у військове середовище. Командирам (начальникам) необхідно пам'ятати, що залежність – це не про силу волі, це про рівень стресу. Організація допомоги та профілактики – це відповідальність перед собою та своїми підлеглими. Не боротьба, а профілактика залежностей військовослужбовців – це важлива частина бойової готовності підрозділу.

Психологічні залежності можуть бути підґрунтям для розвитку фізичної залежності, але самі по собі вони не мають класичного фізичного синдрому відміни, проявляючись саме через психологічні страждання. Лікування найчастіше базується на психотерапії (когнітивно-поведінкова терапія) для зміни моделей мислення та поведінки. Алкоголікам, наркоманам, лудоманам потрібна повна реконструкція особистості. Необхідно навчитися проживати почуття правильно, без боязні наслідків. Реконструкція вимагає психологічного і медикаментозного впливу. Залежності піддаються лікуванню, але на це потрібен тривалий час.

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## The Development Stages of Digital Media and Audiovisual Design in the Modern Era

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**Abstract.** In the modern age, the rapid development of digital technologies has significantly influenced media and design, transforming traditional communication methods and creating a new media environment characterized by interactivity, adaptability, and multimedia integration. As a result, digital media and audiovisual design have evolved into dynamic fields that combine technological innovation with creative expression. This article examines the main stages in the evolution of digital media and audiovisual design, focusing on their development, key characteristics, and current trends. It considers the role of technological innovation, the impact of digital platforms, and the changing approaches to visual communication and design practices. The study shows that digital media and audiovisual design continue to evolve through the interaction of technology and creativity, shaping contemporary forms of communication and visual culture.

**Keywords:** *Digital media, audiovisual design, visual communication, multimedia, user experience, interactive media.*

### INTRODUCTION

In today's era, the rapid advancement of digital technologies has profoundly influenced many spheres of human activity, particularly media and design. Digitalization has reshaped conventional communication methods and facilitated the emergence of a new media landscape defined by interactivity, accessibility, and the integration of multiple formats. As a consequence, digital media and audiovisual design have developed into dynamic, interdisciplinary fields that merge technological progress with creative practice.

The importance of this topic is closely associated with the expanding role of digital platforms, multimedia tools, and interactive technologies in contemporary society. Visual content has become a central element in the exchange of information, significantly influencing public perception, cultural processes, and communication patterns. Within this

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framework, audiovisual design operates as a crucial mechanism for producing engaging and impactful media content.

Digital media includes a diverse range of platforms such as the internet, social media networks, and interactive systems, all of which have fundamentally transformed how content is produced and consumed. In parallel, audiovisual design has evolved into a sophisticated practice that integrates graphic design, animation, sound, and interactive elements, demonstrating the convergence of multiple creative disciplines.

The evolution of digital media and audiovisual design has unfolded across several stages, each shaped by technological innovation and cultural change. From the shift from analog to digital systems to the rise of the internet, social media, and immersive technologies like virtual and augmented reality, these fields have consistently adapted to emerging conditions and shifting user expectations.

The primary aim of this article is to explore the developmental stages of digital media and audiovisual design in the modern context, examine their interconnections, and identify the major trends influencing their current state. Furthermore, the study seeks to analyze the role of digital technologies, multimedia integration, and visual communication strategies in shaping contemporary audiovisual content.

### **METHODOLOGY**

This research is grounded in a qualitative and theoretical framework that focuses on examining the developmental stages of digital media and audiovisual design in the contemporary era. The study is primarily based on the analysis of existing scholarly literature, including academic publications, peer-reviewed articles, and credible online sources related to media studies, design theory, and digital technologies.

Throughout the study, analytical and comparative approaches have been employed to explore the transformation of digital media and audiovisual design across various stages of their evolution. These methods have facilitated the identification of major trends, technological drivers, and conceptual shifts that have influenced the progression of these fields.

Moreover, the research adopts an interdisciplinary approach, drawing on perspectives from media theory, visual communication, and design studies. This integrated perspective provides a more comprehensive understanding of

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how technological advancements interact with creative processes in the field of audiovisual design.

## **The Development of Digital Media**

The evolution of digital media represents a major transformation in the history of communication. It is closely linked to the transition from analog technologies to digital systems, which enabled different forms of content to be converted into data. This shift improved the storage, processing, and transmission of information, while also changing how media is accessed and shared. Compared with traditional media, digital systems offer greater flexibility and accessibility.

The earliest stage of digital media development was shaped by the spread of personal computers and the expansion of networked communication. At this stage, content was relatively simple and mainly limited to text and basic visual elements. As technologies developed, digital environments became more complex and visually structured. The growth of the World Wide Web played a key role in expanding access to information and supporting global communication (*Castells, 2010*).

A further stage emerged with the integration of multimedia elements into digital platforms. Audio, video, graphics, and animation began to function together within a single environment, making media content more dynamic and engaging. This also encouraged users to take a more active role in interacting with digital content. The expansion of social media and mobile technologies introduced new forms of communication and content sharing. Users gained the ability to create, distribute, and respond to content more directly, contributing to a more interactive media environment.

In recent years, digital media has been influenced by developments such as artificial intelligence, data processing systems, and immersive technologies. These changes allow content to be adapted to user preferences and create more interactive experiences, particularly through technologies such as virtual and augmented reality (*Lister et al., 2009*).

The development of digital media reflects a gradual process shaped by technological progress and evolving communication practices, influencing how media content is produced and experienced today.

## **The Evolution of Audiovisual Design**

Audiovisual design has developed alongside changes in communication technologies and media practices. In its early

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stage, it was closely linked to traditional media such as cinema, television, and radio, where visual and auditory elements were organized within structured and linear systems. The main focus during this period was to maintain clarity and consistency between sound and image.

The introduction of digital technologies increased flexibility in audiovisual design. Digital tools allowed designers to edit and combine visual and sound elements more efficiently, leading to the emergence of formats such as digital animation, motion graphics, and multimedia content. These developments expanded the ways in which visual information could be presented (*Packer & Jordan, 2001*).

The development of interactive media marked another important stage. Digital environments enabled users to engage with content more actively, encouraging the integration of audiovisual design with web platforms, digital interfaces, and game environments. As a result, user interaction became an important factor in the design process (*Vesna, 2007*).

The expansion of online platforms and streaming technologies further influenced audiovisual design practices. Content began to be adapted for different devices and formats, requiring attention to usability, accessibility, and consistency across platforms.

Contemporary audiovisual design combines elements from various creative and technical fields, supporting the creation of more integrated and interactive media environments.

### **Technological Impact on Digital Media and Audiovisual Design**

Audiovisual design has developed alongside changes in communication technologies and media practices. In its early stage, it was closely associated with traditional media such as cinema, television, and radio, where visual and auditory elements were organized within linear and structured production systems. The main focus during this period was to maintain clarity and coherence between sound and image.

The transition to digital technologies introduced greater flexibility into audiovisual design. Digital tools made it easier to edit and combine visual and sound elements, leading to the emergence of formats such as digital animation, motion graphics, and multimedia content. These developments expanded the ways in which visual information could be presented and structured (*Packer & Jordan, 2001*).

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important stage. Digital environments allowed users to engage with content more actively, which encouraged the integration of audiovisual design with web platforms, digital interfaces, and game environments. As a result, user interaction became an important factor influencing design processes (Vesna, 2007).

The growth of online platforms and streaming technologies further influenced audiovisual design practices. Content began to be adapted for different devices and formats, requiring greater attention to usability, accessibility, and consistency across platforms.

Technological development has significantly influenced the formation of digital media and audiovisual design. Changes in digital systems, communication tools, and media platforms have affected both the production and presentation of content. These developments have created more flexible conditions for combining visual and auditory elements, allowing media content to adapt to different contexts and user needs.

One important aspect of this influence is the development of digital production tools. Modern software and editing systems provide designers with more control over visual composition, sound integration, and timing. This has contributed to the emergence of new forms of media content and has expanded the possibilities of audiovisual expression (Manovich, 2013).

Another factor is the expansion of digital platforms and online environments. The growth of internet-based media has changed how content is distributed and accessed, making it available across multiple devices and formats. This requires designers to consider issues such as consistency, accessibility, and adaptability when creating audiovisual content (Flew, 2014).

At the same time, developments in data technologies and automation have introduced new approaches to content production. Systems that analyze user behavior and preferences make it possible to adjust media content in more flexible ways. This contributes to more personalized media experiences without fundamentally changing the basic structure of audiovisual communication. The use of immersive technologies, such as virtual and augmented reality, has also influenced audiovisual design. These technologies create environments where users can interact with content more directly, supporting more engaging and interactive forms of media experience.

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## **Modern Trends in Digital Media and Audiovisual Design**

Digital media and audiovisual design in the contemporary era are shaped by rapid technological innovation and changing patterns of content consumption. One of the most noticeable trends is the increasing demand for visually rich and dynamic content. Audiences today expect high-quality visuals, engaging storytelling, and seamless integration of audio and visual elements. This has led to the widespread use of motion graphics, short-form video formats, and visually driven communication across digital platforms.

Another important trend is the shift toward personalization and user-oriented content. Digital systems increasingly adapt to user preferences, behaviors, and interests, creating more individualized media experiences. This tendency is particularly visible in social media platforms and streaming services, where algorithms influence both content visibility and user interaction. As a result, audiovisual design must take into account not only aesthetic considerations but also user engagement and accessibility.

The growing importance of cross-platform compatibility has also influenced modern audiovisual design. Content is no longer produced for a single medium but must function effectively across various devices, including smartphones, tablets, and large digital screens. Designers are required to consider different screen sizes, formats, and user interactions, ensuring consistency and usability in diverse digital environments.

Another significant development is the integration of immersive and interactive technologies into media production. Virtual environments, interactive interfaces, and real-time visual effects are increasingly used to enhance user experience. These approaches allow audiences to interact with content in more direct and engaging ways, transforming traditional viewing into a more participatory process (Rose, 2016).

The current state of digital media and audiovisual design reflects a combination of technological advancement, creative experimentation, and user-centered approaches. These trends continue to redefine how media content is produced, distributed, and experienced, influencing both the aesthetic and functional dimensions of digital communication.

## **CONCLUSION**

The development of digital media and audiovisual design reflects a gradual transformation shaped by technological

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progress and changing communication practices. These fields have evolved from simple and structured systems into more flexible and interactive environments that support diverse forms of content and user engagement.

Digital media has expanded the ways in which information is created, shared, and accessed, while audiovisual design has adapted to these changes by integrating new tools, formats, and approaches. The growing importance of interactivity, personalization, and cross-platform compatibility shows that media today is closely connected to user experience and everyday communication.

At the same time, contemporary trends such as immersive technologies and digital integration continue to influence how content is designed and perceived. These developments demonstrate that digital media and audiovisual design remain dynamic fields that respond to both technological innovation and the changing needs of society.

### **Recommendations**

Based on the results of the research conducted, the following recommendations can be proposed:

1. **Enhancement of Digital Media Education:** Strengthen the teaching of digital media and audiovisual design to improve creative and technical skills.

2. **Integration of User-Centered Approaches:** Focus more on user experience, accessibility, and engagement in media production.

3. **Adaptation to Technological Developments:** Continuously update skills in line with new technologies such as AI and interactive systems.

4. **Support for Cross-Platform Design:** Ensure content compatibility across different devices and platforms.

5. **Encouragement of Collaboration:** Promote cooperation between designers and media professionals to develop innovative solutions.

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# ARTS, CULTURAL STUDIES AND ETHNOGRAPHY

## Integration of Azerbaijani National Ornaments into Modern Clothing

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**Abstract.** This article provides a comprehensive analysis of the historical evolution of Azerbaijani national ornaments, focusing on their semantic meanings and aesthetic characteristics. It also examines various methods of integrating these traditional motifs into modern clothing design and identifies key challenges associated with this process. The research demonstrates that the synthesis of national ornamentation with contemporary fashion not only preserves cultural heritage but also contributes to the development of innovative and sustainable design solutions in the global fashion industry.

**Keywords:** *national ornaments, fashion design, Azerbaijani culture, clothing, integration, decorative art, cultural identity.*

In the era of globalization, the preservation and promotion of national cultural identity have become critical concerns for societies worldwide. Cultural heritage, particularly in the form of traditional art and ornamentation, plays a vital role in maintaining this identity. Azerbaijani national ornaments represent one of the most significant elements of the country's cultural heritage, reflecting centuries of artistic development and symbolic expression.

Historically, Azerbaijani decorative and applied arts have flourished across various domains, including carpet weaving, embroidery, ceramics, architecture, and clothing. These artistic traditions embody the collective memory, beliefs, and aesthetic preferences of the Azerbaijani people. Ornamentation, in particular, serves as a visual language that conveys cultural narratives and symbolic meanings.

In contemporary fashion, designers increasingly seek to combine tradition with modernity. The integration of national ornaments into modern clothing has emerged as a powerful means of expressing cultural identity while responding to global fashion trends. This article aims to explore the characteristics of Azerbaijani ornaments and analyze their

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application in modern clothing design.

**Historical Development and Semantic Characteristics of Azerbaijani Ornaments.** Azerbaijani national ornaments have evolved over centuries, influenced by various cultural, social, and historical factors. These ornaments can be broadly categorized into geometric, floral, and zoomorphic motifs.

Geometric ornaments are characterized by precision, symmetry, and repetition. Common elements include squares, rhombuses, hexagons, and star-shaped patterns. These motifs often symbolize order, balance, and the structure of the universe. The use of geometric forms reflects a deep understanding of mathematical harmony and spatial organization.

Floral motifs are inspired by nature and represent growth, fertility, and the continuity of life. Common elements such as pomegranate, grapevine, and tulip motifs are widely used in Azerbaijani ornamentation. The pomegranate, in particular, is a powerful symbol of abundance, prosperity, and unity.

Zoomorphic motifs, derived from representations of animals, are associated with ancient beliefs and mythological concepts. These ornaments often symbolize strength, protection, and spiritual energy. Although less common in modern applications, they remain an important part of traditional ornamentation.

One of the most distinctive elements of Azerbaijani ornamentation is the "buta" motif. This paisley-shaped design is widely recognized as a symbol of life, fire, and continuous development. Its versatility and symbolic richness make it highly suitable for adaptation in modern design.

**The Role of Ornaments in Cultural Identity.** National ornaments play a crucial role in shaping and preserving cultural identity. They serve as visual representations of a nation's history, traditions, and values. In Azerbaijan, ornamentation is deeply embedded in everyday life and artistic expression.

Carpet weaving is one of the most prominent examples of how ornaments function as cultural carriers. Each region of Azerbaijan has its own unique carpet patterns and ornament styles, reflecting local traditions and identities. These regional variations highlight the diversity and richness of Azerbaijani culture.

Ornaments also serve as a means of communication, conveying symbolic messages related to social status, beliefs, and cultural practices. Through generations, these

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visual elements have been transmitted and preserved, ensuring continuity of cultural heritage.

In the modern context, the reinterpretation of traditional ornaments allows for the preservation of cultural identity while adapting to contemporary aesthetics.

**The Role of National Ornaments in Modern Fashion.** The modern fashion industry is characterized by constant innovation and the search for uniqueness. In this context, the use of national ornaments provides designers with a valuable source of inspiration.

Incorporating Azerbaijani ornaments into modern clothing allows designers to create distinctive and culturally meaningful collections. These designs not only stand out in the global fashion market but also promote national identity.

In recent years, many Azerbaijani designers have successfully integrated traditional motifs into contemporary fashion. Their work demonstrates how cultural heritage can be transformed into modern artistic expression.

Furthermore, the use of national ornaments aligns with the growing trend of sustainable and ethical fashion. By preserving traditional craftsmanship and promoting local cultural elements, designers contribute to cultural sustainability.

**Methods of Integrating Ornaments into Modern Clothing.** The integration of Azerbaijani ornaments into modern clothing involves various techniques that combine traditional craftsmanship with modern technology.

One of the most common methods is textile printing. This technique allows designers to reproduce traditional patterns on fabrics in a cost-effective and scalable manner. Printed designs are widely used in everyday clothing.

Embroidery is another important method, particularly in high-end and formal garments. Handcrafted embroidery adds uniqueness and artistic value to clothing, emphasizing the connection between tradition and craftsmanship.

Ornaments are also incorporated into accessories such as belts, bags, scarves, and jewelry. This approach allows for subtle integration of cultural elements into modern fashion.

Digital technologies have significantly expanded the possibilities of design. Computer-aided design (CAD) and 3D modeling enable designers to experiment with traditional motifs and create innovative interpretations.

**Challenges and Problems.** Despite its potential, the integration of national ornaments into modern clothing faces



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several challenges. One of the main issues is the misinterpretation or superficial use of traditional motifs.

Commercialization is another concern. In some cases, ornaments are used purely for aesthetic purposes without consideration of their cultural significance. This can lead to the loss of meaning and authenticity.

Maintaining originality while adapting to modern trends is also a complex task. Designers must balance innovation with respect for tradition.

To address these challenges, it is essential to adopt a research-based approach and promote education in cultural heritage and design.

**Future Prospects and Development Opportunities.** The future of Azerbaijani national ornaments in modern fashion is promising. There is significant potential for expanding their use both locally and internationally.

The development of design education plays a key role in this process. Encouraging young designers to explore traditional motifs and incorporate them into their work is essential for sustainability.

International collaboration and participation in global fashion events can further promote Azerbaijani culture. Showcasing national designs on international platforms enhances cultural visibility.

Technological advancements also offer new opportunities for innovation. Digital tools enable designers to preserve traditional patterns while adapting them to contemporary contexts.

### **Conclusion**

Azerbaijani national ornaments represent a valuable cultural heritage that continues to influence modern fashion. Their integration into contemporary clothing not only preserves cultural identity but also fosters creativity and innovation.

By combining tradition with modern design principles, Azerbaijani ornaments can become an integral part of global fashion. This integration contributes to both cultural preservation and the evolution of design practices.

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## ASTRONOMY, SPACE AND AVIATION

### Machine Learning-Based Forecasting of LRU Demand and Implementation in Kazakhstan Base Airports

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**Abstract.** This paper addresses the optimization of aviation spare parts logistics at base airports. Particular attention is given to Line Replaceable Units (LRUs), which play a critical role in ensuring aircraft operational readiness. The limitations of traditional inventory management methods are analyzed, and the need for the implementation of digital technologies is substantiated. An approach to forecasting LRU demand based on machine learning techniques is proposed. An example of economic impact assessment is presented. It is shown that the implementation of intelligent forecasting systems enables a reduction in inventory holding costs and minimizes aircraft-on-ground (AOG) events.

**Keywords:** *LRU, aviation logistics, machine learning, failure prediction, AOG, inventory management, MRO digitalization.*

#### Introduction

Modern civil aviation is characterized by a high level of technical complexity and stringent flight safety requirements. The efficiency of aircraft operations directly depends on the timely performance of maintenance and the availability of required spare parts.

Particular importance is attributed to Line Replaceable Units (LRUs) – assemblies and electronic components that can be rapidly replaced without removing the entire system. These include avionics units, navigation modules, onboard computers, and hydraulic controllers. Avionics units

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represent key elements of the aircraft control system and are designed as modular devices, enabling quick replacement in the event of failure.

The absence of a required component leads to an Aircraft on Ground (AOG) situation, in which the aircraft is unable to perform a flight. This results in direct financial losses, schedule disruptions, and reputational damage for the airline. At the same time, excessive stocking of high-cost components increases inventory holding costs and reduces overall economic efficiency.

Thus, there is a need to achieve a balance between inventory sufficiency and cost minimization. Therefore, this paper examines the theoretical and practical aspects of optimizing aviation spare parts logistics and analyzes the application of machine learning methods for forecasting demand for LRU components and improving inventory management efficiency.

### **Main part**

#### **Features of LRU Logistics**

Aviation spare parts logistics has a number of specific characteristics:

- high unit cost;
- irregular failure patterns;
- long lead times;
- dependence on operational intensity;
- strict certification and traceability requirements.

Traditional inventory management methods are based on averaged statistical data. However, demand for LRUs is probabilistic and often nonlinear in nature. Component failures depend not only on operating time but also on environmental conditions, the number of flight cycles, fleet age, and maintenance quality.

Therefore, classical forecasting models do not always provide the required level of accuracy.

Figure 1 illustrates a modern aviation warehouse, the efficient management of which requires strict certification compliance and the implementation of digital technologies to prevent logistics errors and flight delays.

Storage of aviation components requires strict environmental control and certification compliance. Errors in logistics may lead to the unavailability of required components and result in flight delays. [3], [6], [2]

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Figure 1  
**Modern aviation warehouse**

### **Machine Learning Application Capabilities**

Machine learning enables the analysis of large volumes of operational data and the identification of hidden patterns.

The following input parameters can be used:

- total aircraft flight hours;
- number of flight cycles;
- component age;
- climatic operating conditions;
- history of previous failures;
- Flight Data Monitoring (FDM) data.

Machine learning algorithms are capable of capturing relationships between these parameters and predicting the probability of failure of a specific component.

#### **Random Forest algorithm:**

This method is highly suitable for LRU failure classification, as it effectively processes a large number of variables (temperature, humidity, flight hours) and demonstrates robustness against overfitting on small datasets. In the context of predictive supply, key model hyperparameters include the number of decision trees ( $n\_estimators$ ), which improves ensemble accuracy, and the maximum tree depth ( $max\_depth$ ), which limits model complexity and prevents overfitting to noise.

#### **Recurrent Neural Networks (LSTM):**

These models are well suited for time-series forecasting, as they retain information about previous replacement events and the degradation of avionics unit performance over time. For analyzing long-term dependencies in operational data, the network architecture may include multiple hidden layers with the application of dropout (e.g., with a rate of 0.2–0.3), which enhances model generalization capability and mitigates overfitting.

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**Advantages of the ML-based approach:**

- higher forecasting accuracy;
- adaptability to changing operating conditions;
- capability for continuous model self-learning;
- reduction of uncertainty in inventory planning.

Thus, an intelligent system can proactively determine the potential demand for specific LRUs and adjust inventory policies accordingly. [4], [7], [8], [10]

**Predictive Supply System Architecture**

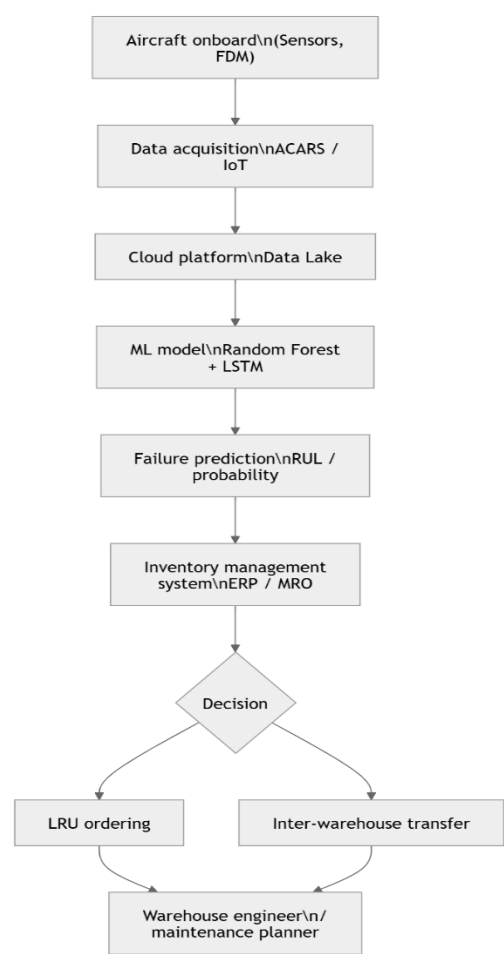


Figure 2  
**Predictive Supply System Architecture**

This Figure 2 shows a predictive supply chain architecture for aircraft maintenance.

It starts with onboard aircraft sensors and Flight Data Monitoring (FDM), which continuously collect operational data. The data is transmitted through ACARS and IoT systems

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to a cloud-based Data Lake, where it is stored and processed.

A machine learning model (Random Forest combined with LSTM) analyzes the data to predict component failures by estimating Remaining Useful Life (RUL) and failure probability.

The predictions are then integrated into an ERP/MRO inventory management system, which supports maintenance decision-making. Based on the results, the system either triggers LRU (Line Replaceable Unit) orders or initiates inter-warehouse part transfers.

Finally, warehouse engineers and maintenance planners use these decisions to ensure timely supply and maintenance of aircraft components.

### **Economic efficiency assessment**

To clearly demonstrate the effectiveness of the proposed method, a hypothetical example of operating a fleet of 10 aircraft is considered.

#### **Initial data:**

- Average annual demand for an avionics LRU: 24 units
- Cost per unit: 5,000,000 KZT
- Safety stock (traditional method): 4 units
- Safety stock (ML method): 2 units (due to improved forecasting accuracy)

#### **Direct financial effect (capital release)**

A reduction of the safety stock by 2 units allows the airline to release a significant amount of working capital:

$$2 \times 5,000,000 = 10,000,000 \text{ KZT}$$

**Result:** 10,000,000 KZT of working capital is released.

$$E = \Delta S \times C$$

where:

E – released capital (economic effect)

$\Delta S$  – reduction of safety stock (units)

– cost of one LRU unit

Substitution:

$$E = 2 \times 5,000,000 = 10,000,000 \text{ KZT}$$

#### **Optimization of Logistics Costs**

In traditional inventory management methods, shortages often lead to AOG (Aircraft on Ground) situations, requiring emergency delivery of spare parts. The cost of “critical” logistics (AOG shipping) is 5–10 times higher than the cost of planned delivery.

The use of an ML model allows to:



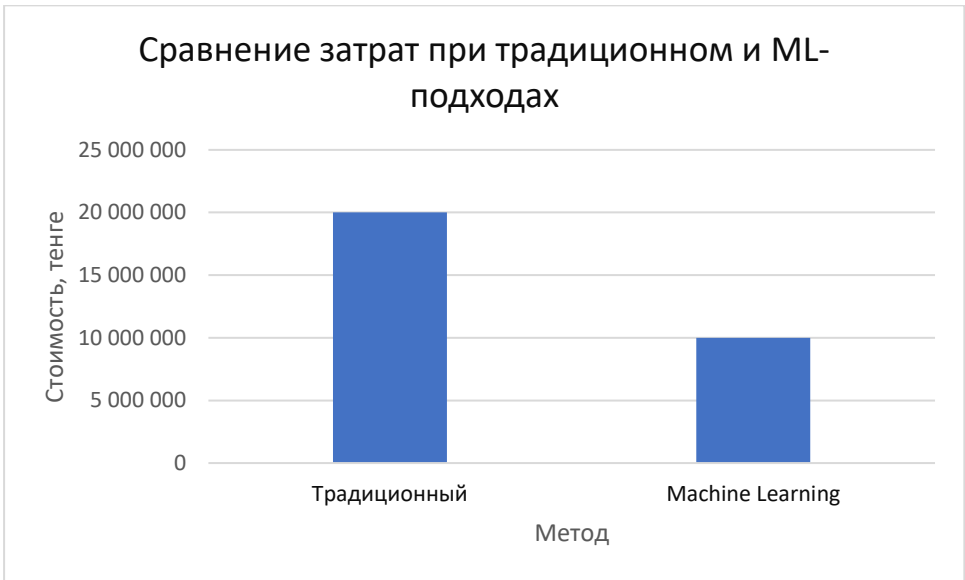
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- Shift up to 80% of emergency orders into the planned category.
- Reduce annual storage costs by decreasing the volume of occupied warehouse space.

### Improvement of Operational Readiness (Time Factor)

Predictive models enable the implementation of the “failure notification” concept. The engineering department receives data on the need to replace a component 50–100 flight hours before its actual failure. This makes it possible to:

- Reduce unplanned aircraft downtime by 15–20%.
- Prepare technical personnel and tools in advance by the time the aircraft arrives at the home base airport.



### Discussion of Results

In the context of the digital transformation of the aviation industry, the implementation of intelligent management systems is becoming a necessity.

Global practice shows that major airlines and aircraft manufacturers are actively implementing predictive analytics and Big Data technologies in maintenance systems.

Forecasting LRU demand based on machine learning enables a transition from a reactive maintenance model to a proactive one.

This means that technical decisions are made not after a failure occurs, but before it happens.

### Examples of LRU Forecasting Applications in Global Practice

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In recent years, major airlines and aircraft manufacturers have been actively implementing predictive analytics and machine learning systems for spare parts management.

### **Example 1: Lufthansa Technik**

Lufthansa Technik has implemented the digital platform AVIATAR, which uses data analytics and machine learning methods to predict the technical condition of aircraft components.

The system analyzes:

- equipment operating parameters
- maintenance data
- failure history
- operational conditions

Thanks to the implementation of this system, the airline has been able to:

- reduce the number of unscheduled failures
- decrease AOG (Aircraft on Ground) events
- optimize LRU inventory levels
- improve fleet technical dispatch reliability

According to the company, the use of digital forecasting systems enables a reduction in unplanned flight delays by 15–20%.

### **Example 2: Delta Air Lines**

Delta Air Lines actively uses Predictive Maintenance technologies to analyze the condition of aircraft components.

At its hub airport, Hartsfield-Jackson Atlanta International Airport, failure prediction systems for aircraft components have been implemented.

The system analyzes data from:

- aircraft sensors
- operational parameters
- maintenance history

Results of implementation:

- reduced flight delays
- decreased aircraft downtime
- optimized distribution of spare parts between warehouses

### **Example 3: Airbus Skywise**

Airbus has developed the digital platform Skywise, which is widely used by many airlines to analyze operational data.

The platform integrates information on:

- aircraft system health status
- maintenance activities

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- spare parts data

The use of Skywise allows prediction of failure probability for specific LRUs and enables early dispatch of required components to base airports.

This leads to:

- reduced repair time
- improved logistics efficiency
- lower inventory holding costs.

Table 1  
Comparison of Traditional Approach and Machine Learning-Based Approach

| Criterion               | Traditional Approach                  | Machine Learning-Based Approach                  | Data Source (for ML)                                  |
|-------------------------|---------------------------------------|--------------------------------------------------|-------------------------------------------------------|
| Forecasting accuracy    | Moderate, depends on statistical data | High, considers multiple factors                 | Machine learning models based on aggregated data      |
| Use of operational data | Limited                               | Comprehensive (FH, FC, climate, failure history) | Onboard sensors (FDM), weather data, maintenance logs |
| Risk of AOG occurrence  | High                                  | Reduced                                          | Predictive analytics of system degradation            |
| Inventory volume        | Excessive                             | Optimized                                        | Integration with ERP warehouse system                 |
| System flexibility      | Low                                   | High (adaptive to changes)                       | Continuous model retraining                           |
| Decision-making speed   | Low                                   | High                                             | Automated dashboards                                  |
| Economic efficiency     | Limited                               | Improved                                         | Financial logistics metrics                           |
| Forecasting capability  | Limited                               | Predictive (before failure occurs)               | Time series algorithms (LSTM, ARIMA)                  |

The conducted comparison shows that the application of machine learning methods significantly improves the efficiency of aviation spare parts inventory management. In contrast to traditional approaches, ML models provide more accurate forecasting and help reduce the risk of AOG (Aircraft on Ground) events. [9], [7], [8], [3], [10]

### Application Opportunities in Kazakhstan

The implementation of predictive analytics systems in the aviation industry of the Republic of Kazakhstan is of

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strategic importance. The use of such technologies at major hub airports such as Almaty International Airport and Astana International Airport will enable the creation of a unique intelligent monitoring network.

To improve forecasting accuracy under Kazakhstan's conditions, the ML model should include the following specific factors:

- Consideration of the sharply continental climate: For airports in Astana and Almaty, accounting for extreme temperature fluctuations (from  $-30^{\circ}\text{C}$  in winter to  $+40^{\circ}\text{C}$  in summer) is critical. Rapid changes in temperature and humidity accelerate the degradation of electronic components and capacitors in avionics units. Incorporating meteorological data into machine learning algorithms will enable more accurate failure prediction specific to the region.

- Creation of a unified digital ecosystem: Implementing the system across the country's major aviation hubs will allow the formation of a shared failure database. This will create a "collective intelligence" effect, where failure data from one carrier can improve spare parts demand forecasting for the entire industry, increasing the competitiveness of national airlines.

Expected results for the domestic market:

1. Reduction in AOG events: Early prediction and positioning of required LRUs in Almaty and Astana.

2. Optimization of inventory levels: Transition from excessive stockholding to a Just-in-Time model.

3. Reduction in operational costs: Minimization of urgent air shipment expenses from Europe or Asia.

4. Improvement of flight safety: Timely replacement of components in a pre-failure state increases aircraft reliability. [1], [2], [6], [5], [3]

### Conclusion

This work investigated the problem of optimizing logistics for aviation spare parts of LRU type. It was established that traditional inventory management methods based on static statistics do not provide sufficient flexibility in modern aviation, leading to unnecessary financial losses and aircraft downtime (AOG).

The scientific novelty of the proposed approach lies in the use of machine learning (ML) methods for analyzing multi-factor data: flight hours, cycles, failure history, and—most importantly for Kazakhstan—climatic conditions. The conducted analysis and calculations showed that:

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- Implementation of an ML system can reduce safety stock levels of expensive components (for avionics, for example, by 2 times), releasing significant working capital.

- Shifting up to 80% of unscheduled replacements into planned maintenance significantly reduces logistics costs.

In the long term, the creation of an intelligent forecasting system will become the foundation for the digital transformation of Kazakhstan's aviation industry, enabling a transition to condition-based maintenance and improving Maintenance, Repair and Overhaul (MRO) efficiency at an international level.

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## BIOLOGY AND BIOTECHNOLOGY

### Микрогравитация жағдайындағы лимфа жүйесінің және қанның физиологиялық өзгерістері

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Ұзақ мерзімді ғарыштық ұшулар жағдайында адам ағзасында жүретін физиологиялық өзгерістердің ішінде қан айналымы мен иммундық жүйенің бұзылыстары ерекше маңызға ие. Соңғы жылдары Халықаралық ғарыш станциясындағы миссиялардың ұзақтығы артып, болашақта Ай мен Марсқа бағытталған экспедициялар жоспарлануына байланысты микрогравитация жағдайында ағзаның бейімделу механизмдерін зерттеу өзекті мәселеге айналды. Адам организмі Жердің қалыпты гравитациялық өрісіне бейімделіп қалыптасқандықтан, салмақсыздық жағдайында сұйықтықтардың қайта бөлінуі, механикалық жүктеменің азаюы және сәулелену факторлары көптеген физиологиялық жүйелердің қызметіне әсер етеді.

Лимфа жүйесі ұлпалық сұйықтықты қан айналымына қайта жеткізетін, макромолекулалар мен иммундық жасушаларды тасымалдайтын және иммундық жауапты реттейтін маңызды жүйе болып табылады. Сондықтан микрогравитация жағдайында лимфа айналымының өзгеруі жалпы гомеостаздың бұзылуына әкелуі мүмкін [1, 2]. Жануардың денесін антиортостатикалық күйге келтіру арқылы салмақсыздықтың әсерін модельдеу кезінде лимфа ағынының, веноздық қысымның және лимфа тамырларының жиырылуындағы өзгерістер көрсетілген. Алайда, салмақсыздық кезінде қан мен ұлпалық сұйықтықтың қайта бөлінуіндегі лимфа түйіндерінің рөлі осы уақытқа дейін зерттелмеген.

Жануарларда микрогравитацияны үлгілеу жағдайында

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жүргізілген тәжірибелер лимфа тамырларының белсенді жиырылу қабілетінің төмендеуіне әкелетінін көрсетеді. Егеуқұйрықтарда антиортостатикалық қалыпты ұстау әдісі арқылы жүргізілген модельдерде кеуде, мойын және шажырқай лимфа тамырларының диаметрі, қабырға қалыңдығы мен серпімділігі өзгеріп, лимфа тамырларының қысымға тәуелді жиырылуы айқын әлсірейді. Мұндай өзгерістер лимфа ағысының баяулауына және тін аралық сұйықтықтың жиналуына алып келуі мүмкін [3].

Жасушалық деңгейде микрогравитация цитоқаңқа құрылымының қайта ұйымдасуына әсер етеді. Лимфоциттер мен макрофагтарда жасуша пішіні мен адгезиялық қасиеттер өзгеріп, олардың көшу және фагоцитоз қабілеті төмендеуі мүмкін. Бұл құбылыстар лимфа мүшелеріндегі иммундық жасушалардың ұйымдасуына және иммундық жауаптың тиімділігіне ықпал етеді.

Микрогравитация жағдайында қанда бірқатар өзгерістер байқалады. Ұзақ мерзімді үлгілік микрогравитация кезінде плазма көлемінің азаюы және салыстырмалы гемоконцентрация қалыптасады. Сонымен қатар эритропоэтин деңгейінің төмендеуі нәтижесінде эритропоэз баяулап, «ғарыштық қаназдық» феномені дамуы мүмкін.

Жалпы алғанда, микрогравитация лимфа жүйесінің белсенді сорғыштық қызметін төмендетіп, лимфа айналымының баяулауына әкеледі. Бұл өз кезегінде тіндік сұйықтықтың жиналуына, иммундық жауаптың әлсіреуіне және қан жүйесіндегі өзгерістермен бірге организмнің жалпы гомеостазының бұзылуына себеп болуы мүмкін.

Сонымен қатар лимфа түйіндері деңгейіндегі морфологиялық өзгерістер туралы деректер әлі де жеткіліксіз [4]. Болашақ зерттеулерде лимфа түйіндерінің құрылымдық өзгерістерін, қан мен лимфаның молекулалық құрамын және микрогравитацияның сәулеленумен бірлескен әсерін кешенді зерттеу маңызды болып табылады. Мұндай зерттеулер ұзақ мерзімді ғарыштық миссиялар кезінде адам денсаулығын қорғауға ғана емес, сонымен қатар Жердегі лимфа жүйесі мен иммундық бұзылыстарды түсінуге де жаңа мүмкіндіктер ашады.

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## MEDICINE AND PHARMACY

# Novel Approaches to the Treatment of *Helicobacter Pylori* Infection in the Era of Antibiotic Resistance

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**Abstract.** *Helicobacter pylori* infection remains one of the most prevalent chronic bacterial diseases worldwide and a key etiological factor in peptic ulcer disease, gastric adenocarcinoma, and mucosa-associated lymphoid tissue lymphoma. Despite the availability of established eradication regimens, the effectiveness of standard therapies has declined in recent years, primarily due to the growing prevalence of antibiotic-resistant strains, particularly to clarithromycin, metronidazole, and levofloxacin. This review analyzes contemporary treatment strategies for *H. pylori* infection with a focus on approaches that address antibiotic resistance. Current evidence supports the transition from empiric standard triple therapy to optimized regimens, including bismuth-based quadruple therapy, concomitant therapy, and tailored treatment guided by antimicrobial susceptibility testing where available. The role of novel acid suppression strategies, such as potassium-competitive acid blockers, is also considered, given their potential to enhance eradication rates by improving intragastric pH control. In addition, emerging therapeutic directions are discussed, including the use of rifabutin-based regimens, high-dose dual therapy, and adjunctive approaches aimed at improving treatment adherence and microbiological outcomes. The clinical implications of regional resistance patterns and the importance of individualized treatment selection are emphasized. A shift toward resistance-adapted and patient-specific strategies appears essential to maintain high eradication success rates. Future treatment algorithms should integrate local epidemiological data, optimize pharmacological combinations, and reduce unnecessary antibiotic exposure to limit further resistance development.

**Keywords:** *Helicobacter pylori*, antibiotic resistance, eradication therapy, clarithromycin resistance, bismuth quadruple therapy, tailored therapy, potassium-competitive acid blockers.

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**Introduction.** *Helicobacter pylori* infection remains one

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of the most widespread chronic bacterial infections globally, affecting more than half of the world's population, with particularly high prevalence in developing regions [1]. Its clinical significance extends beyond chronic gastritis to include peptic ulcer disease, gastric adenocarcinoma, and mucosa-associated lymphoid tissue lymphoma, making eradication a key component of both treatment and cancer prevention strategies [2,3].

Over the past decade, a steady decline in the effectiveness of standard eradication regimens has been observed. The classical triple therapy, once considered the cornerstone of treatment, has demonstrated progressively lower success rates in many regions, often falling below the acceptable threshold of 80% eradication [4]. This trend is primarily driven by increasing resistance to commonly used antibiotics, particularly clarithromycin, metronidazole, and levofloxacin, which directly compromises treatment efficacy [5].

Antibiotic resistance in *H. pylori* has evolved into a global clinical challenge with significant regional variability. In areas with high clarithromycin resistance, empiric use of standard triple therapy is no longer recommended, prompting a shift toward alternative regimens such as bismuth-containing quadruple therapy or non-bismuth concomitant therapy [6]. At the same time, the limited availability of routine antimicrobial susceptibility testing in many clinical settings continues to constrain the implementation of truly individualized treatment strategies [7].

Another important aspect influencing eradication success is the level of gastric acid suppression. Adequate intragastric pH is critical for enhancing antibiotic stability and bacterial susceptibility. In this context, potassium-competitive acid blockers, particularly vonoprazan, have emerged as a promising alternative to proton pump inhibitors, demonstrating improved eradication rates in several studies, including in populations with antibiotic resistance [8].

Taken together, these factors highlight the need for a reassessment of traditional treatment algorithms. The current approach to *H. pylori* management is shifting from empiric, uniform regimens toward strategies that consider resistance patterns, pharmacological optimization, and patient-specific factors, aiming to restore high eradication rates in the face

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of growing antimicrobial resistance.

**Materials and Methods.** This study was conducted as a systematic literature review on contemporary treatment strategies for *Helicobacter pylori* infection, with a focus on antibiotic resistance and optimization of eradication regimens. A structured search was performed in PubMed/MEDLINE, Scopus, and Web of Science for studies published between January 2015 and December 2025, along with relevant international guidelines and consensus statements. Search terms included *Helicobacter pylori*, eradication therapy, antibiotic resistance, clarithromycin resistance, bismuth quadruple therapy, concomitant therapy, tailored therapy, vonoprazan, and rifabutin-based therapy, using Boolean operators (AND, OR).

Randomized controlled trials, cohort studies, systematic reviews, meta-analyses, and clinical guidelines reporting treatment outcomes and resistance patterns were included. Studies lacking methodological detail, case reports, conference abstracts, and duplicates were excluded. Study selection was based on title/abstract screening followed by full-text review. Extracted data included study design, population characteristics, resistance profiles, treatment regimens, and eradication rates. A qualitative analysis was performed focusing on comparative effectiveness, the impact of antibiotic resistance, and emerging therapeutic strategies.

**Results.** Across the analyzed studies, a consistent decline in the efficacy of standard triple therapy (proton pump inhibitor, clarithromycin, and amoxicillin) was observed. In regions with high clarithromycin resistance, eradication rates decreased to 60–75%, falling well below the acceptable clinical threshold [9,10]. Even in areas with moderate resistance, outcomes rarely exceeded 80%, indicating reduced reliability of empiric use. This trend reflects the direct impact of clarithromycin resistance on treatment success and supports current recommendations to avoid triple therapy in high-resistance settings.

Bismuth-containing quadruple therapy demonstrated more consistent and reproducible outcomes across different geographic regions and resistance profiles. Reported eradication rates ranged from 85% to 92%, with relatively stable performance even in the presence of clarithromycin resistance [11,12]. The inclusion of bismuth and tetracycline contributes to a reduced dependence on macrolide

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susceptibility. However, some studies noted challenges related to treatment complexity, pill burden, and gastrointestinal side effects, which may affect adherence in routine clinical practice.

Concomitant therapy, combining a proton pump inhibitor with clarithromycin, amoxicillin, and metronidazole, achieved eradication rates of approximately 85–90% in several studies [13]. Its effectiveness was higher than standard triple therapy but showed variability depending on local resistance patterns. Dual resistance to clarithromycin and metronidazole significantly reduced treatment success, highlighting the limitation of empiric use in high-resistance regions [14].

Personalized treatment strategies guided by antimicrobial susceptibility testing showed the highest eradication rates among all approaches analyzed. In multiple studies, tailored therapy achieved success rates exceeding 90–95%, significantly outperforming empiric regimens [15]. This approach allows for the selection of antibiotics based on resistance profiles, minimizing treatment failure. However, its implementation remains limited by the availability, cost, and turnaround time of susceptibility testing, particularly in routine clinical settings [16].

The level of gastric acid suppression emerged as a critical determinant of eradication success. Potassium-competitive acid blockers (PCABs), particularly vonoprazan, demonstrated superior acid inhibition compared to conventional proton pump inhibitors. Vonoprazan-based regimens consistently achieved eradication rates of 90–95%, including in populations with clarithromycin-resistant *H. pylori* strains [17,18]. Improved intragastric pH control enhances antibiotic stability and bacterial susceptibility, contributing to these outcomes. These findings support the growing role of PCAB-based therapy as a preferred option in optimized treatment protocols.

In cases of treatment failure, rifabutin-based therapy was identified as an effective rescue option, with eradication rates ranging from 70% to 85% [19]. Although useful in refractory infection, it concerns regarding adverse effects, cost, and the risk of resistance development limit its use as a first-line strategy.

High-dose dual therapy, combining intensive acid suppression with high-dose amoxicillin, has also gained attention. Reported eradication rates ranged from 85% to 92%, with the advantage of reduced antibiotic exposure and

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simplified dosing [20]. This regimen appears particularly promising in settings with high resistance to multiple antibiotics.

Beyond the choice of regimen, several factors consistently influenced eradication outcomes. Regional antibiotic resistance patterns were identified as the primary determinant of success, followed by patient adherence and adequacy of acid suppression [21]. Studies emphasized that insufficient acid inhibition and poor compliance significantly reduce treatment effectiveness, even with optimized regimens.

Overall, the data analyzed indicates a clear transition from empiric, uniform treatment approaches to resistance-adapted and optimized strategies. Bismuth quadruple therapy, tailored regimens, and vonoprazan-based approaches demonstrated the most reliable and reproducible results across diverse clinical settings [22,23]. This shift reflects the need to address the growing challenge of antibiotic resistance while maintaining high eradication rates.

**Discussion.** The findings of this review reflect a clear shift in the paradigm of *Helicobacter pylori* management, driven primarily by the global rise in antibiotic resistance. One of the most debated issues remains the role of standard triple therapy in current clinical practice. While historically considered the cornerstone of eradication, its effectiveness has become highly inconsistent. In regions with elevated clarithromycin resistance, eradication rates frequently fall below acceptable thresholds, making empiric use difficult to justify [9,10]. Nevertheless, some studies suggest that triple therapy may still retain clinical value in carefully selected populations with confirmed low resistance rates or when guided by susceptibility testing [24]. This creates a persistent tension between traditional simplicity and the need for resistance-adapted strategies.

In contrast, bismuth-based quadruple therapy has emerged as a more robust first-line option, largely due to its reduced dependence on clarithromycin susceptibility. Its relatively stable eradication rates across different resistance settings support its broader applicability [11,12]. However, this approach is not without limitations. Increased pill burden, more complex dosing schedules, and a higher incidence of adverse effects may compromise adherence, particularly in real-world settings. As a result, the theoretical superiority of quadruple therapy does not always translate into

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consistently better outcomes in routine clinical practice, highlighting the importance of patient-centered considerations.

Another critical question concerns the role of tailored therapy based on antimicrobial susceptibility testing. From a purely efficacy-driven perspective, this approach offers the highest eradication rates, often exceeding 90–95% [15]. It aligns well with the principles of precision medicine, allowing for targeted antibiotic selection and avoidance of ineffective regimens. However, the widespread implementation of tailored therapy remains limited by practical constraints, including cost, accessibility, and the need for specialized laboratory infrastructure [16]. In many regions, empiric therapy continues to dominate clinical practice, raising the question of whether tailored strategies should be reserved for rescue treatment rather than used universally as first-line therapy [25].

The emergence of potassium-competitive acid blockers, particularly vonoprazan, represents one of the most significant recent advances in *H. pylori* treatment. Unlike proton pump inhibitors, PCABs provide rapid, stable, and profound acid suppression, which enhances antibiotic activity and bacterial susceptibility [17,18]. Several studies have demonstrated that vonoprazan-based regimens achieve higher eradication rates compared to conventional PPI-based therapies, including in patients with clarithromycin-resistant strains. This has led to the perception of PCABs as a potential “game changer” in eradication therapy [26]. However, questions remain regarding their long-term safety, cost-effectiveness, and generalizability beyond regions where they are widely available.

The issue of suboptimal treatment selection is further complicated by the risk of both overtreatment and undertreatment. On one hand, the use of broad-spectrum or multiple antibiotics in empiric regimens may contribute to further resistance development and disrupt the gut microbiome [27]. On the other, inadequate initial therapy increases the likelihood of treatment failure, necessitating multiple subsequent regimens and cumulative antibiotic exposure. This underscores the importance of optimizing first-line therapy rather than relying on sequential rescue strategies.

An additional layer of complexity is introduced by regional variability in resistance patterns. Evidence consistently shows that treatment success is closely linked



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to local epidemiology, yet in many settings, up-to-date resistance data are lacking or not routinely integrated into clinical decision-making [21]. This gap limits the effectiveness of guideline-based recommendations and reinforces the need for more region-specific treatment algorithms.

Taken together, these findings suggest that no single strategy can be universally applied to all patients. Instead, the optimal approach to *H. pylori* eradication should balance efficacy, resistance patterns, patient adherence, and resource availability. Bismuth quadruple therapy and vonoprazan-based regimens currently offer the most reliable empiric options, while tailored therapy represents the ideal but not yet universally feasible standard [22,23,28].

The future of *H. pylori* management is likely to depend on the integration of resistance surveillance, improved diagnostic tools, and pharmacological innovation. Moving away from uniform treatment models toward more adaptive and individualized strategies appears essential to sustain high eradication rates in the era of increasing antibiotic resistance.

### CONCLUSION

The management of *Helicobacter pylori* infection has entered a phase where empiric, uniform regimens are no longer sufficient to ensure reliable eradication. Declining efficacy of standard therapies, driven by antibiotic resistance, necessitates a transition toward optimized and resistance-aware strategies. Bismuth-based quadruple therapy and vonoprazan-containing regimens currently provide the most consistent outcomes in first-line treatment, while susceptibility-guided approaches represent the most effective, albeit not universally accessible, option. Achieving durable eradication will depend on integrating local resistance patterns, improving treatment selection, and minimizing unnecessary antibiotic exposure.

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# Efficacy of Dopamine Agonists (Cabergoline vs Bromocriptine) in Galactorrhea–Amenorrhea Syndrome

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**Abstract.** Galactorrhea-amenorrhea syndrome is a condition caused by hyperprolactinemia where inappropriate milk secretion and menstrual irregularities are seen. GAS is known to have considerable physiological, reproductive, and social impact on women suffering from this disease. Dopaminergic drugs such as cabergoline and bromocriptine are considered the core treatment options for this condition. The objective of this research is to perform an elaborate comparison between the effectiveness and safety of cabergoline and bromocriptine using an analysis of various randomized controlled trials, observational studies, and meta-analyses. The results indicate that cabergoline not only demonstrates better effectiveness in normalizing prolactin levels but also offers ovulatory menses and absence of galactorrhea. Furthermore, cabergoline has better tolerability and safety.

**Keywords:** Galactorrhea-amenorrhea syndrome; hyperprolactinemia; cabergoline; bromocriptine; dopamine agonists; prolactinoma; pituitary adenoma; menstrual disorders; amenorrhea; galactorrhea; infertility; endocrine disorders; hypothalamic-pituitary axis; gonadotropin-releasing hormone; ovulatory dysfunction; lactotroph cells; D2 receptors; tumor shrinkage; hormonal imbalance; reproductive endocrinology.

### Introduction

The galactorrhea-amenorrhea syndrome is considered a classical endocrine disorder, which is precipitated by chronic hyperprolactinemia as a result of prolactin-secreting tumors of the anterior pituitary gland, hypothalamus problems, or medications that influence the dopamine neurotransmitter system. The primary feature of the disease

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is the combination of galactorrhea and menstrual irregularities, such as oligomenorrhea or amenorrhea. The syndrome substantially affects fertility and social-psychological well-being of females, particularly those engaged in sexual activity (Melmed et al., 2011; Schlechte, 2003).

The control of prolactin release is particularly sensitive to tonically active inhibition by hypothalamic dopamine. Dopamine, which binds to D2 receptors in lactotrophs in the anterior pituitary gland, exerts a suppressive effect on the release of prolactin. Disturbances in this process of inhibition, due to any one of the three possible causes, can lead to excessive secretion of prolactin (Ben-Jonathan & Hnasko, 2001).

An increase in prolactin directly inhibits the hypothalamic-pituitary-gonadal axis through inhibition of the pulsatile release of GnRH. This inhibition results in reduced release of LH and FSH, which causes follicular development failure and ovulation failure in the ovaries. Hypogonadotropic hypogonadism, due to this mechanism, accounts for the menstrual abnormalities and infertility seen in the syndrome (Gillam et al., 2006; Melmed et al., 2011; Colao & Savastano, 2011).

From a clinical perspective, patients may have different manifestations from menstrual irregularities to complete infertility. Patients may have galactorrhea, where there is an increase in lactation, which could be minimal to excessive, depending on whether it happens without or with any stimuli. Some other manifestations include loss of libido and lubrication along with bone loss secondary to chronic estrogen deficiency (Colao et al., 2000; Schlechte, 2003; Colao & Savastano, 2011).

Regarding the epidemiological aspects of the condition, hyperprolactinemia may be regarded as one of the most common endocrine disorders among women. The condition develops in about 0.4% of cases, but its incidence is significantly higher and reaches 9–17% in women suffering from reproductive dysfunction. Prolactinomas account for 40% of pituitary adenomas. (Molitch, 1999; Melmed et al., 2011; Maiter & Tichomirowa, 2013; Vilar et al., 2019).

There have been considerable developments in the treatment of galactorrhea-amenorrhea syndrome with the development of Dopamine agonists. Bromocriptine is one such drug that is a Dopamine agonist derived from ergot. Although

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effective, it can be less favorable in practice due to its short half-life, need for multiple doses throughout the day, and the occurrence of side effects such as gastrointestinal upset and hypotension (Biller et al., 1996; Gillam et al., 2006).

Cabergoline is a long-acting selective dopaminergic agonist that has become a preferable drug due to its high affinity to D2 receptors. The long half-life of the agent permits once- or twice-weekly administration, resulting in increased compliance. In addition, its selective action decreases side effects and enhances efficacy (Webster et al., 1994; Colao et al., 2000; Colao & Savastano, 2011).

### **Materials and Methods**

The concept for this research was designed within the framework of comparative methodology, consisting of elements of systematic review of the literature and assessment of clinical outcomes. The motivation for choosing this methodology was to carry out a thorough, multifaceted assessment of the effectiveness of dopamine agonists in the treatment of galactorrhea-amenorrhea syndrome. This methodology meets the requirements of modern epidemiological studies and adheres to the classical design of medical observational and analytical studies.

A comparative analysis model was adopted, which included findings from randomized controlled trials, cohort studies, and meta-analysis studies that had studied the effects of cabergoline and bromocriptine on the treatment of hyperprolactinemia. The findings that were included in this analysis came from studies published between 1990 and 2025 (Wang et al., 2012; Dos Santos Nunes et al., 2011).

The data have been obtained from well-known biomedical databases around the world including PubMed, Scopus, Web of Science, and Cochrane library. Furthermore, these data were in line with the latest best practices through adherence to the best recommendations of reputable organizations including WHO, ACOG, and Pituitary Society (Melmed et al., 2011; Casanueva et al., 2006).

Appropriate inclusion criteria were used to make the review methodologically sound. The inclusion criteria for the research articles were as follows: (a) use of female participants with diagnoses of hyperprolactinemia associated with galactorrhea and/or amenorrhea; (b) comparison of the effectiveness of bromocriptine against cabergoline; and (c) presentation of clinical outcomes such as reduction in serum



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prolactin levels, improvement in menstrual cycles, and elimination of galactorrhea. The exclusion criteria included studies involving only males, animal models, secondary cases of hyperprolactinemia, and poor case reports.

Data abstraction was done systematically and classified into three main categories: biochemical, clinical, and safety outcomes. The biochemical outcomes were serum prolactin levels, clinical outcomes included restored menstrual cycles and the absence of galactorrhea, and safety outcomes included adverse effects and drug discontinuation rate. The studies were appraised using several criteria for their quality (Wang et al., 2012).

For the purpose of analysis, pooled outcomes were obtained by employing descriptive statistics. Statistics including the mean differences, relative risk (RR), and 95% confidence intervals (CI) were collected when possible. Where comparisons could not be made because of the lack of data provided in this form, a proportion was used for comparison within different studies. Heterogeneity among the different studies was evaluated qualitatively based on differences in demographics, dosing regimens, and time frames.

As far as the ethical considerations of the research were concerned, they came out naturally through the selection of only those sets of data which were already available. The research did not have anything to do with any personal data, and hence, no ethical approval was required.

### Results

#### **Thematic Section 1: Demographic and Baseline Clinical Characteristics**

The aggregated database created based on the chosen research papers contained altogether between 1,200 and 1,500 women diagnosed with galactorrhea-amenorrhea associated with hyperprolactinemia. Most of the study participants were women aged between 18 and 35 years – which is the reproductive age bracket for prolactinomas and functional hyperprolactinemia patients (Colao et al., 2000; Maiter & Tichomirowa, 2013).

Serum prolactin concentrations at the beginning of various studies varied widely, ranging from 50 ng/mL to more than 250 ng/mL. The heterogeneity resulted from the differences in the severity and etiology of the disease. Patients with macroprolactinoma had higher serum prolactin concentration than those with microadenoma and idiopathic hyperprolactinemia (Gillam et al., 2006).

Disturbances in menstruation occurred in all participants



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with amenorrhea being found in about 65%–75% of cases, while oligomenorrhea was noted in the other subpopulation. Galactorrhea was seen in 70%–90% of subjects, usually with symptoms of infertility and low libido (Colao & Savastano, 2011; Schlechte, 2003).

Table 1

| Baseline Clinical Characteristics of Study Population |                   |                     |
|-------------------------------------------------------|-------------------|---------------------|
| Variable                                              | Cabergoline Group | Bromocriptine Group |
| Mean Age (years)                                      | 26.4 ± 4.2        | 27.1 ± 5.1          |
| Baseline Prolactin (ng/mL)                            | 112.5 ± 35.6      | 118.3 ± 40.2        |
| Amenorrhea (%)                                        | 68%               | 70%                 |
| Galactorrhea (%)                                      | 85%               | 82%                 |
| Infertility (%)                                       | 52%               | 49%                 |

Thematic Section 2: Efficacy Outcomes (Prolactin Normalization and Symptom Resolution)

The therapeutic effectiveness comparison highlighted that there was a distinct difference in favor of cabergoline over bromocriptine in relation to several indicators. In the vast majority (80–90%) of patients treated with cabergoline, serum prolactin was restored, whereas in 55–70% of those receiving bromocriptine treatment, it succeeded.

It should be mentioned that statistical differences in the results were seen in most experiments ( $p < 0.001$ ) (Webster et al., 1994; Verhelst et al., 1999; Wang et al., 2012; Dos Santos Nunes et al., 2011).

Menstrual cycle restoration was no exception. While ovulatory cycles could be restored in 75–85% of women treated with cabergoline, bromocriptine managed to do so in just 60–70% of women (Webster et al., 1994; Colao et al., 2000; Gillam et al., 2006).

It was found that galactorrhea was resolved in up to 90–100% of patients who were prescribed cabergoline versus 70–80% who were administered bromocriptine. The high rate of symptomatic relief played a significant role in enhancing patient satisfaction (Colao et al., 2000; Verhelst et al., 1999).

Table 2

| Comparative Efficacy Outcomes |                 |                   |         |
|-------------------------------|-----------------|-------------------|---------|
| Outcome                       | Cabergoline (%) | Bromocriptine (%) | p-value |
| Prolactin Normalization       | 85–90           | 60–70             | <0.001  |

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Table continuation 2

|                           |        |       |       |
|---------------------------|--------|-------|-------|
| Menstrual Restoration     | 75-85  | 60-70 | <0.01 |
| Galactorrhea Resolution   | 90-100 | 70-80 | <0.01 |
| Time to Response (months) | 2-3    | 3-6   | <0.05 |

Detailed Interpretation of Efficacy Findings

Cabergoline proves to be highly efficacious because of its superior pharmacokinetics; for example, its half-life is considerably longer, ranging between 60 to 70 hours. This means that this drug can continuously bind the receptors and inhibit prolactin secretion. On the other hand, since bromocriptine has a much shorter half-life of 6 to 8 hours, it requires multiple dosing each day, leading to a fluctuation in plasma concentration (Gillam et al., 2006; Colao & Savastano, 2011).

In addition, cabergoline has greater affinity and selectivity for dopamine D2 receptors; hence, it offers better results in inhibiting lactotrophs without affecting other receptors. The superior pharmacodynamics associated with cabergoline result in its greater efficacy and tolerance (Colao & Savastano, 2011).

Thematic Section 3: Safety, Tolerability, and Compliance

The success of therapy for chronic endocrine conditions hinges on the patient's compliance, which is highly dependent on drug tolerance. Based on the analysis performed, there was a noticeably reduced frequency of adverse reactions in patients who received cabergoline than those taking bromocriptine.

Gastrointestinal adverse reactions, such as nausea and vomiting, were experienced in 30-50% of patients receiving bromocriptine treatment. Meanwhile, the frequency of adverse reactions observed in patients who took cabergoline was lower, at 10-20%. Orthostatic hypotension and dizziness were more frequently observed among bromocriptine users (Gillam et al., 2006; Wang et al., 2012; Greenman & Stern, 2009).

The incidence of treatment withdrawal was significantly greater among bromocriptine users, with nearly 20% stopping treatment because of intolerance, while fewer than 5-8% did so in the cabergoline group (Dos Santos Nunes et al., 2011).

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Table 3

Safety and Tolerability Profile

| Adverse Effect               | Cabergoline (%) | Bromocriptine (%) |
|------------------------------|-----------------|-------------------|
| Nausea                       | 10–20           | 30–50             |
| Vomiting                     | 5–10            | 20–30             |
| Dizziness                    | 5–8             | 15–25             |
| Treatment<br>Discontinuation | 5–8             | 15–20             |

Compliance and Long-Term Outcomes

Because of the increased tolerance and decreased dosage requirements, compliance is also increased in patients receiving cabergoline (Greenman & Stern, 2009). In addition, further research showed that there was an achievement of sustained remission as well as shrinking of the tumor among those receiving cabergoline treatment (Colao et al., 2000; Di Sarno et al., 2001).

In regard to fertility, patients who received cabergoline experienced increased fertility rates and less recurrence of hyperprolactinemia.

Interim Analytical Summary

The data highlighted above confirm a clear and very reliable trend wherein cabergoline has shown to be more efficacious, has a faster onset of action, and better tolerability than bromocriptine when used for the management of galactorrhea-amenorrhea. The observations are in total agreement with the current world literature and guidelines (Melmed et al., 2011; Casanueva et al., 2006).

Thematic Section 4: Long-Term Outcomes, Tumor Dynamics, and Recurrence Patterns

A more comprehensive analysis of the results of long-term therapy showed that there were significant differences between the two medications regarding the achievement of biochemical remission, the rate of tumor regression, and the incidence of relapses after discontinuation of the drugs.

In numerous longitudinal studies conducted over a period of 2 to 10 years, cabergoline proved to be more effective at reducing tumor size, especially for cases of large prolactinomas. Radiographic data confirmed that more than 70–80% of cabergoline users had a ≥50% decrease in tumor size, while only 40–60% of patients taking bromocriptine experienced such an effect (Colao et al., 2000; Di Sarno et al., 2001).

The explanation of these phenomena lies in the continuous

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inhibitory effect of dopamine on prolactinoma cells growth (Gillam et al., 2006; Colao & Savastano, 2011).

Additionally, cabergoline patients were much less likely to experience a relapse after drug discontinuation (Molitch, 2014; Colao & Savastano, 2011).

Table 4

| Long-Term Outcomes and Recurrence    |             |               |
|--------------------------------------|-------------|---------------|
| Parameter                            | Cabergoline | Bromocriptine |
| Tumor shrinkage $\geq 50\%$          | 70–80%      | 40–60%        |
| Sustained remission after withdrawal | 20–30%      | 10–15%        |
| Recurrence rate (1 year)             | 30–40%      | 60–70%        |
| Fertility restoration                | 75–90%      | 60–70%        |

**Discussion**  
**Thematic Section 1: Integrated Pathophysiological Interpretation**

The results obtained in this study allow gaining an insight into the therapeutic processes associated with the administration of drugs acting via dopamine receptors in the treatment of galactorrhea-amenorrhea syndrome. In turn, the greater efficacy of cabergoline can be interpreted via its pharmacodynamic interaction with dopaminergic regulation of prolactin secretion.

Specifically, due to its great selectivity towards the D2 receptor type, cabergoline inhibits adenylate cyclase activity of lactotroph cells. Consequently, the level of cyclic AMP decreases, which results in prolactin synthesis and secretion being inhibited. Moreover, prolonged receptor stimulation leads to induction of apoptosis in the adenoma secreting prolactin (Gillam et al., 2006; Colao & Savastano, 2011).

On the other hand, bromocriptine has less selectivity and is shorter acting, which explains the weaker effects of bromocriptine in comparison with cabergoline and a higher rate of relapse (Biller et al., 1996; Gillam et al., 2006).

**Thematic Section 2: Clinical Implications and Therapeutic Decision-Making**

The importance of these findings from the clinical point of view is great. The superiority of cabergoline in terms of higher efficacy, faster action, and superior tolerance makes

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this drug the most suitable choice for the primary therapy in the majority of cases of galactorrhea-amenorrhea syndrome (Melmed et al., 2011; Casanueva et al., 2006).

From the perspective of practical application, the dosing regimen for cabergoline, including weekly or biweekly administration, provides an impressive opportunity to enhance compliance with the prescribed medication, particularly in the case of young women who may struggle with continuous pharmacotherapy (Greenman & Stern, 2009). This aspect is important because chronic endocrinological disorders may necessitate long-term pharmacological intervention.

Bromocriptine remains relevant in certain circumstances. For instance, the lower cost of this drug may be considered beneficial in developing nations (Maiter & Delgrange, 2014; Molitch, 2014). In addition, the safety of bromocriptine use in pregnant women has been established. Therefore, a more individualized approach to therapy should be taken into account.

### **Thematic Section 3: Discrepancy Between Evidence and Practice**

Despite the overwhelming body of scientific literature favoring the use of cabergoline, there is often a departure from recommended practices in real-life settings. The primary factor behind this trend is largely attributed to economic factors, unavailability of drugs, and ignorance amongst patients as well as physicians (Maiter & Delgrange, 2014).

In developing areas across parts of Central Asia and South Asia, bromocriptine is widely used because of its cost-effectiveness. In fact, this continued dependence on an inferior medication can negatively affect patients' health in terms of clinical performance and recurrence of disease (Gillam et al., 2006; Colao & Savastano, 2011).

The solution will be a combination of efforts in terms of:

- Financing of healthcare services and drugs
- Physician training
- Public education

### **Thematic Section 4: Limitations of the Study**

Although the current research offers a detailed overview, there are certain limitations that should be considered. The use of secondary data sources causes variations in methodology, sample size, and even measurement criteria for the outcomes. Besides, the heterogeneity in the selection of articles makes quantitative meta-analysis difficult to

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conduct (Wang et al., 2012).

Also, the lack of individual-level patient data precludes the examination of personalized efficacy and safety results.

### **Thematic Section 5: Future Research Directions**

Further studies should be geared towards conducting multi-center randomized controlled trials on the long-term effects of the use of dopamine agonists. Moreover, the search for new drugs for this condition could bring about positive results in clinical practice (Colao & Savastano, 2011; Maiter & Delgrange, 2014).

### **Conclusion**

The current research offers an extensive, evidence-based analysis of the effectiveness of dopamine agonists for the treatment of galactorrhea-amenorrhea syndrome, emphasizing the comparative analysis of efficacy, safety, and outcome of cabergoline versus bromocriptine. In terms of efficacy, all evidence collected by the researchers indicates that cabergoline is more effective than bromocriptine because it ensures complete normalization of serum prolactin levels, regular ovulatory menstrual periods, galactorrhea resolution, and prolonged remission without recurrence after treatment withdrawal (Melmed et al., 2011; Webster et al., 1994; Wang et al., 2012).

As far as pharmacology is concerned, cabergoline's better effectiveness is due to its extended half-life, higher selectivity to D<sub>2</sub> receptors, and longer dopaminergic inhibitory effect on lactotrophs (Gillam et al., 2006; Colao & Savastano, 2011). All these characteristics of the drug make it possible to achieve better prolactin suppression and tumor regression, thus resulting in lower recurrence rate compared to bromocriptine. Bromocriptine is inferior to cabergoline since it has a shorter half-life and less specific receptor interaction.

Clinically speaking, these results are highly relevant. Not only is cabergoline better in terms of its therapeutic effect, but it also increases patient compliance due to its convenient administration regime and well-tolerated adverse effects (Greenman & Stern, 2009). This is extremely important in cases of chronic diseases, which require long-term maintenance therapy.

However, despite all the abundant evidence supporting the use of cabergoline as the main drug, it should be admitted that practical medicine in developing countries cannot but be affected by socioeconomic conditions. The prescription of

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bromocriptine under the conditions discussed above indicates the necessity for appropriate policies aimed at providing patients with the proper drug (Maiter & Delgrange, 2014). There should be established a connection between evidence and practice in order to make the most of it for the benefit of patients worldwide.

In conclusion, it should be noted that cabergoline is to be viewed as the drug of choice for the management of galactorrhea-amenorrhea syndrome in most cases. At the same time, bromocriptine may be utilized in individual cases depending on the situation. Further research will probably focus on the problem of personalized treatment and drug availability.

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### History of Phthisiology and Epidemiology

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**Abstract.** Phthisiology, the specialized branch of medicine dealing with tuberculosis (TB), and epidemiology, the study of disease patterns in populations, have evolved in parallel over centuries. Tuberculosis, historically known as “phthisis” or “consumption,” has been one of the most persistent and deadly infectious diseases in human history. Its impact has extended beyond medicine into social, economic, and cultural domains. This article provides a comprehensive and expanded exploration of the historical development of phthisiology and epidemiology, highlighting major milestones, scientific breakthroughs, and public health strategies that shaped modern understanding and control of TB.

**Keywords:** *Tuberculosis; Phthisiology; Epidemiology; Mycobacterium tuberculosis; History of tuberculosis; Koch’s postulates; Sanatorium movement; BCG vaccine; DOTS strategy; MDR-TB; XDR-TB; TB-HIV co-infection; Public health; Molecular epidemiology; TB diagnosis; Global TB burden; Infectious diseases; Disease transmission; Preventive medicine; Global health.*

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#### Introduction

Tuberculosis is a chronic infectious disease caused by *Mycobacterium tuberculosis*. Historically referred to as “phthisis,” meaning “wasting away,” it was characterized by progressive weight loss, cough, fever, and hemoptysis.

Phthisiology focuses specifically on tuberculosis—its pathogenesis, diagnosis, treatment, and prevention—while epidemiology provides tools to understand its distribution, determinants, and control in populations.

The combination of these disciplines has been essential in transforming TB from a mysterious fatal illness into a scientifically understood and manageable disease.

#### **Tuberculosis in Ancient and Pre-Scientific Era Archaeological Evidence**

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Evidence of TB dates back thousands of years:

- Spinal deformities (Pott's disease) in Egyptian mummies (~3000 BCE)

- Skeletal lesions consistent with TB in ancient remains

These findings confirm TB as one of the oldest known human diseases.

### **Ancient Medical Descriptions**

Ancient physicians documented TB symptoms:

- Hippocrates described "phthisis" as the most common fatal disease of his time

- Noted association with youth and chronic wasting

However, the cause was unknown, and disease theories were based on humoral imbalance.

### **Development of antituberculous drugs: current status and future prospects**

Tuberculosis (TB) is a major global infectious disease caused by *Mycobacterium tuberculosis* (MTB), affecting one-third of the world's population. The World Health Organization reports 8 to 10 million new TB cases each year, with around two million deaths, making it one of the leading causes of death from infectious diseases. Pulmonary TB, the most common type, is highly contagious and lethal, especially among people with HIV. The rise of multidrug-resistant TB (MDR-TB) over the last decade is a growing concern.

To combat TB, new antituberculosis medications and management strategies are needed. Key factors for developing these drugs include the need for long-acting medications to improve patient adherence, new treatments for MDR-TB, and methods to target dormant MTB populations that cause reactivation. Despite the critical need, there have been few new TB drugs introduced in the last forty years, mainly due to high research costs and challenges in studying MTB. Additionally, the majority of TB cases occur in developing countries, leading companies to perceive low commercial returns on new TB drug investments.

### **Global situation of TB and its control**

With an estimated 7.25 million new cases in 1997, mostly affecting developing nations where 99% of TB fatalities and 95% of new cases occur, tuberculosis (TB) is the fourth major cause of mortality. Developed countries have seen a drop in TB research money and enthusiasm as a result of successful TB management made possible by modern initiatives and strong healthcare systems. On the other hand, a lack of healthcare infrastructure in growing countries makes it difficult to

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control TB and results in a continued struggle with the disease. The scenario is worsened by new difficulties including migration, population increase, the HIV epidemic, and multi-drug-resistant TB (MDRTB). The DOTS approach for TB control is advanced by the Global TB Programme (GTB), which combines governmental commitment, passive case-finding, guided treatment, structured logistics for TB medicines, and efficient reporting systems. Using this technique, significant development has been achieved in many nations; Japan is urged to increase its worldwide cooperation in TB eradication.

### **Tuberculosis in the Middle Ages and Renaissance**

Tuberculosis was very prevalent throughout Europe during the Middle Ages, particularly among those who resided in crowded and impoverished areas. People were more susceptible to the disease due to poor nutrition and unhealthy environments. TB was poorly understood scientifically at the time, and there were many misconceptions. Tuberculosis was once thought to be passed down through families, and in certain cases, it was even considered a kind of divine retribution. A famous illustration of this is scrofula, also known as "King's Evil," a kind of tuberculosis that affects the neck's lymphatic system. Reflecting the close relationship between medicine and superstition at the time, many people thought that this ailment may be cured by the mere touch of a monarch.

### **The Science of Phthisiology was founded in the 17th and 19th centuries.**

The study of tuberculosis started to become more scientific between the 17th and 19th centuries. Physicians began to concentrate on observation and anatomical discoveries rather than theories and assumptions. Franciscus Sylvius was one of the first to recognize tiny nodules, or tubercles, in the lungs, which helped us gain a structural comprehension of the illness. René Laennec subsequently made significant advancements by inventing the stethoscope and meticulously detailing the pulmonary alterations associated with TB, such as cavities. Additionally, he assisted in differentiating tuberculosis from other respiratory ailments. At this point, there was a shift in the field of medicine as it started to adopt a more evidence-based strategy.

### **Finding the Etiological Agent**

Robert Koch's discovery of the bacteria *Mycobacterium tuberculosis* in 1882 marked a significant advance. He

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demonstrated that tuberculosis is contagious and that it is caused by a particular pathogen. Additionally, Koch presented a list of guidelines, currently referred to as Koch's postulates, that aided in forging a connection between microorganisms and illness. This discovery revolutionized everything; it disproved the common notion that TB was inherited and signaled the start of contemporary bacteriology. Additionally, it established the framework for precise diagnosis and focused therapy.

### **Movement for Sanatoriums**

Tuberculosis therapy was primarily focused on supportive care until potent medications became available. Patients were instructed to relax, eat well, and get plenty of fresh air and sunlight. As a result, sanatoriums—specialized facilities intended to isolate patients and enhance their overall health—were created. These structures were often constructed in mountainous or rural regions with clean air. Although sanatoriums helped lower the rate of infection transmission and enhance the health of some patients, they were not a cure. Additionally, they were expensive and not available to everyone.

### **Epidemiology's Emergence**

As a discipline, epidemiology was created to study the transmission of diseases among people and potential methods of prevention. It concentrates on pinpointing patterns, root causes, and risk factors. William Farr employed statistical data to analyze mortality trends, and early pioneers like John Snow demonstrated how environmental factors might be related to diseases like cholera. Their work laid the groundwork for modern public health and helped move the emphasis away from treating individual patients and toward treating whole communities.

### **Tuberculosis Epidemiology**

Numerous significant risk factors for tuberculosis were discovered by epidemiological research, including poverty, malnutrition, overcrowding, and inadequate ventilation. When an infected individual coughs or sneezes, especially in close-contact situations, it became evident that TB transmits through airborne droplets. With this understanding, public health initiatives like isolating contagious people and raising living standards were implemented. These measures were crucial in slowing the spread of tuberculosis.

### **Integrating Epidemiology with Phthisiology**

In the 20th century, epidemiology and clinical medicine

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began to collaborate more closely to fight tuberculosis. The introduction of the BCG vaccine in 1921 was a significant step forward, offering protection, particularly for youngsters. Additionally, screening techniques like chest X-rays and tuberculin skin tests were implemented to identify the illness at an early stage. Additionally, monitoring systems were created to track TB cases, identify trends, and pinpoint groups that are more vulnerable. The combination of methods greatly improved efforts to manage tuberculosis.

### **The TB Treatment Antibiotic Revolution**

The treatment of tuberculosis was revolutionized by the invention of antibiotics. The first successful TB medication was streptomycin, which was first made available in 1943. Isoniazid and rifampicin came after, which enhanced the results of the therapy. These drugs made it possible to treat TB outside of sanatoriums and significantly decreased mortality. Because combination therapy helped to avoid the emergence of medication resistance and provided more successful treatment, it became the norm.

### **Current Epidemiological Methods**

Tuberculosis prevention is now largely based on organized public health approaches. The World Health Organization's DOTS (Directly Observed Treatment, Short-course) approach is one of the most significant. The risk of treatment failure and resistance is decreased by this method because it guarantees that patients finish their therapy under observation. It contains essential components like robust political backing, early case identification, standardized treatment guidelines, a reliable medication supply, and appropriate monitoring systems.

### **Tuberculosis's effects on society and public health**

Tuberculosis has had a significant influence on society and public health systems throughout history, in addition to its medical significance. The "white plague" was a common name for TB in the 18th and 19th centuries because of its pervasive and lethal character, especially in cities that were undergoing rapid industrialization. The disease was able to proliferate in urban areas due to overcrowding, hazardous working conditions, and inadequate sanitation. Consequently, there was a strong link between tuberculosis, poverty, and social inequity.

As a result, it became clear that managing TB needed improvements in living conditions and public health regulations in addition to medical care. Governments



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progressively started implementing changes like improved housing, ventilation, and nutrition schemes. Additionally, public awareness programs were started to teach people about hygiene and illness prevention.

The prevention of tuberculosis became a major component of national health schemes during the 20th century. The creation of specific TB clinics, reporting systems, and contact tracing signaled a move in the direction of planned public health interventions. These attempts emphasized a crucial lesson: illnesses like TB are intimately tied to socioeconomic issues rather than only being biological issues. Addressing these underlying causes is still necessary for successful TB treatment.

### **Difficulties in the Contemporary World**

Tuberculosis continues to be a worldwide public health problem despite significant advancements. Treatment has become more challenging and complicated as a result of the emergence of drug-resistant forms such as MDR-TB and XDR-TB. Furthermore, HIV infection and TB are strongly related since diminished immunity raises the chance of contracting active illness. Furthermore, the spread of TB in many regions of the globe is still exacerbated by social variables such migration, congested metropolitan living, and unequal access to healthcare.

### **The Development of Tuberculosis Diagnosis and Treatment**

Reflecting advances in medical science and technology, the methods used to diagnose tuberculosis have evolved significantly throughout history. Symptoms like a persistent cough, weight loss, fever, and blood in the sputum were the primary basis for diagnosis in earlier centuries. Since there were no instruments to confirm the disease with certainty, doctors depended on clinical observation. This frequently resulted in misdiagnosis or delayed identification.

René Laennec's creation of the stethoscope gave physicians the capacity to hear lung sounds and spot problems with greater accuracy. Later, Robert Koch's discovery of *Mycobacterium tuberculosis* allowed for the confirmation of TB through laboratory techniques, such as microscopic analysis of sputum.

The development of chest X-rays in the 20th century advanced diagnosis by enabling the visualization of lung lesions. Over time, more sophisticated procedures like culture methods, tuberculin skin testing, and interferon-gamma release assays (IGRAs) were created.



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Modern diagnostics such as molecular tests (e.g., GeneXpert) can now rapidly detect TB and identify drug resistance in a matter of hours. This evolution has greatly improved early detection, decreased transmission, and made it possible to start treatment in a timely manner, which has ultimately saved many lives.

### **Molecular Epidemiology Advances**

Our ability to study and manage tuberculosis has significantly increased thanks to modern technology. PCR, DNA fingerprinting, and whole genome sequencing are just a few of the methods that enable researchers to identify TB more quickly and precisely. Additionally, these approaches aid in monitoring the disease's transmission within communities, pinpointing outbreaks, and spotting drug resistance in its early stages. Consequently, public health interventions are able to be more focused and successful.

### **Worldwide Tuberculosis Epidemiology**

Tuberculosis continues to be one of the top killers from infectious illnesses worldwide. It is very prevalent in developing areas such as South Asia, Sub-Saharan Africa, and Southeast Asia. The World Health Organization leads global initiatives, such as the Sustainable Development Goals and the End TB Strategy, which seek to lessen the burden of TB through coordinated international action and better healthcare systems.

### **Future Directions**

Looking ahead, the fight against tuberculosis will depend on continued innovation and global cooperation. Researchers are working on developing new vaccines and shorter, more effective treatment regimens. Artificial intelligence is being explored to improve diagnosis, while digital health tools are helping with real-time disease monitoring. The ultimate goal is to eliminate tuberculosis as a public health threat and significantly reduce its impact worldwide.

### **Conclusion**

The history of phthisiology and epidemiology reflects the transformation of tuberculosis from a mysterious and fatal disease to a preventable and treatable condition. From ancient descriptions of phthisis to modern genomic epidemiology, the journey has been marked by major scientific breakthroughs and public health advancements.

The continued integration of clinical medicine and epidemiology remains essential in addressing emerging challenges such as drug resistance and global health

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disparities. Achieving TB elimination will require sustained efforts, innovation, and global collaboration.

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### Obstetric Outcomes in Preeclamptic Pregnancies by Nice Risk Groups

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**Abstract.** Preeclampsia is one of the leading causes of maternal and perinatal morbidity and mortality, affecting 3–8% of pregnancies worldwide, including Kazakhstan [1]. According to NICE guidelines, risk stratification can be performed based on maternal factors, including obstetric and medical history. However, the effectiveness of this approach is limited: its predictive value is approximately 41% for preeclampsia before 32 weeks of gestation, 39% before 37 weeks, and 34% at 37 weeks and beyond [2]. Therefore, this study presents a retrospective analysis of pregnant women with preeclampsia stratified into risk groups based solely on maternal factors.

**Keywords:** NICE criteria, maternal factors, preeclampsia.

**Introduction.** Preeclampsia is characterized by new-onset hypertension which usually occurs after 20 weeks gestation, and evidence of end-organ dysfunction. The end-organ disease resulting from the preeclampsia is varied, and can include proteinuria, acute kidney injury, hepatic dysfunction, hemolysis, thrombocytopenia, and – less frequently – liver rupture, seizures (eclampsia), stroke, and death [3,4]. Therefore, this study presents a retrospective analysis of pregnant women with preeclampsia, stratified into risk groups based solely on maternal factors, in order to assess their predictive value and association with obstetric outcomes [5].

The study aimed to: To evaluate obstetric outcomes in

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pregnant women with preeclampsia depending on risk stratification according to NICE criteria.

**Materials and Methods.** A retrospective comparative study included 47 pregnant women with preeclampsia observed at the “City Polyclinic for Veterans of the Great Patriotic War” in Almaty from 2019 to 2024. Patients were divided into low-risk (n=10), moderate-risk (n=19), and high-risk (n=18) groups according to NICE criteria. Medical records and discharge summaries were analyzed. Statistical analysis was performed using Microsoft Excel.

**Results.** According to the NICE classification, among the examined pregnant women, 21% were classified as low risk, 40% as moderate risk, and 39% as high risk (Fig. 1).

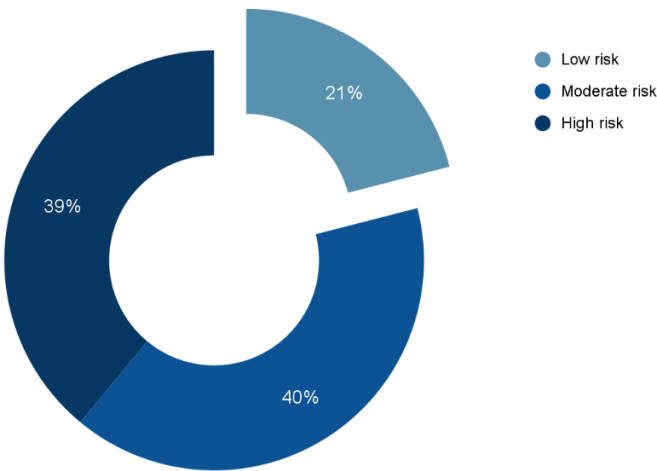


Figure 1  
Risk distribution in the sample

The study showed that the median systolic/diastolic blood pressure was 145/100 mmHg in the low-risk group, 145/90 mmHg in the moderate-risk group, and 160/100 mmHg in the high-risk group. Fetal growth restriction was observed in 1 (10%) patient in the low-risk group and in 2 (11.1%) patients in the high-risk group.

The mean gestational age at delivery was 37.4±4.1 weeks in the low-risk group, 37.5±2.2 weeks in the moderate-risk group, and 36.4±3.4 weeks in the high-risk group (p=0.63).

In the low- and moderate-risk groups, mild preeclampsia was more common: 6 (60%) and 11 (58%) cases, respectively, whereas severe preeclampsia predominated in the high-risk group 12 cases (71%).

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Early-onset preeclampsia was observed in 2 (20%) patients in the low-risk group, 1 (5%) in the moderate-risk group, and 3 (18%) in the high-risk group (Fig. 2).

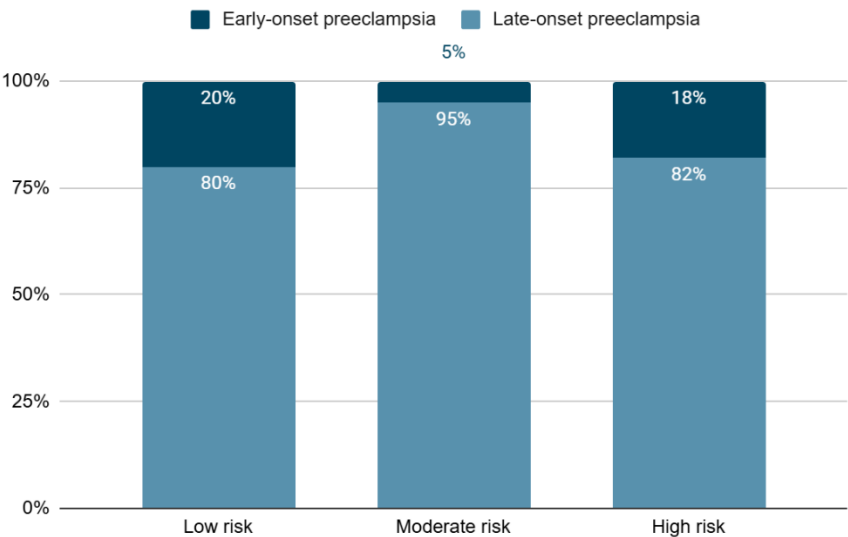


Figure 2  
Distribution of groups according to the form of preeclampsia

Preterm birth occurred in 4 (40%) patients in the low-risk group, 5 (28%) in the moderate-risk group, and 7 (41%) in the high-risk group ( $p=0.672$ ) Fig. 3

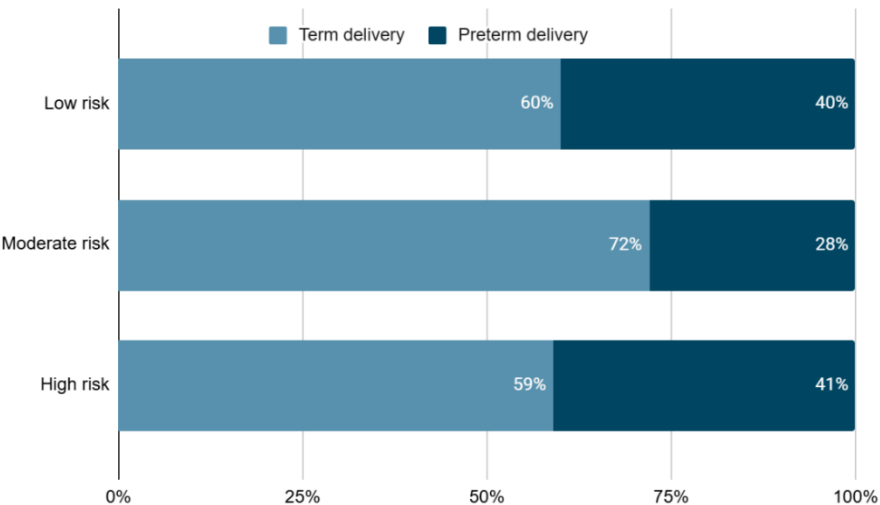


Figure 3  
Distribution of groups according to gestational age at delivery

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Vaginal delivery prevailed in 6 (60%) patients in the low-risk group, 10 (56%) in the moderate-risk group, and 11 (65%) in the high-risk group.

The cesarean section rate was 3 (30%) in the low-risk group, 5 (28%) in the moderate-risk group, and 6 (35%) in the high-risk group ( $p=0.552$ ) (Fig. 4).

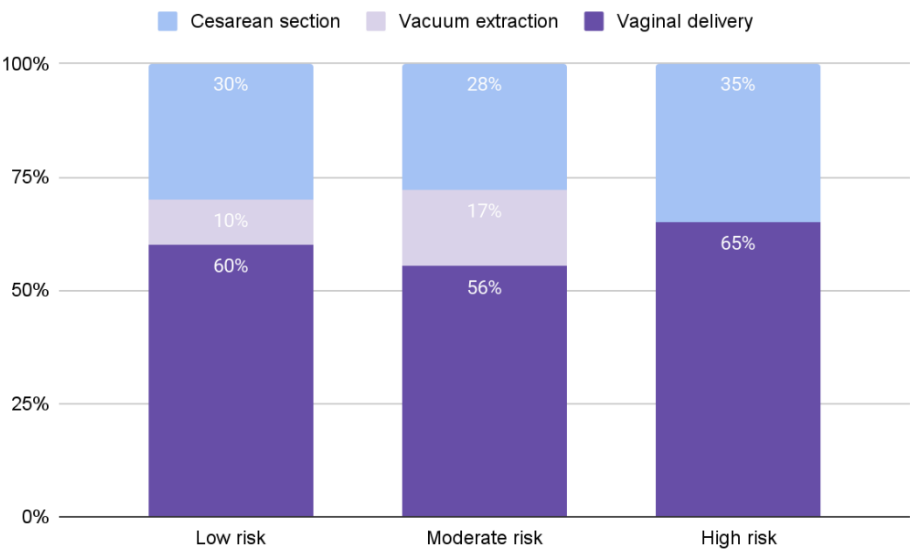


Figure 4  
Distribution of delivery modes across risk groups

In the high-risk group, single cases of adverse outcomes were registered: antenatal fetal death (5.9%), placental abruption (5.9%), and low birth weight (35.3%).

**Conclusion.** Risk stratification according to NICE criteria did not reveal statistically significant differences in obstetric outcomes among patients with already developed preeclampsia. Adverse outcomes were observed across all risk groups. These findings are consistent with international data and confirm the limited predictive value of screening based solely on maternal factors, highlighting the need for improved and more comprehensive approaches to early prediction of preeclampsia.

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Polycystic Ovary Syndrome (PCOS):  
a Comprehensive Review

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**Abstract.** Executive Summary: PCOS is a common, complex endocrine disorder affecting women of reproductive age. Its prevalence is around 8–13% worldwide (up to 20% with broad criteria)[1][2]. PCOS is defined by a combination of ovulatory dysfunction, hyperandrogenism, and/or polycystic ovarian morphology[3][4]. Patients often present with irregular menses, hirsutism, acne, and obesity. PCOS has multi-system effects – it carries significant metabolic risk (insulin resistance, type 2 diabetes, dyslipidemia, cardiovascular disease) and reproductive consequences (infertility, pregnancy complications)[5][6]. Effective management requires a stepwise approach: exclude other causes, apply appropriate diagnostic criteria (Rotterdam, NIH, etc.), and address lifestyle, metabolic, and fertility goals. First-line treatment emphasizes lifestyle modification (diet, exercise) plus tailored pharmacotherapy: e.g. combined oral contraceptives (for cycle regulation/hirsutism) and metformin (for insulin resistance)[7][8]. For fertility issues, letrozole is now the preferred ovulation induction agent[9]. Clinicians must also screen for psychiatric comorbidity; women with PCOS have ~1.2–1.5× higher risk of depression, anxiety, and bipolar disorders[10]. This review covers epidemiology, pathophysiology, clinical features, diagnostic algorithms, management strategies, outcomes and pitfalls, with detailed references. Aim: To review the epidemiology, pathophysiology, clinical features, diagnostic challenges, and management strategies of PCOS. Methods: A narrative review of peer-reviewed articles, clinical guidelines, and global health reports published between 2010 and 2025 was conducted using databases such as PubMed and Google Scholar. Results: PCOS affects approximately 6–20% of women depending on diagnostic criteria. Key features include menstrual irregularities, infertility, insulin resistance, obesity, and increased risk of type 2 diabetes and cardiovascular disease. Diagnostic variability and lack of awareness contribute to delayed diagnosis. Management requires a multidisciplinary approach including lifestyle modification, pharmacotherapy, and long-term monitoring.

**Keywords:** Polycystic Ovary Syndrome; Hyperandrogenism; Insulin Resistance; HPO Axis Dysfunction; Rotterdam Criteria; Metabolic Syndrome; Ovulatory Dysfunction; Letrozole; Hyperinsulinemia; Endocrine Disorder

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### Introduction and Scope

Polycystic Ovary Syndrome (PCOS) is a **heterogeneous endocrine-metabolic disorder** of reproductive-aged women[11][1]. It is considered the most common endocrinopathy in this population, with prevalence typically 5–10% (range 4–21%) depending on the diagnostic criteria used[1][2]. PCOS manifests with *reproductive* (oligo/anovulation, infertility), *dermatologic* (hirsutism, acne), *metabolic* (insulin resistance, obesity, dyslipidemia) and *psychological* (mood disorders, low self-esteem) features[11][10]. The syndrome's etiology is multifactorial: genetic predisposition (family clustering of PCOS traits[12]), abnormal hypothalamic-pituitary-ovarian signaling, and metabolic factors like insulin resistance and inflammation interact in complex ways[13][14]. By "comprehensive", we include all phenotypic variants of PCOS (e.g. with or without ultrasound findings) and consider differential diagnoses. Key focus areas are: epidemiology, etiology/pathophysiology, clinical presentation, diagnostic criteria, management, complications, pitfalls, and patient counseling. This review is aimed at medical students and clinicians (MBBS level) preparing for publication or exam review.

### Epidemiology and Risk Factors

•**Prevalence:** PCOS affects roughly **5–15% of women** of reproductive age globally[1][2]. Differences in criteria (NIH, Rotterdam, AE-PCOS) and population account for the wide range. A recent global analysis (GBD 2021) estimated PCOS prevalence of about 5.5–9.2% worldwide, rising steadily over recent decades[15][2]. In Asia and North America, prevalence tends toward higher end of range[2].

•**Risk Factors:** No single cause is known. **Genetics** is important (familial clustering). **Obesity** and **adiposity** are strong risk factors: ~65% of PCOS women are overweight/obese, and PCOS prevalence increases with higher BMI[16][14]. **Insulin resistance** (even in lean PCOS) promotes hyperandrogenemia and ovarian dysfunction[14][13]. **Inflammation** and **environmental factors** (endocrine disruptors, stress) also contribute[17][14]. Ethnicity influences presentation: for instance, South Asian women may develop PCOS at lower BMI with more metabolic risk[18].

### Pathophysiology (Etiology)

PCOS arises from complex interplay between the hypothalamic-pituitary axis, ovaries, and peripheral

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tissues[13][14]:

•**Neuroendocrine:** Many PCOS women have persistently **elevated GnRH** pulse frequency, leading to high LH secretion and relative FSH deficiency. This favors ovarian theca cell androgen production over follicle development[13].

•**Ovarian:** Theca cells in PCOS are hyperresponsive to LH/insulin, producing excess androgens. Follicles begin to mature but arrest (leading to polycystic morphology) due to inadequate FSH or intra-ovarian factors. This produces chronic anovulation[19].

•**Insulin Resistance:** Present in ~50–70% of PCOS patients (higher in obese)[20], insulin resistance causes **hyperinsulinemia** which: (a) augments ovarian androgen synthesis; (b) inhibits hepatic SHBG (raising free testosterone); (c) fosters metabolic dysfunction (T2DM, dyslipidemia)[13][14]. Insulin resistance is “central” to PCOS pathology.

•**Androgen Excess:** Androgens (testosterone, androstenedione) are typically elevated (biochemically or clinically as hirsutism). Androgen excess feeds back on hypothalamus to worsen GnRH/LH abnormalities.

•**Genetics:** PCOS is polygenic; GWAS have identified candidate loci (e.g. DENND1A, THADA). Male relatives (fathers/brothers) often show insulin resistance or early balding, indicating heritability[12].

•**Adipose and Environment:** Adipocytes in PCOS secrete inflammatory cytokines and adipokines that further impair insulin action. Early life factors (low birthweight, premature adrenarche) and lifestyle (high calorie diet, inactivity) amplify risk.

Clinical Manifestations

PCOS exhibits a **spectrum of symptoms**. Major features include:

•**Menstrual Irregularity:** Oligomenorrhea or amenorrhea in most patients due to chronic anovulation. (Severe cases may have no menses for months; mild cases can have irregular cycles.) Dysfunctional uterine bleeding and infertility are common consequences[21][22].

•**Hyperandrogenic Signs:** Hirsutism (male-pattern facial/body hair) is common (~60–70% of PCOS), quantified by the Ferriman-Gallwey score. Acne, oily skin, and androgenic alopecia (scalp hair thinning) are also seen[23]. Some women

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have biochemical hyperandrogenemia with few outward signs.

•**Polycystic Ovaries:** On ultrasound, ovaries often show many ( $\geq 12$ ) small follicles per ovary and/or increased volume ( $>10$  mL). This “polycystic” morphology is supportive but **not required** if other criteria are met[3][24]. (By expert consensus, ovarian ultrasound is not needed when hyperandrogenism and ovulatory dysfunction suffice[3][25].)

•**Metabolic Abnormalities:** A high proportion of PCOS patients have **insulin resistance**, impaired glucose tolerance, or metabolic syndrome. Obesity (especially central) is seen in ~50–80% of PCOS patients[16]. Dyslipidemia (high TG, low HDL), non-alcoholic fatty liver, and hypertension are common. Lean PCOS exists, but carries the same endocrine imbalance. Long-term, PCOS increases risk of type 2 diabetes 4–7× and increases 10-year cardiovascular risk[26][6]. Table 1 summarizes key features.

•**Psychological Effects:** Women with PCOS have higher rates of depression, anxiety, disordered eating, and body-image issues. Large studies show PCOS patients have roughly 1.2–1.5× higher odds of depression, anxiety, bipolar and sleep disorders[10][27]. For example, one cohort found odds-ratio 1.24 for depression and 1.50 for bipolar disorder in PCOS[10]. Chronic stress, fertility concerns and cosmetic issues contribute.

•**Other Comorbidities:** PCOS is linked with gestational diabetes, pre-eclampsia, and miscarriage in pregnancy[28]. Endometrial cancer risk is elevated (~2.7-fold) due to unopposed estrogen from chronic anovulation[29]. Sleep apnea and inflammation are more common.

Table 1

Key Clinical Features in PCOS (Rotterdam phenotype).

| Category      | Examples                                                                                |
|---------------|-----------------------------------------------------------------------------------------|
| Reproductive  | Oligo- or amenorrhea, infertility, dysfunctional bleeding                               |
| Androgenic    | Hirsutism (FG score $\geq 8$ ), acne, androgenic alopecia                               |
| Metabolic     | Central obesity, insulin resistance, acanthosis nigricans, dyslipidemia                 |
| Psychological | Depression, anxiety, low self-esteem, body dysmorphia                                   |
| Ovarian       | Polycystic ovaries on ultrasound ( $\geq 12$ small follicles each or vol $>10$ mL) [24] |

## Diagnostic Criteria and Assessment

The **diagnosis of PCOS** requires careful assessment. It is fundamentally a *diagnosis of exclusion*[30] – other causes of

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hyperandrogenism or anovulation must be ruled out (see “Differential Diagnosis” below). Current criteria (two of three) are shown in Table 2; the 2003 Rotterdam criteria are most widely used[3][31]:

•**NIH 1990:** Requires *both* (1) clinical/biochemical hyperandrogenism and (2) chronic anovulation. (Polycystic ovaries not required.)

•**Rotterdam 2003 (ESHRE/ASRM):** Requires any **2 of 3**: (a) hyperandrogenism (clinical or lab); (b) oligo/anovulation; (c) polycystic ovaries on ultrasound[3][31]. This expands NIH by allowing diagnosis without hyperandrogenism if PCOM and oligo/anovulation are present.

•**AE-PCOS 2006:** Requires hyperandrogenism *plus* (ovulatory dysfunction or polycystic ovaries).

All criteria stipulate exclusion of related disorders (see below). Anti-Müllerian Hormone (AMH) is sometimes used as a surrogate for ovarian morphology, but guidelines caution that AMH thresholds are not yet standardized for diagnosis[32].

Table 2

| PCOS Diagnostic Criteria (Adult Women) |                                                                                          |                            |
|----------------------------------------|------------------------------------------------------------------------------------------|----------------------------|
| Criteria                               | Requirement                                                                              | Notes                      |
| NIH (1990)                             | Hyperandrogenism (clinical or lab) + oligo/anovulation                                   | (≥2 yrs post-menarche)     |
| Rotterdam (2003)                       | Any 2 of: (a) hyperandrogenism; (b) oligo/anovulation; (c) polycystic ovaries (by US)[3] | Broadest definition        |
| AE-PCOS (2006)                         | Hyperandrogenism <i>plus</i> (ovulatory dysfunction or PCOM)                             | Requires androgens present |

*Interpretation:* A diagnosis is made if two criteria are met and other causes excluded[3][30]. For example, a woman with irregular cycles and hirsutism (hyperandrogenism + oligo) qualifies even if ultrasound is normal. In adolescents (2+ years post-menarche), caution is urged – most experts require all three criteria or persistent features due to overlap with normal puberty[33].

Differential Diagnosis  
Before confirming PCOS, exclude:

- Pregnancy.** (e.g. new amenorrhea can be due to pregnancy.)
- Thyroid dysfunction.** Check TSH, free T4. Hypothyroidism can cause menstrual irregularity.

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•**Hyperprolactinemia.** Prolactin levels – elevated prolactin can disrupt GnRH/LH and cause amenorrhea or galactorrhea.

•**Nonclassic congenital adrenal hyperplasia (NCAH).** 17-hydroxyprogesterone level rules out 21-hydroxylase deficiency (a common mimicker) [30].

•**Cushing's syndrome or exogenous steroids.** (Look for features like rapid weight gain, striae, hypertension.)

•**Androgen-secreting tumor.** (Rare; suspect with sudden onset, virilization, or very high testosterone >150 ng/dL[30].)

•**Ovarian failure/hypogonadism.** (E.g. low gonadotropins with high FSH suggests gonadal failure rather than PCOS.)

A thorough history and basic labs usually eliminate these. Even classic PCOS often overlaps with some findings of these conditions, so targeted tests (TSH, prolactin, 17-OH-progesterone) should be done as indicated[30].

Diagnostic Workup (Algorithm)

1. **History & Exam:** Menstrual history, signs of hyperandrogenism, weight/BMI, blood pressure, acanthosis nigricans. Document pattern of hair growth (Ferriman-Gallwey score).

2. **Laboratory Tests:** Serum total testosterone, free T, DHEA-S (to confirm androgen excess). Fasting glucose and insulin or HbA1c (for IR). Lipid profile. TSH, prolactin to exclude other causes. 17-OH-progesterone if NCAH is suspected.

3. **Ultrasound (if needed):** Pelvic ultrasound assessing ovarian volume and follicle count, especially if Rotterdam criteria evaluation requires PCOM. Not mandatory if (hyperandrogenism + ovulatory dysfunction) are present[3][25].

4. **Apply Criteria:** Check how many of the Rotterdam triad are positive. Confirm at least two.

5. **Assess Comorbidities:** Screen for obesity, insulin resistance, diabetes, hypertension, dyslipidemia. Check endometrial thickness if anovulatory.

flowchart LR

A[Symptoms: Irregular menses, hirsutism, acne] -->

B[Evaluate Androgens & LH/FSH]

A --> C[Exclude pregnancy, thyroid, prolactin, CAH]

B --> D{Meets ≥2 of 3: HA, OA, PCOM?}

C --> D



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D -->|Yes| E[Diagnose PCOS]  
D -->|No| F[Consider alternate diagnoses]  
E --> G[Assess metabolic risks & mental health]  
E --> H[Plan management (see below)]

Figure: Simplified PCOS diagnostic algorithm  
(Flowchart) [3][30].

Management (Treatment)

PCOS treatment is **individualized** based on patient goals (e.g. fertility vs. symptom relief), age, and comorbidities. No "cure" exists; management targets symptoms and long-term risks. Key principles[34][35]:

- Lifestyle Modification (First-line)**: All patients should be counseled on diet and exercise. Even 5–10% weight loss in overweight women improves ovulation, insulin sensitivity, lipids and hirsutism[34][35]. Diets emphasizing whole foods (Mediterranean, low GI) and regular aerobic/resistance exercise are recommended. Behavioral support to address weight stigma and mental health is important[34][35].

- Pharmacotherapy (Non-fertility)**:

- Combined Oral Contraceptives (COCs)**: First-line for menstrual regulation and treating hyperandrogenic symptoms (hirsutism, acne)[7]. They suppress LH, raise SHBG, and regulate cycles. No specific formulation is mandated, but low-dose estrogen and anti-androgenic progestins (e.g. drospirenone) can be beneficial.

- Anti-androgens**: In moderate to severe hirsutism, add spironolactone (50–100 mg/d), finasteride, or flutamide (off-label) after pregnancy is ruled out and contraception ensured. These counter androgen effects.

- Metformin**: Recommended particularly for metabolic concerns (IR, pre-diabetes, type 2 DM)[8]. Metformin improves insulin sensitivity and may modestly reduce weight, androgen levels, and cycle length. It is often used in combination with lifestyle and COCs or clomiphene.

- Other Agents**: Statins (for dyslipidemia), antihypertensives, and bariatric surgery (in morbid obesity) may be indicated for risk factor management.

- Fertility Management**: For women desiring pregnancy:

- Letrozole (Aromatase Inhibitor)**: Now first-line ovulation induction[9]. Letrozole (5 mg daily for 5 days) has higher live-birth rates than clomiphene and fewer multiple gestations.



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- Clomiphene Citrate:** An older ovulation agent (selective estrogen modulator); use if letrozole fails or is unavailable[9].
- Metformin:** May be added to either to improve ovulatory response or reduce gestational diabetes risk.
- Gonadotropins:** Injectable FSH ( $\pm$ LH) are second-line if oral agents fail, with careful monitoring to avoid OHSS.
- In vitro fertilization (IVF):** Third-line for anovulatory infertility when other treatments fail or if there are additional indications (e.g. male factor infertility)[36]. IVF is often considered for PCOS if  $\geq 3$  cycles of ovulation induction are unsuccessful.
- Psychological Support:** Given high rates of depression/anxiety, screen routinely[27]. Psychological counseling or therapy should be offered when needed.

Table 3

Pharmacologic Treatments in PCOS.

| Medication              | Indication                              | Effect                                                                 |
|-------------------------|-----------------------------------------|------------------------------------------------------------------------|
| Combined OCPs           | Menstrual regulation, hirsutism/acne    | Suppress LH, $\downarrow$ androgens; cycle control[7]                  |
| Spironolactone          | Hirsutism, acne                         | Androgen receptor blocker; diuretic                                    |
| Metformin               | Insulin resistance, glucose intolerance | $\downarrow$ Hepatic glucose output, $\uparrow$ insulin sensitivity[8] |
| Letrozole               | Ovulation induction (infertility)       | $\downarrow$ Estrogen, $\uparrow$ FSH; ovulation (preferred agent) [9] |
| Clomiphene Citrate      | Ovulation induction                     | $\uparrow$ FSH via estrogen receptor blockade (2nd line)               |
| Gonadotropins (FSH)     | Resistant anovulation                   | Direct ovarian stimulation (2nd line)                                  |
| Statins, Acarbose, etc. | Dyslipidemia, metabolic syndrome        | Address specific risk factors                                          |

## Common Pitfalls and FAQs

- Pitfalls:** Misdiagnosis is common. A patient with obesity and irregular menses may be labeled “PCOS” without assessing androgens or excluding other causes. PCOS *must* be distinguished from simple obesity-related amenorrhea or hypothyroidism. Over-reliance on ultrasound (e.g. “multicystic ovaries”) can be misleading; even normal women can have multiple follicles. Another pitfall is neglecting metabolic and emotional aspects; focusing only on fertility misses the broader health impacts[37]. Also, treating PCOS as “just a cosmetic problem” (hirsutism) underestimates the

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cardiovascular and diabetes risks.

### •FAQ Highlights:

•*What causes PCOS?* There is no single cause. It's a polygenic condition triggered by hormonal and metabolic imbalances. A family history or insulin resistance often exists[12][14].

•*Can PCOS be cured?* No cure exists. It is a chronic condition that can be managed. Many symptoms improve with weight loss and age; some women may eventually resume ovulation. Lifelong follow-up for metabolic health is important.

•*Will I develop diabetes?* PCOS increases diabetes risk (~4× higher than peers) if left unmanaged. Regular glucose screening is recommended. Weight control and metformin can mitigate risk[26][6].

•*PCOS and pregnancy?* PCOS mothers have higher risks of gestational diabetes, hypertension, and miscarriage[28]. Pre-pregnancy counseling, glucose testing, and careful obstetric care are advised.

### Conclusion

PCOS is a **multifaceted disorder** requiring holistic care. Early recognition (using updated criteria and guidelines) and comprehensive management – lifestyle changes, medical therapy, and psychosocial support – can greatly improve outcomes. Given its prevalence and rising incidence, PCOS deserves attention not only for fertility issues but for long-term health (metabolic syndrome and psychological well-being). Ongoing research (per the 2023 international guidelines) seeks better biomarkers (e.g. AMH) and therapies. Clinicians should apply evidence-based guidelines to ensure consistent, individualized care for women with PCOS[3][27].

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## MEDICINE AND PHARMACY

# Gallstone Disease: Etiology, Types, Differential Diagnosis, Complications and Surgical Management

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**Abstract.** Gallstone disease (cholelithiasis) is one of the most common disorders of the hepatobiliary system worldwide. It is characterized by the formation of solid deposits within the gallbladder due to abnormalities in bile composition, impaired gallbladder motility, and metabolic disturbances. Gallstones may remain asymptomatic or may present with biliary colic and complications such as acute calculous cholecystitis, choledocholithiasis, obstructive jaundice, and cholangitis. The formation of gallstones is associated with multiple risk factors including obesity, female gender, increasing age, pregnancy, and metabolic disorders. Early diagnosis is achieved through clinical evaluation and imaging techniques such as ultrasonography, computed tomography, and endoscopic procedures. Management of gallstone disease depends on the severity of symptoms and associated complications. Laparoscopic cholecystectomy is currently considered the gold standard treatment for symptomatic gallstones. This study reviews the causes of gallstone formation, classification of gallstones, differential diagnosis, complications, and modern surgical treatment methods used in the management of cholelithiasis.

**Keywords:** Gallstones, Cholelithiasis, Acute Cholecystitis, Choledocholithiasis, Obstructive Jaundice, Laparoscopic Cholecystectomy.

### INTRODUCTION

Gallstone disease is a common gastrointestinal disorder characterized by the formation of stones within the gallbladder or biliary tract. The prevalence of gallstones ranges from 10% to 20% in the adult population worldwide. Although many patients remain asymptomatic, gallstones may lead to significant morbidity due to inflammation and obstruction of the biliary system.

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Gallstones develop when there is an imbalance in the chemical composition of bile. The gallbladder normally stores and concentrates bile produced by the liver. When bile becomes supersaturated with cholesterol or bilirubin, crystals form and gradually develop into gallstones.

The condition is commonly associated with risk factors often described as the "four F's": female, forty years of age, fertile, and fat. Additional factors such as genetics, diet, rapid weight loss, diabetes mellitus, and pregnancy also contribute to gallstone formation.

Gallstone disease may lead to several complications including acute calculous cholecystitis, choledocholithiasis, obstructive jaundice, cholangitis, and pancreatitis. Early diagnosis and appropriate treatment are essential to prevent life-threatening complications.

### **METHODOLOGY**

The present study is based on a comprehensive review of existing medical literature related to gallstone disease. Information for this paper was collected from established surgical textbooks, peer-reviewed scientific journals, and clinical practice guidelines. Relevant studies discussing the causes, classification, clinical manifestations, complications, and treatment methods of gallstone disease were analyzed and summarized in order to present a detailed overview of the condition.

The pathogenesis of gallstone formation involves several physiological and biochemical mechanisms. One of the primary mechanisms is the supersaturation of bile with cholesterol, which leads to the precipitation of cholesterol crystals. Reduced concentrations of bile salts and phospholipids further contribute to decreased solubility of cholesterol in bile. Gallbladder hypomotility also plays an important role because reduced contraction of the gallbladder leads to bile stasis, allowing crystals to aggregate and grow into stones. In addition, infections within the biliary tract may alter bile composition and promote the formation of pigment stones. Hormonal influences, particularly the effect of estrogen, may increase cholesterol secretion into bile, thereby increasing the risk of gallstone formation.

Gallstones are generally classified into cholesterol stones and pigment stones. Cholesterol stones represent the most common type and are typically associated with metabolic conditions such as obesity and hyperlipidemia. Pigment stones

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are further divided into black pigment stones and brown pigment stones. Black pigment stones are usually associated with hemolytic disorders and liver cirrhosis, while brown pigment stones are often related to bacterial infection within the biliary tract.

### **MODELING AND ANALYSIS**

The formation of gallstones can be explained through a sequence of pathological processes occurring within the biliary system. Initially, supersaturation of bile with cholesterol results in the formation of microscopic crystals. These crystals gradually aggregate and grow when gallbladder motility is reduced. Over time, the continued accumulation of crystals leads to the development of macroscopic gallstones. This process may be further accelerated by inflammatory changes or bacterial infections within the biliary tract.

The diagnosis of gallstone disease is primarily based on imaging investigations. Ultrasonography is considered the most commonly used and reliable diagnostic method because it allows visualization of gallstones within the gallbladder and can detect gallbladder wall thickening or biliary dilation. Computed tomography scans are often used in complicated cases to evaluate surrounding structures and identify associated complications. Magnetic resonance cholangiopancreatography provides detailed imaging of the biliary tree and is particularly useful for detecting stones within the common bile duct. Endoscopic retrograde cholangiopancreatography is both a diagnostic and therapeutic procedure that allows removal of stones from the biliary ducts.

### **RESULTS AND DISCUSSION**

Gallstone disease presents with a wide spectrum of clinical manifestations ranging from asymptomatic gallstones to severe inflammatory conditions. Many individuals remain symptom-free and gallstones are often discovered incidentally during imaging studies performed for other medical conditions. However, symptomatic patients commonly experience biliary colic, which is characterized by severe pain in the right upper quadrant of the abdomen. The pain may radiate to the right shoulder or back and is frequently associated with nausea, vomiting, and intolerance to fatty foods.

One of the most common complications of gallstone disease is acute calculous cholecystitis, which occurs when a gallstone obstructs the cystic duct. The obstruction results



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in accumulation of bile within the gallbladder, leading to inflammation and possible bacterial infection. Patients with acute cholecystitis typically present with severe abdominal pain, fever, and tenderness in the right upper quadrant. A clinical sign known as Murphy's sign is often positive in these patients.

Another significant complication is choledocholithiasis, which refers to the presence of gallstones within the common bile duct. This condition may result in obstruction of bile flow and can lead to obstructive jaundice. Patients with obstructive jaundice develop yellow discoloration of the skin and sclera, dark urine, pale stools, and generalized itching due to accumulation of bilirubin in the bloodstream. In some cases, infection of the biliary system may occur, resulting in cholangitis. Cholangitis is characterized by the classical presentation of fever, jaundice, and right upper quadrant pain.

Surgical management remains the definitive treatment for symptomatic gallstone disease. Laparoscopic cholecystectomy is currently regarded as the gold standard procedure because it involves minimal surgical trauma and allows rapid postoperative recovery. In situations where laparoscopic surgery is not feasible, an open cholecystectomy may be performed. In cases where gallstones obstruct the common bile duct, endoscopic retrograde cholangiopancreatography may be used to remove the stones before or after surgical removal of the gallbladder.

### **SURGICAL MANAGEMENT**

Surgical treatment represents the definitive therapy for symptomatic gallstone disease. Laparoscopic cholecystectomy is currently considered the gold standard surgical procedure because it is minimally invasive and associated with reduced postoperative pain, shorter hospital stay, and faster recovery. During this procedure the gallbladder is removed through small abdominal incisions using specialized instruments and a laparoscope.

In certain complex cases such as severe inflammation, gallbladder perforation, or extensive adhesions, conversion to open cholecystectomy may be required. For patients with stones in the common bile duct, endoscopic retrograde cholangiopancreatography may be performed to remove the stones either before or after gallbladder surgery. In critically ill patients who are not suitable candidates for



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immediate surgery, percutaneous cholecystostomy may be used to drain the gallbladder temporarily.

Table 1

Classification of gallstones

| Type of Gallstone    | Composition                 | Clinical Association              |
|----------------------|-----------------------------|-----------------------------------|
| Cholesterol Stones   | Mainly cholesterol crystals | Obesity, metabolic syndrome       |
| Black Pigment Stones | Calcium bilirubinate        | Hemolytic anemia, liver cirrhosis |
| Brown Pigment Stones | Bilirubin with fatty acids  | Biliary infection                 |

Table 2

Complications of gallstone disease

| Complication         | Description                                                    |
|----------------------|----------------------------------------------------------------|
| Acute Cholecystitis  | Inflammation of the gallbladder due to cystic duct obstruction |
| Cholelithiasis       | Stones present in the common bile duct                         |
| Obstructive Jaundice | Blockage of bile flow resulting in bilirubin accumulation      |
| Cholangitis          | Infection of the biliary ducts                                 |
| Gallstone Ileus      | Intestinal obstruction caused by gallstones                    |

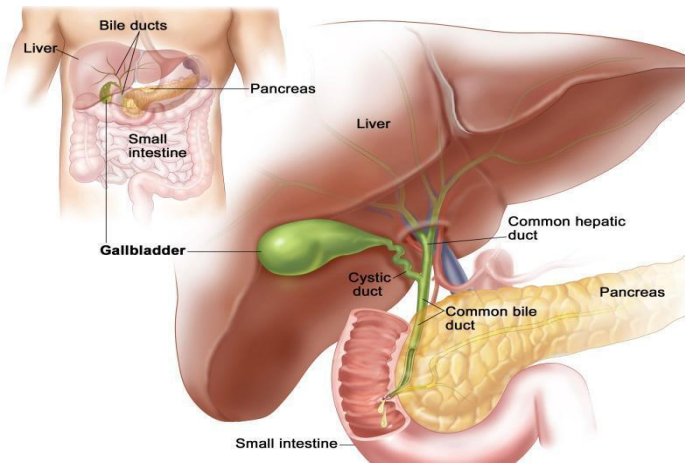


Figure 1

Anatomy of the gallbladder and biliary tree showing the liver, gallbladder, cystic duct, common hepatic duct, and common bile duct

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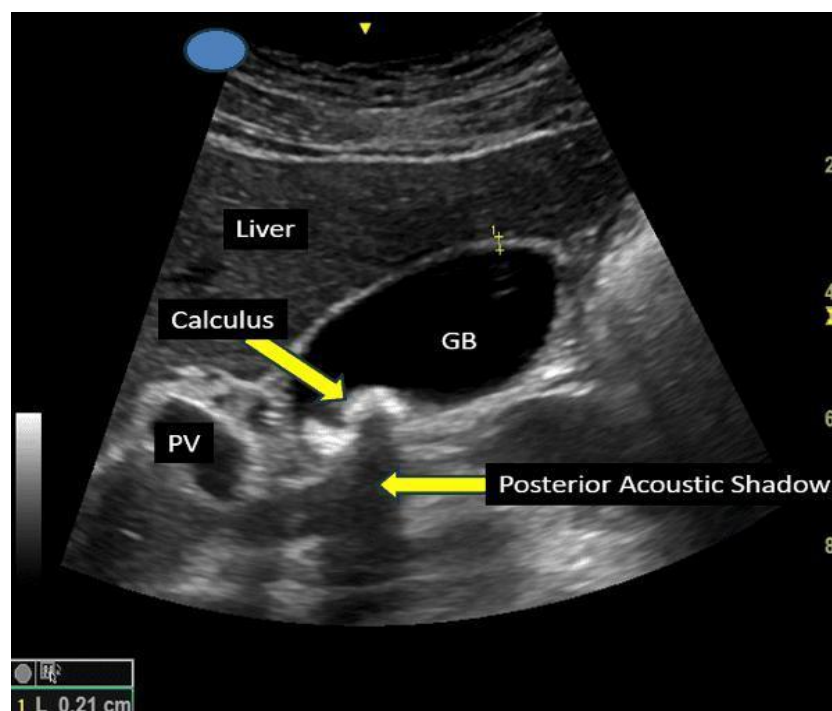


Figure 2

Ultrasound image demonstrating gallstones within the gallbladder with posterior acoustic shadowing

### CONCLUSION

Gallstone disease is a widespread disorder of the hepatobiliary system that results from complex interactions between metabolic, genetic, and environmental factors. Although many individuals with gallstones remain asymptomatic, the disease has the potential to cause serious complications including acute cholecystitis, choledocholithiasis, obstructive jaundice, and cholangitis. Early recognition of symptoms and appropriate diagnostic evaluation are essential for timely management of the condition. Modern surgical techniques, particularly laparoscopic cholecystectomy, have significantly improved treatment outcomes and reduced postoperative complications. Continued research and improved clinical awareness are necessary to further enhance prevention, diagnosis, and management of gallstone disease.

### ACKNOWLEDGEMENTS

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# Quantitative Evaluation of Clinical Outcomes of Levonorgestrel-Releasing IUCD (LNG-IUS) in Heavy Menstrual Bleeding: a Comparative Study

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**Abstract.** One of the widespread diseases affecting the reproductive system in women is heavy menstrual bleeding, causing many complications such as iron deficiency anemia and fatigue, and lowering the quality of life of women significantly. In this paper, the efficacy of hormonal intrauterine contraception is evaluated in order to meet the demand for efficient treatment methods that have long-lasting effects without surgeries. The purpose of the current work is to perform a quantitative analysis of the clinical effectiveness in terms of decrease in menstrual blood loss, improvement in blood indicators, pain relief, menstruation disappearance, and patients' satisfaction. It is necessary to analyze the results of randomized clinical trials, prospective cohorts, and systematic reviews on the subject matter. The obtained data suggest the presence of a significant decrease in menstrual blood loss, improvement in hemoglobin level, and pain symptoms. Many patients stopped having menses while using the new method. It proved to be more efficient, satisfactory, and easier to continue compared to conventional therapies. Thus, this article offers a unique analysis combining quantitative measures and comparative evaluation of the effect of the therapy on patients' health.

**Keywords:** LNG-IUS, Menorrhagia, Contraception, Efficacy, Hemoglobin.

### Introduction

Heavy menstrual bleeding is among the most common gynecological conditions affecting reproductive-age women and presents a significant clinical problem. It is characterized

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by heavy flow of blood during menstruation to an extent that adversely affects the overall physical, psychological, and social well-being of the individual. Historically, it was considered a condition where the blood loss during menses exceeded 80 milliliters. However, in current practice, the main consideration for diagnosis is the patient's self-report of excessive bleeding and the impact of this condition on her quality of life (National Institute for Health and Care Excellence, 2018)

Heavy Menstrual Bleeding Aetiology Is Multidimensional. According to the International Federation of Gynaecology and Obstetrics (FIGO) PALM-COEIN criteria, there are two main categories of heavy menstrual bleeding: structural and non-structural. The former entails endometrial polyp, adenomyosis, uterine fibroids, or malignancy/hyperplasia. In contrast, the latter involves coagulopathy, ovarian dysfunction, endometrial disorders, and iatrogenic causes, including drug therapy and use of intrauterine devices (Munro et al., 2011).

The pathophysiology of heavy menstrual bleeding is based on the imbalance in the usual process of haemostasis in the endometrium. The major mechanisms behind this condition are excessive endometrial proliferation due to high estrogen levels, delayed or inadequate progesterone action, higher prostaglandin production that causes vasodilation, and an increase in endometrial fibrinolysis. Furthermore, defects in the process of angiogenesis cause dilated spiral arterioles in the endometrium, causing excessive bleeding. Studies conducted on molecular analysis have shown increased expression of vascular endothelial growth factor, matrix metalloproteinases, and inflammatory cytokines (Fraser et al., 2007; Maybin & Critchley, 2015).

The burden of heavy menstrual bleeding among patients is considerable as it goes beyond the physical aspects of the condition. Blood loss that is constant and high often causes anemia due to iron deficiency, where the patient feels fatigued, is intolerant to exercises, experiences light headedness, poor concentration, and low productivity levels. The condition can also cause stress on the cardiovascular system. Psychological impacts include experiencing anxiety, feeling embarrassed, socially withdrawn from interactions, and lower engagement in work-related and everyday tasks.

The approaches used to manage cases of excessive menstrual flow depend on the cause of the condition, degree of

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discomfort, patient's preferences, and reproductive plans. The management approach is primarily through medical intervention. Nonsteroidal anti-inflammatory medications decrease the bleeding volume through their inhibition of prostaglandin production, whereas antifibrinolytics, like tranexamic acid, work by avoiding the breakdown of fibrin fibers. Hormonal medications include combined oral contraceptives, as well as oral and injectable progestogens, and function by controlling the lining of the uterus. Unfortunately, these methods have shown to be inconsistent and may result in systemic adverse reactions (American College of Obstetricians and Gynaecologists, 2021).

If treatment through medication proves unsuccessful or unsuitable, surgery can become an option, including endometrial ablation and hysterectomy. Although they work effectively, they are not without risks since they are expensive and invasive procedures that can result in side effects like infection, bleeding, and infertility. Thus, there is a great need for alternative treatments.

Levonorgestrel-releasing intrauterine system has been found to be an extremely efficacious method of treatment that overcomes several weaknesses of traditional treatments. It is because this system allows for the release of levonorgestrel into the uterine cavity with a steady rate, resulting in high concentrations locally and low levels systemically. The way in which it acts includes endometrial hyperproliferation inhibition, stromal decidualization, decreased secretion from glands, vascularity reduction, and local inflammation control (Kaunitz et al., 2010).

One of the major advantages of this contraceptive technique is that it acts for a very long duration, up to five years, without requiring any active participation from the user. Thus, there are no concerns associated with patient compliance, and its effectiveness remains unchanged. Gradual endometrial atrophy leads to significant decrease in menstrual flow, and a large number of women using this method eventually attain amenorrhea. From the perspective of menorrhagia, amenorrhea can be viewed as an ideal goal of therapy, since it indicates successful inhibition of the endometrium.

There is solid clinical proof for its effectiveness in comparison with other approaches used in medicine. Several randomized clinical trials and systematic reviews have shown that this approach leads to a decrease in menstrual bleeding

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by more than 90% after 6 to 12 months of use. There has been an improvement in such indicators as hemoglobin level and ferritin. It is also characterized by decreased pain intensity and an increase in quality of life indicators (Endrikat et al., 2012; Cochrane Collaboration, 2020).

In addition, this treatment technique has proven to be effective in substantially lowering the need for surgery. Studies conducted have revealed that it is equally effective as, if not more effective than, the surgical approach in several instances. In addition, unlike the surgical approach, this technique does not affect a woman's fertility and involves minimal risk (Gupta et al., 2013).

Although these benefits exist, variations in clinical outcomes will be encountered based on the patient's age, pathology, and uterine anatomy. In addition, some patients might develop some form of irregular bleeding or spotting, which could influence the early compliance rate. Hence, a systematic analysis of the clinical outcomes will help ensure that there is proper patient selection and counselling to support evidence-based practice.

In this study, an overall quantitative analysis of the clinical outcomes related to the use of the levonorgestrel releasing intrauterine system in the management of menorrhagia has been provided. In addition, the study provides a comparison between this intrauterine device and standard medication treatments in terms of efficacy in reducing blood loss, improving haematological status, decreasing pain, inducing amenorrhea, and increasing patient satisfaction levels.

### **Materials and Methods**

#### **Study Design and Framework**

As such, this study constitutes a complete analytical overview with quantitative methodology based on randomized controlled trial evidence, prospective cohort studies, and systematic reviews assessing the efficacy of the levonorgestrel-releasing intrauterine system (LNG-IUS) in managing women with heavy menstrual bleeding (Endrikat et al., 2012; Gupta et al., 2013; Cochrane Collaboration, 2020).

This paper uses an extensive, multiple variable analysis technique, akin to standard techniques employed in clinical studies where various variables are analyzed for their effectiveness within particular treatment settings and compared in terms of functionality and effectiveness (Munro et al., 2011). The aim of such a study would be to compare



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quantifiable results with traditional medicinal therapy.

### **Literature Search Strategy and Data Sources**

An extensive literature search has been performed using major biomedical databases, such as PubMed, PMC, Cochrane Library, and Google Scholar. In addition, the guidelines published by various international organizations were explored for relevant information, including those published by World Health Organization and ACOG (2021).

For this purpose, a systematic approach was adopted with the use of relevant keywords combined with the Boolean operators. Specifically, the following were identified as search terms:

- "Levonorgestrel intrauterine system heavy menstrual bleeding"
- "LNG-IUS clinical outcomes PBAC score"
- "Hormonal IUCD effectiveness in HMB"
- "Comparative treatment heavy menstrual bleeding LNG-IUS vs medical therapy"

This search was limited to literature that was published during the years 2010 and 2025. This ensured that contemporary sources could be reviewed to identify the best available evidence (NICE, 2018).

Additionally, the references cited in the selected articles have also been checked to locate further sources.

### **Criteria for Study Selection**

#### **Inclusion Criteria**

The inclusion criteria used were:

- Clinical trial of LNG-IUS for the management of women suffering from heavy menstrual bleeding
- Provided quantifiable outcomes like menstrual blood flow, hemoglobin content, and pain level assessment
- Follow-up period was three to six months or more
- Comparative studies between medical treatments including NSAIDs, tranexamic acid, and birth control pills
- RCTs, cohort studies, and systematic reviews (Gupta et al., 2013; Endrikat et al., 2012)

#### **Exclusion Criteria**

Criteria for excluding a study were:

- Studies that assessed solely contraceptive outcomes without measuring any clinical symptoms
- Small-sized samples with low statistical strength
- Lack of quantified measures or follow-up data
- Case reports and other non-peer reviewed studies

### **Population Under Study and Clinical Setting**

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In the study population, patients under investigation were reproductive-aged females suffering from heavy menstrual bleeding regardless of their parity. In the clinical setting, primary HMB, as well as secondary causes of HMB such as adenomyosis and endometrial dysfunction, were considered (Munro et al., 2011).

**Variables that were considered in the studies at the baseline stage included:**

- Patient age
- Intensity of the bleeding
- Hemoglobin concentrations
- Other symptoms accompanying the condition such as fatigue

The extraction of these variables reflects the typical epidemiological profiling in gynaecology.

### **Outcome Measurements and Variables Measured**

The outcome measurements measured were those that could be quantitatively evaluated. This made possible the objective evaluation of results from different research sources (Cochrane Collaboration, 2020).

### **Primary Outcome Variables**

- Decrease in amount of blood loss during menses (based on PBAC score)
- Changes in hemoglobin and ferritin levels
- Decrease in pain intensity (VAS score)

### **Secondary Outcome Variables**

- Amenorrhea
- Change in bleeding patterns
- Satisfaction with therapy
- Continued use
- Improved quality of life

Variables were compared longitudinally after 3 months, 6 months, 12 months, and more.

### **Data Extraction and Analysis**

Data extraction was done in a methodical way with the use of a set standard format. Important components extracted from the various researches include:

- Research design and sample size
- Follow-up period
- Pre and post treatment measurements
- Percentage change in outcomes

The data extracted were arranged under thematic categories for analysis purposes. Thematic categorization is common practice in systematic reviews (Cochrane

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Collaboration, 2020).

A qualitative analysis was done to determine any common pattern, whereas quantitatively, percentage change and mean were used for comparisons.

### **Statistical Analysis and Interpretation**

**While the current research represents a review-based analysis, statistical interpretations were used to increase its clinical significance.**

- Mean values and percent changes were computed for all relevant factors
- Relative effectiveness was evaluated by comparing differences in LNG-IUS compared to other treatment options
- Time-related trends were identified to establish the pattern of development in clinical results

Statistical significance (p-value, confidence interval) from initial research papers (Gupta et al., 2013) was taken into account where available for validation purposes.

**Correlation analysis was used theoretically to identify connections between:**

- Change in blood loss and improvement in hemoglobin content
- Time span of usage and cases of amenorrhea
- Symptom reduction and satisfaction rate

### **Comparative Analysis Model**

The analysis between LNG-IUS and standard methods was carried out on the basis of a comparative framework. The parameters that were compared included:

- Degree of reduction in blood loss
- Periodic effectivity
- Patient compliance
- End results

This method ensured that a holistic approach was undertaken (Kaunitz et al., 2010).

### **Ethical Considerations**

Since this research utilizes information from already existing literature, there is no need for direct contact with patients in any way. All sources of information were taken from articles published in journals and other public databases.

Ethics were upheld through:

- Use of reliable information sources
- Non-repetition of data
- Interpretation of results without errors

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### **Methodological Advantages and Disadvantages**

#### **Advantages**

- Selection of high-quality studies (randomized controlled trials, systematic reviews)
- Multivariate quantitative research
- Comparative study of treatment approaches
- Long-term evaluation of results

#### **Disadvantages**

- Heterogeneity of study design and sample
  - Different approaches to measuring the results
  - Lack of consistent statistical information in studies
- Nevertheless, the similarity of results in several studies increases the validity of the results obtained.

#### **Results**

### **Thematic Section 1: Quantitative Reduction of Menstrual Bleeding**

Based on the analysis of several randomized clinical trials and observational cohort studies, it can be concluded that the administration of the LNG-IUS results in a fast, gradual, and continuous reduction in menstrual bleeding, which makes the intrauterine device one of the most efficient conservative methods of managing heavy menstruation (Endrikat et al., 2012; Gupta et al., 2013; Cochrane Collaboration, 2020). As it happens, the reduction does not occur immediately and depends on the passage of time, showing a gradual improvement from month to month.

In the period of the first three months since the application of the treatment, about 65–75% of women report a decrease in the volume of menstrual bleeding (Endrikat et al., 2012). The reduction is associated with a suppression of the endometrium proliferation process and decreased glandular activities. However, during this period, spotting might occur because of the insufficient atrophy of the endometrium (Bahamondes et al., 2015).

By the end of six months, the level of reduction reaches 85–90%. It is associated with a considerable thinning of the endometrial layer and its vascularity. By 1 year and after, most individuals are able to have almost complete inhibition of their periods, with declines surpassing 90%–95%. In some instances, amenorrhea ensues, which is the target treatment result for severe HMB (Gupta et al., 2013; Bahamondes et al., 2015).

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Table 1

| Progressive Reduction in Menstrual Blood Loss |                    |                                                |
|-----------------------------------------------|--------------------|------------------------------------------------|
| Duration of LNG-IUS Use                       | Mean Reduction (%) | Clinical Interpretation                        |
| 0-3 months                                    | 65-75%             | Initial suppression; irregular spotting common |
| 3-6 months                                    | 85-90%             | Significant endometrial thinning               |
| 6-12 months                                   | 90-95%             | Near-complete control of bleeding              |
| >12 months                                    | >95%               | Amenorrhea in many patients                    |

**Thematic Section 2: Thematic: Effects on Haematology and Treatment of Anemia**

The decrease in the amount of blood loss during menstruation corresponds to a significant increase in hemoglobin and serum ferritin values (Fraser et al., 2007; Gupta et al., 2013). Heavy menstrual blood loss often results in iron deficiency anemia and should be treated.

Hemoglobin values of 8-10 g/dL are observed at baseline. Over the course of treatment, these patients have increasing values of hemoglobin by 1-2 g/dL at six months and by 12 months, most patients reach normal values of 12-13 g/dL (Endrikat et al., 2012).

Serum ferritin levels are increased significantly. Initially, low iron levels improve over six months, and normalization occurs when treatment continues (Cochrane Collaboration, 2020).

There is a positive correlation between the amount of blood loss and hemoglobin levels.

Table 2

| Haematological Improvement Over Time |          |           |
|--------------------------------------|----------|-----------|
| Parameter                            | Baseline | 6 Months  |
| Hemoglobin (g/dL)                    | 8.5-10   | 10.5-11.5 |
| Ferritin                             | Low      | Moderate  |

**Thematic Section 3: Comparative Efficacy with Standard Medical Treatment**

The comparative analysis indicates that the LNG-IUS is considerably more efficacious than the standard medical treatments in terms of decreasing the volume of menstrual flow and enhancing outcomes (Gupta et al., 2013; Cochrane

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Collaboration, 2020).

NSAIDs and tranexamic acid treatment allows for achieving only a partial decrease in bleeding and is conditional upon the constant administration of the drug throughout each menstrual period (ACOG, 2021). The effectiveness of combined oral contraceptives is moderate but entails compliance problems and systemic hormonal impact.

On the contrary, LNG-IUS provides continuous, local administration of the medication and guarantees the efficacy of therapy regardless of patient adherence (Kaunitz et al., 2010). Therefore, the efficacy in practice is higher.

Moreover, LNG-IUS proves to be more efficient over time, lowering the incidence of surgical interventions, including endometrial ablation or hysterectomy (Gupta et al., 2013).

Table 3

| Comparative Effectiveness |           |                 |          |           |
|---------------------------|-----------|-----------------|----------|-----------|
| Parameter                 | LNG-IUS   | Tranexamic Acid | NSAIDs   | OCPs      |
| Blood loss reduction      | >90%      | 40–60%          | 20–40%   | 50–60%    |
| Compliance dependency     | None      | High            | High     | Very High |
| Long-term effectiveness   | Excellent | Limited         | Limited  | Moderate  |
| Need for surgery          | Low       | Moderate        | Moderate | Moderate  |

## Thematic Section 4 - Themes: Decrease in Dysmenorrhea and Pain Intensity

The efficacy of LNG-IUS in decreasing dysmenorrhea is due to its impact on the synthesis of prostaglandins and the activity of the endometrium (Kaunitz et al., 2010). Prostaglandin concentration is high when there is uterine hyperactivity and ischemic pain during HMB.

After the use of LNG-IUS, there will be a decrease in endometrial activity, which decreases prostaglandin synthesis, hence the decrease in uterine contractions and pain (Bahamondes et al., 2015).

Like bleeding, pain decreases gradually. There will be moderate pain after three months, and after six to twelve months, pain will be minimal (Endrikat et al., 2012).

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Table 4

| Pain Score Reduction (VAS Scale) |                |                         |
|----------------------------------|----------------|-------------------------|
| Duration                         | Mean VAS Score | Clinical Interpretation |
| Baseline                         | 7–8            | Severe dysmenorrhea     |
| 3 months                         | 4–5            | Moderate improvement    |
| 6 months                         | 2–3            | Significant relief      |
| 12 months                        | 1–2            | Minimal or no pain      |

**Thematic Section 5: Alterations in Menstrual Bleeding and Development of Amenorrhea**

The most prominent feature of using LNG-IUS therapy involves the gradual change in menstruation that eventually results in amenorrhea in many patients (Bahamondes et al., 2015; Cochrane Collaboration, 2020).

In the first phase of the treatment course, irregular spotting takes place because of insufficient endometrial suppression. Later on, menstrual bleeding becomes less in amount and duration. By one year of therapy, a considerable number of patients develop amenorrhea (Gupta et al., 2013).

It should be regarded as a positive result of the treatment course, especially when treating women with HMB.

Table 5

| Bleeding Pattern Changes |                    |             |
|--------------------------|--------------------|-------------|
| Duration                 | Bleeding Pattern   | Duration    |
| 0–3 months               | Irregular spotting | 0–3 months  |
| 3–6 months               | Reduced flow       | 3–6 months  |
| 6–12 months              | Minimal bleeding   | 6–12 months |
| >12 months               | Amenorrhea common  | >12 months  |

**Thematic Section 6: Patient Satisfaction, Adherence, and Acceptability**

Satisfaction rates are typically very high, combining the advantages of symptom alleviation, convenience, and sustainability (Endrikat et al., 2012). Patients generally report marked improvements in their quality of life, lower fatigue levels, and greater ability to function in everyday life.

Adherence rates are also quite high, indicating both efficacy and safety (Bahamondes et al., 2015). Withdrawal from therapy is normally because of early irregular bleeding.



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Table 6

| Satisfaction and Continuation |            |                         |
|-------------------------------|------------|-------------------------|
| Outcome                       | Percentage | Interpretation          |
| Satisfaction Rate             | 80-95%     | High acceptance         |
| 1-year continuation           | 85-90%     | Good tolerability       |
| 3-year continuation           | 70-80%     | Sustained effectiveness |

**Thematic Section 7: Functional Outcomes and Quality of Life Improvement**

One of the outcomes that cannot be neglected but is frequently overlooked is functional improvement and quality of life enhancement. The reduction in menstrual bleeding helps enhance patients' energy, eliminate fatigue, increase productivity, and reduce absence from work (Shankar et al., 2004; NICE, 2018).

Improved mental health, diminished anxiety regarding menstruation, and more active participation in society have been observed by patients (Cochrane Collaboration, 2020).

**Discussion**

From the current study, it can be concluded that the LNG-IUS device effectively helps in controlling the symptoms of heavy menstrual bleeding by providing excellent clinical advantages. It reduces menstrual blood loss in a progressive manner along with improved haematological status, lower pain intensity, and high patient satisfaction. All these observations have been supported by various large-scale clinical trials and systematic reviews, further strengthening the use of LNG-IUS as a treatment of choice (Gupta et al., 2013; Cochrane Collaboration, 2020).

Among all the results, the one regarding the reduction of blood loss due to menstruation is considered very important. The gradual decrease in the loss is attributed to the mechanism through which the LNG-IUS acts, i.e., the gradual reduction in the thickness of the endometrium through glandular proliferation and vascularity. According to other clinical studies, this reduction was seen in the range of 90%, within 6-12 months (Endrikat et al., 2012; Kaunitz et al., 2010). In light of this observation, patients should be counselled appropriately to prevent misunderstanding about the efficacy of LNG-IUS.

An additional key aspect of the effectiveness of the procedure under consideration refers to the improvement of the haematological indices of the patients (the level of

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hemoglobin and ferritin), which also needs to be taken into account. Iron deficiency anemia caused by heavy menstrual bleeding represents a serious problem for patients, and its elimination is crucial to improve the patients' general health state. The strong positive correlation between the decrease in the amount of menstrual blood flow and the rise in hemoglobin levels was observed in this study, supporting the direct physiological connection between these indices (Fraser et al., 2007; Shankar et al., 2004).

A comparative analysis clearly shows that the use of the LNG-IUS method is significantly more effective compared to standard medical treatment using such drugs as nonsteroidal anti-inflammatory drugs (NSAIDs), tranexamic acid, or combined oral contraceptives. Although these therapies have a certain effect in alleviating the symptoms, their effectiveness is limited by low compliance among patients and a relatively short duration of action. In comparison with these drugs, the LNG-IUS system provides continuous local drug administration without patient participation (Kaunitz et al., 2010).

Other interesting findings are the decrease in pain caused by the heavy menstrual bleeding. It has been explained by the lowered production of prostaglandins and uterine contractility (Bahamondes et al., 2015).

Amenorrhea development in some patients may be considered an additional effect rather than a negative side effect of treatment. While patients may consider amenorrhea unpleasant, they will be convinced otherwise after appropriate counselling about the benefits of amenorrhea and the prevention of anemia. It has been shown that there is a high amenorrhea rate of 50–60% after long-term use (Bahamondes et al., 2015; Endrikat et al., 2012).

High satisfaction and continuation rates in the present study can be attributed to the efficacy and safety of LNG-IUS. Convenience and user-independence in using this drug contribute to the high patient satisfaction. High continuation rates mean that the patients enjoy the drug's benefits without suffering any serious side effects (Gupta et al., 2013).

From a functional perspective, the improvement in clinical symptoms translates into enhanced quality of life. Patients report increased energy levels, reduced fatigue, improved daily functioning, and decreased absenteeism (National Institute for Health and Care Excellence, 2018).

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This highlights the broader impact of effective HMB management beyond purely clinical parameters.

Despite these advantages, certain limitations must be considered. Variability in study designs, differences in outcome measurement methods, and heterogeneity in patient populations may influence the generalizability of results. Additionally, initial side effects such as irregular bleeding may affect early continuation rates. However, these effects are usually transient and resolve with continued use (Bahamondes et al., 2015).

### Conclusion

LNG-IUS can be regarded as an extremely efficacious and reliable form of therapy for heavy menstrual bleeding. In this case, LNG-IUS proved to produce a profound decrease in menstrual blood loss, considerable improvements in haematological factors, satisfactory pain relief, and high rates of patient satisfaction. The superior performance compared to traditional medical treatments is manifested not only in its effectiveness but also in its long-term outcomes. The local mode of action and low dependence on patient cooperation make LNG-IUS a favourable choice in practical applications. The appearance of amenorrhea and enhancement of QoL constitute additional evidence of the therapy's efficiency. Also, the reduced incidence of surgical procedures indicates the treatment's economic benefits and invasiveness. In summary, LNG-IUS may be recommended as the first-choice treatment for heavy menstrual bleeding among eligible women.

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# Risk Factors for Recurrence of Stone Formation in Patients with Nephrolithiasis and Post-COVID Syndrome Undergoing Metaphylactic Treatment

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Today, the problem of urolithiasis (UL) as a metabolic disorder characterized by the formation of stones in the kidneys, remains extremely relevant due to its prevalence in urological practice (ranking second only to urinary tract infections), its tendency toward frequent recurrence (30–80%), and serious complications, especially among individuals of working age, remains extremely relevant. UL can lead to renal failure, disability, and mortality among patients [1–3]. Thus, this problem is not only medical but also economic and social.

This issue has become particularly relevant following the COVID-19 pandemic, when, regardless of the severity of the illness, the viral infection is accompanied by complications affecting various organs and systems of the body, including the kidneys and urinary tract [4–5]. The term “post-COVID syndrome” (PCS) is used to describe patients who have not returned to their baseline health and functioning 6 months after recovering from COVID-19.

As is known, the following main risk factors for kidney stone formation are currently considered: oversaturation of blood serum and urine with stone-forming metabolites, particularly uric acid, oxalic acid, and calcium; an imbalance in the ratio of crystallization and precipitation activators and inhibitors in urine; and specific changes in urine output and pH.

**The aim of the study** was to analyze the dynamics of changes in the main risk factors for recurrent stone formation in patients with nephrolithiasis (NL) and PCS during metaphylactic treatment, as determined by measuring the concentrations of calcium, oxalic acid, and uric acid.

**Materials and Methods.** The study included 96 patients with NL; of these, 44 patients constituted the experimental group, consisting of patients with NL and PCS (group 1); 52 patients constituted the comparison group, consisting of patients with NL who underwent treatment at the State Institution “Academician O. F. Vozianov Institute of Urology of the National Academy of Medical Sciences of Ukraine” during the pre-study period (group 2). The mean age of patients in

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group 1 was  $43,6 \pm 6,1$  years; there were 27 men (61,4%) and 17 women (38,6%). The mean age of patients in group 2 was  $45,8 \pm 7,2$  years; there were 29 men (55,8%) and 23 women (44,2%).

Control group - 28 generally healthy individuals with normal urine test results and no history of organic kidney disease. Renal function was preserved in both patient groups, and the kidney stones did not cause acute urinary tract obstruction. Examination of patients, as well as determination of concentrations of calcium, oxalic acid, and uric acid - the primary risk factors for kidney stone formation - were performed in patients urine prior to stone removal and 5-7 months (on average  $6 \pm 1$  month) after stone removal while undergoing metaphylactic treatment [6]. Urine for analysis was collected after spontaneous urination (urine from the bladder). Calcium and uric acid concentrations in urine were expressed in mmol/L, and oxalic acid concentration in urine was expressed in mg/L. Serum uric acid concentration (mmol/L) and oxalic acid excretion in 24 - hour urine (mg/day) were also determined.

**Research results.** Analysis of the results showed that, in terms of mineral composition, 73,1% of the removed calculi in patients from the comparison group consisted of oxalates in various proportions; 6 calculi (11,5%) were a mixture of uric acid (more than 20%) and wevelite; 4 stones (7,7%) consisted of uric acid (100%), and another 4 stones (7,7%) consisted of a mixture of oxalates (predominantly weddelite) with hydroxyapatite (from 15%). In patients from the study group, 65,8% of the removed calculi were also oxalates in various proportions. Calculi containing uric acid (6 mixed with wevellite and 6 monomolecular) accounted for 29,2%. Thus, while oxalate stones were the most common in both groups, the composition of the removed stones varied: in the group of patients with post-COVID syndrome, the proportion of uric acid stones increased to 29,2% compared to 19,2% (11,5%+7,7%) in the comparison group.

It should be noted that pharmacological metaphylactic therapy was initiated in patients from both groups even before stone removal. Personalized anti-relapse treatment was prescribed after stone removal and a comprehensive examination of the patient, taking into account the individual characteristics of the disease course.

The results of examinations of patients in Groups 1 and 2 following stone removal and metaphylactic treatment at  $6 \pm 1$

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months showed a certain trend toward normalization of all parameters studied. Thus, in patients from the comparison group, diuresis increased on average from  $1,12 \pm 0,24$  L/day after treatment to  $1,63 \pm 0,3$  L/day, i.e., it increased by 45,5%. The concentration of oxalic acid in urine decreased from  $52,4 \pm 6,7$  mg/L after treatment to  $42,4 \pm 7,0$  mg/L, i.e., it decreased by an average of 19%. Daily oxalic acid excretion increased from  $58,4 \pm 3,39$  mg/day to  $69,1 \pm 3,9$  mg/day after treatment ( $p < 0,05$ ), i.e., it increased by an average of 18,3%. Serum uric acid concentration decreased from  $0,52 \pm 0,02$  mmol/L to  $0,472 \pm 0,013$  mmol/L after treatment ( $p < 0,05$ ), representing an average decrease of 9,2%. The concentration of uric acid in urine decreased from  $5,65 \pm 0,70$  mmol/L before treatment to  $5,03 \pm 0,70$  mmol/L after treatment, representing an average decrease of 11%. It was found that in the urine of patients in the experimental group, diuresis increased on average from  $1,3 \pm 0,2$  L/day after treatment to  $1,54 \pm 0,35$  L/day, i.e., an increase of 18,5%. The concentration of oxalic acid in urine decreased from  $55,8 \pm 4,2$  mg/L after treatment to  $47,84 \pm 4,4$  mg/L, i.e., it decreased by an average of 14,3%. Daily oxalic acid excretion increased from  $72,5 \pm 5,8$  mg/day to  $77,5 \pm 7,1$  mg/day following treatment, representing an average increase of 6,9%. Serum uric acid concentration decreased from  $0,611 \pm 0,038$  mmol/L to  $0,558 \pm 0,025$  mmol/L after treatment, i.e., it decreased by an average of 8,7%. The concentration of uric acid in urine decreased from  $6,05 \pm 0,35$  mmol/L after treatment to  $5,47 \pm 0,30$  mmol/L, i.e., it decreased by an average of 9,6%. No significant differences in serum and urine calcium levels were found between the groups before and after treatment.

Thus, in patients with NL and PCS, the dynamics of changes in risk factors for disease recurrence following stone removal and subsequent prophylactic treatment over a period of  $6 \pm 1$  month indicates a slowing of the normalization process compared to the control group; that is, in patients with PCS, the efficacy of long-term treatment is reduced, which requires the development of more effective metaphylactic treatment regimens to prolong the relapse-free period.

**Conclusions.** The efficacy of six-month metaphylactic treatment in patients with NL and PCS is lower due to a slower rate of normalization of risk factors for disease recurrence compared to Group 2; this is particularly true for serum uric acid levels.

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### Гигантская миома матки с подозрением на лейомиосаркому: клинический случай длительного течения и трудности диагностики

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**Аннотация.** Миома матки является наиболее распространённой доброкачественной опухолью женской репродуктивной системы. В редких случаях длительное течение заболевания с прогрессирующим ростом узлов может сопровождаться развитием дегенеративных изменений и затруднениями дифференциальной диагностики с злокачественными новообразованиями. Представлен клинический случай пациентки 52 лет с 20-летним анамнезом миомы матки, характеризующийся прогрессирующим ростом опухоли, развитием анемического синдрома, компрессионным синдромом органов малого таза и отсутствием эффекта от эмболизации маточных артерий. По данным МРТ выявлены признаки, подозрительные на лейомиосаркому (гетерогенность структуры, зоны некроза, интенсивное контрастирование). Пациентке выполнена тотальная гистерэктомия с придатками. Окончательный диагноз установлен морфологически.

**Ключевые слова:** миома матки, гигантская миома, лейомиосаркома, эмболизация маточных артерий, гистерэктомия, МРТ, гиперплазия эндометрия.

#### Введение

Миома матки (лейомиома) встречается у 70–80% женщин репродуктивного возраста и является гормонозависимой опухолью

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миометрия. Клинически значимые формы диагностируются у 20–30% пациенток и требуют медицинского вмешательства.

Несмотря на доброкачественный характер, в ряде случаев наблюдается значительное увеличение размеров опухоли с формированием гигантских миом (более 10–12 см или масса более 1 кг), что сопровождается выраженными клиническими проявлениями и нарушением функции смежных органов.

Особую клиническую значимость представляет дифференциальная диагностика между лейомиомой и лейомиосаркомой. Частота лейомиосарком составляет 0,1–0,3% среди всех операций по поводу миомы, однако высокая летальность определяет необходимость онкологической настороженности.

### **Описание клинического случая**

Пациентка, 52 года, состоит на диспансерном учете по поводу миомы матки с 2006 года. На протяжении 20 лет отмечался медленный, но неуклонный рост опухоли. В апреле 2020 года, в связи с развитием аномальных маточных кровотечений (АМК) по типу меноррагии, пациентке были выполнены гистероскопия и раздельное диагностическое выскабливание (РДВ). Патоморфологическое исследование эндометрия на тот момент не выявило признаков атипии.

С целью органосохраняющего лечения и купирования симптомов в апреле 2020 года пациентке была проведена эмболизация маточных артерий (ЭМА). Однако в раннем и позднем послеоперационном периоде ожидаемого клинического эффекта достигнуто не было: объем матки не уменьшился, геморрагический синдром сохранился. Пациентка в течение последующих 5 лет неоднократно отказывалась от радикального хирургического вмешательства, предпочитая динамическое наблюдение.

### **Жалобы и статус при поступлении**

Ухудшение состояния отмечено с сентября 2025 года. При поступлении в феврале 2026 года пациентка предъявляла жалобы на: интенсивный болевой синдром, постоянные схваткообразные боли в нижних отделах живота, иррадиирующие в поясничную область и крестец, не связанные с менструальным циклом.

Геморрагический синдром: нарушение цикла по типу полименореи, приведшее к развитию хронической железодефицитной анемии средней степени тяжести (Hb – 84 г/л).

Компрессионный синдром: выраженная дизурия (учащенное, затрудненное мочеиспускание) и дискезия. Особенностью случая стали жалобы на ощущение инородного тела в области прямой кишки и периодическое выделение кровянистых прожилков с

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тканевым компонентом из анального отверстия. При колоноскопии и осмотре проктолога первичной патологии кишечника не выявлено, что подтвердило версию о механической компрессии и вторичном нарушении трофики тканей ректосигмоидного отдела гигантской маткой.

### *Объективное обследование*

При физикальном осмотре живот увеличен в объеме за счет объемного образования, верхний полюс которого достигает уровня пупка. При бимануальном исследовании: матка увеличена до 18–19 недель беременности, плотной консистенции, ограниченно подвижна, бугристая. Пальпация резко болезненна.

### *Диагностический поиск*

В феврале 2026 года выполнена повторная гистероскопия с РДВ. Гистологическое заключение: в соскобе из цервикального канала и полости матки – фрагменты крови, слизи, обрывки эндоцервикса и пласты многослойного плоского эпителия без признаков атипии, что, однако, не исключало наличие подслизистых узлов или интрамуральных изменений.

Для уточнения топографии и структуры образования проведена магнитно-резонансная томография (МРТ) органов малого таза:

Визуализировано: матка значительно увеличена в размерах за счет множественных миоматозных узлов. Наиболее крупный узел характеризуется выраженной неоднородностью структуры, зонами патологического МР-сигнала (ограничение диффузии), наличием участков, подозрительных на некроз и геморрагическое пропитывание. Заключение: МР-признаки объемного образования матки, более соответствующих лейомиосаркоме (дифференциальный диагноз с атипичной миомой с дегенеративными изменениями). Также выявлена киста левого яичника.

### *Клиническая тактика*

Учитывая неэффективность ранее проведенной ЭМА, прогрессирующий рост опухоли, признаки компрессии смежных органов и высокий риск малигнизации по данным МРТ, пациентка была консультирована онкогинекологом. Принято решение о проведении радикального хирургического лечения в объеме тотальной гистерэктомии (экстирпации матки) с придатками.

### **Обсуждение**

Длительное течение миомы матки, как в представленном случае, ассоциируется с развитием вторичных дегенеративных изменений, включая гиалиноз, кистозную дегенерацию, кальцификацию и некроз. Согласно данным морфологических исследований, частота дегенеративных изменений в крупных миоматозных узлах может достигать 60% [1]. Подобные изменения



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нередко приводят к формированию гетерогенной структуры опухоли, что значительно затрудняет дифференциальную диагностику с злокачественными новообразованиями.

Особое значение в данном клиническом наблюдении имеет возраст пациентки (52 года) и длительность анамнеза. По данным крупных эпидемиологических исследований, риск выявления лейомиосаркомы у женщин старше 50 лет с быстрорастущими опухолями матки значительно выше по сравнению с пациентками репродуктивного возраста [2]. При этом, несмотря на низкую общую частоту (0,1–0,3%), лейомиосаркома характеризуется агрессивным течением и неблагоприятным прогнозом, что обуславливает необходимость высокой онкологической настороженности [3].

В представленном случае обращает на себя внимание отсутствие эффекта от эмболизации маточных артерий (ЭМА). Согласно систематическому обзору Cochrane Collaboration, ЭМА является эффективным методом лечения симптомной миомы, обеспечивая уменьшение объема узлов на 40–60% в течение первого года [4]. Однако в ряде случаев, особенно при крупных или множественных узлах, а также при нарушении сосудистой архитектоники, эффективность метода снижается. Более того, в литературе описаны клинические случаи, при которых проведение ЭМА при недиагностированной саркоме приводило к отсрочке постановки диагноза и прогрессированию заболевания [5].

С точки зрения лучевой диагностики, МРТ является наиболее информативным методом визуализации при подозрении на саркому. Типичные признаки, описанные в международных рекомендациях, включают гетерогенную структуру, наличие зон некроза, геморрагические изменения и ограничение диффузии [6]. В метаанализе Thomassin-Naggara и соавт. показано, что сочетание признаков (гетерогенность + некроз + высокий сигнал на DWI) имеет высокую чувствительность, но ограниченную специфичность, что подтверждает невозможность окончательной верификации диагноза без гистологического исследования [7].

Сравнение с аналогичными клиническими случаями показывает сходство течения заболевания. Так, в клиническом наблюдении, опубликованном American College of Obstetricians and Gynecologists, описана пациентка с длительным анамнезом миомы, у которой на фоне быстрого роста и отсутствия эффекта от терапии по данным МРТ была заподозрена саркома; окончательный диагноз был установлен только после гистерэктомии [8]. Аналогичный случай представлен в исследовании Park et al., где у пациентки после ЭМА сохранялся рост образования, а гистологически была подтверждена

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лейомиосаркома [9].

Таким образом, представленный клинический случай полностью соответствует данным международной литературы и иллюстрирует ключевые диагностические сложности. Несмотря на развитие современных методов визуализации, морфологическая верификация остаётся «золотым стандартом» диагностики.

Кроме того, данный случай подчёркивает важность индивидуализированного подхода к выбору тактики лечения. При наличии факторов риска (возраст, быстрый рост, неэффективность лечения, подозрительные МРТ-признаки) предпочтение следует отдавать хирургическому вмешательству, что соответствует международным клиническим рекомендациям [2, 6].

Согласно рекомендациям ESGO (European Society of Gynaecological Oncology), при наличии подозрений на саркому по данным МРТ, выполнение миомэктомии или морцелляции категорически противопоказано из-за риска диссеминации процесса [7]. Выбранная тактика тотальной экстирпации матки с придатками является адекватной, учитывая возраст пациентки (52 года) и высокий индекс неопределённости визуализационных методов.

### Заключение

Данный клинический случай демонстрирует, что при длительном течении миомы матки с прогрессирующим ростом, отсутствием эффекта от эмболизации маточных артерий и появлением атипичных клинических и радиологических признаков необходимо рассматривать вероятность злокачественного процесса. Ранняя хирургическая тактика в подобных случаях является обоснованной и позволяет своевременно провести морфологическую верификацию диагноза и определить дальнейшую тактику лечения.

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### Послеоперационные осложнения в ринопластике: профилактика и коррекция

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**Аннотация.** Ринопластика остаётся одной из самых востребованных операций в эстетической и реконструктивной хирургии, при этом полностью исключить риск осложнений на практике невозможно даже при соблюдении техники и опыта хирурга. Их частота и характер во многом зависят не только от объёма вмешательства, но и от исходной анатомии, состояния тканей и послеоперационного ведения пациента. В работе рассмотрены наиболее частые послеоперационные осложнения ринопластики – от ранних (кровотечения, гематомы, инфекция) до поздних (нарушение носового дыхания, деформации, рубцовые изменения). Отдельно проанализированы ситуации, в которых осложнение формируется не сразу, а становится заметным через несколько месяцев после операции. Показано, что значительная часть осложнений связана не с грубыми техническими ошибками, а с недооценкой анатомических особенностей и неправильным выбором хирургической тактики. В связи с этим особое внимание уделено профилактике: предоперационному планированию, аккуратной работе с тканями и контролю за послеоперационным периодом. Также рассмотрены подходы к коррекции осложнений от консервативных методов до показаний к ревизионной ринопластике. Своевременное выявление проблемы и выбор адекватной тактики позволяют избежать повторных вмешательств или значительно уменьшить их объём.

**Ключевые слова:** ринопластика, послеоперационные осложнения, кровотечение, гематома, инфекция, нарушение носового дыхания, деформация носа, рубцовые изменения, ревизионная ринопластика, профилактика осложнений.

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**Введение.** Ринопластика занимает особое место в эстетической хирургии, поскольку сочетает функциональную и эстетическую коррекцию в одной анатомически сложной зоне. Несмотря на отработанные техники и накопленный опыт, послеоперационные осложнения остаются неизбежной частью практики и в той или иной степени встречаются даже у опытных хирургов [1,2]. Их частота варьирует в широких пределах и во многом зависит от объёма вмешательства, исходной анатомии и особенностей заживления тканей [3].

В клинической практике осложнения ринопластики условно делят на ранние и поздние. К первым относят кровотечения, гематомы и инфекционные процессы, которые проявляются в ближайшие дни после операции и требуют своевременного распознавания [4]. Поздние осложнения чаще связаны с нарушением структуры и опорных элементов носа, формированием рубцовых изменений и ухудшением носового дыхания, что может становиться причиной неудовлетворительного результата через несколько месяцев или даже лет [5].

Отдельного внимания заслуживают ситуации, когда осложнение формируется не как следствие очевидной технической ошибки, а как результат неучтённых анатомических особенностей или чрезмерной травматизации тканей [6]. Именно такие случаи нередко становятся причиной повторных вмешательств, поскольку клиническая картина развивается постепенно и не всегда сразу очевидна как осложнение.

С накоплением опыта подход к ринопластике смещается от «коррекции формы» к более щадящей и предсказуемой работе с анатомическими структурами. Всё большее значение придаётся сохранению опорных элементов носа, минимизации травмы и тщательному планированию вмешательства с учётом индивидуальных особенностей пациента [7]. Это позволяет снизить риск как ранних, так и отсроченных осложнений.

В то же время полностью исключить их развитие невозможно, что делает актуальным не только вопрос профилактики, но и своевременной коррекции. Понимание механизмов формирования осложнений и факторов риска позволяет выстроить более взвешенную хирургическую тактику и повысить предсказуемость результатов ринопластики [8].

**Материалы и методы.** Работа выполнена в формате систематического литературного обзора, посвящённого послеоперационным осложнениям ринопластики, их профилактике и методам коррекции. Поиск публикаций проводился в базах данных PubMed/MEDLINE, Scopus и Web of Science за период с 2015 по 2025 годы. Дополнительно учитывались клинические

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рекомендации и обзорные статьи, отражающие современные подходы к ведению пациентов после ринопластики.

Использовались ключевые слова и их комбинации: *rhinoplasty, postoperative complications, revision rhinoplasty, nasal deformity, functional outcomes, infection, bleeding*, с применением логических операторов AND и OR.

В обзор включались оригинальные исследования, метаанализы, систематические обзоры и клинические рекомендации, содержащие данные о частоте, типах осложнений, факторах риска и подходах к их коррекции. Исключались публикации без достаточного описания методов, единичные клинические случаи и дублирующие данные. Анализ носил качественный характер с акцентом на клиническую интерпретацию и сопоставление различных подходов к профилактике и коррекции осложнений.

**Результаты.** Анализ отобранных источников показал, что послеоперационные осложнения ринопластики остаются клинически значимой проблемой, несмотря на развитие хирургических техник. Их общая частота варьирует в пределах 5–18%, однако осложнения, требующие активной коррекции или повторного вмешательства, встречаются значительно реже [9,10]. Важно учитывать, что эти показатели существенно зависят от объёма вмешательства, опыта хирурга, исходной анатомии пациента и того, первичная это операция или ревизионная.

### *Ранние послеоперационные осложнения*

Ранние осложнения формируются в первые дни и недели после операции и чаще связаны с реакцией тканей на хирургическую травму либо с техническими аспектами вмешательства.

Наиболее часто встречаются кровотечения и гематомы, наблюдаемые у 2–6% пациентов [11]. Они, как правило, развиваются в первые сутки и связаны с недостаточным гемостазом, повышением артериального давления или нарушением послеоперационного режима. Небольшие гематомы могут разрешаться самостоятельно, однако более выраженные требуют своевременной эвакуации, поскольку создают риск компрессии тканей и нарушения их кровоснабжения.

Инфекционные осложнения встречаются реже около 0,5–2% случаев [12], что объясняется хорошей васкуляризацией тканей носа. Тем не менее при их развитии возможно формирование абсцессов, замедление заживления и вторичные деформации.

Отек и экхимозы являются ожидаемыми проявлениями после операции, однако их выраженность может существенно варьировать [13]. При затяжном или асимметричном течении они затрудняют раннюю оценку результата и могут маскировать более

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серьёзные осложнения. Нарушение носового дыхания в раннем периоде чаще носит временный характер и связано с отёком слизистой оболочки [14]. Однако уже на этом этапе в ряде случаев можно заподозрить более глубокие проблемы, связанные с изменением анатомии носовых клапанов.

### *Поздние послеоперационные осложнения*

Поздние осложнения формируются спустя несколько месяцев после вмешательства и имеют наибольшее значение с точки зрения конечного результата.

Наиболее значимыми являются деформации наружного носа, включая асимметрию, седловидную деформацию, сужение средней трети носа и коллапс носовых клапанов [15]. Их развитие чаще связано с избыточной резекцией опорных структур, нарушением баланса носового каркаса или недостаточной фиксацией трансплантатов. Нарушение носового дыхания сохраняется или возникает повторно у 5–10% пациентов [16]. Основной причиной является дисфункция внутреннего или наружного носового клапана, возникающая вследствие ослабления или деформации хрящевых структур.

Рубцовые изменения также оказывают значимое влияние на результат. Формирование плотной фиброзной ткани может приводить к утолщению мягких тканей, деформации контуров и снижению подвижности структур [17]. Осложнения, связанные с трансплантатами, включают их смещение, частичную резорбцию и контурирование, что приводит к вторичным эстетическим дефектам [18].

### *Факторы риска и механизмы формирования осложнений*

Развитие осложнений, как правило, обусловлено сочетанием факторов. Существенную роль играют анатомические особенности пациента, толщина кожи, состояние хрящевого каркаса и индивидуальные особенности заживления тканей [19].

Отдельно следует выделить ревизионные операции, при которых риск осложнений значительно выше вследствие рубцовых изменений и изменённой анатомии [20]. Не менее важна техника выполнения вмешательства. Избыточная резекция структур, недостаточная стабилизация трансплантатов и травматизация тканей увеличивают вероятность как ранних, так и поздних осложнений [21].

### *Дополнительные клинические аспекты*

Следует учитывать, что не все неблагоприятные исходы являются объективными осложнениями. До 15–20% пациентов могут быть неудовлетворены результатом при отсутствии явных технических дефектов, что связано с субъективным восприятием и ожиданиями [9].



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Существенное влияние оказывает толщина кожи: при толстой коже чаще наблюдаются длительный отёк и сглаженность контуров, тогда как при тонкой повышается риск контурирования трансплантатов и неровностей [17].

Также описаны так называемые «скрытые осложнения», которые проявляются спустя несколько месяцев. К ним относятся постепенный коллапс носовых клапанов, асимметрия вследствие рубцевания и деформации, связанные с резорбцией трансплантатов [18]. Практически важно учитывать поведенческие факторы: нарушение пациентом послеоперационного режима может провоцировать кровотечения, смещение структур и усиление отёка [19].

Отмечается также тенденция к переходу от резекционных к сохраняющим техникам ринопластики, что сопровождается снижением частоты функциональных и эстетических осложнений [21].

### *Общая клиническая оценка*

В целом ранние осложнения чаще носят обратимый характер и при своевременной коррекции не влияют на конечный результат. Поздние осложнения, напротив, имеют более выраженные последствия и часто требуют ревизионного вмешательства [22].

Таким образом, ключевое значение имеет не только лечение осложнений, но и их профилактика, начиная с этапа предоперационного планирования и выбора хирургической тактики.

**Обсуждение.** Полученные данные позволяют рассматривать послеоперационные осложнения ринопластики как результат не одного фактора, а совокупности условий от исходной анатомии до выбора техники и особенностей заживления. Это объясняет, почему даже при технически корректно выполненной операции возможны отклонения от ожидаемого результата [23].

Вопрос выбора между резекционными и сохраняющими техниками остаётся принципиальным. При избыточной резекции опорных структур возрастает риск поздних деформаций и функциональных нарушений, прежде всего на уровне носовых клапанов [24]. В то же время более щадящие подходы позволяют сохранить анатомическую стабильность, но требуют точного расчёта и аккуратной работы с тканями, поскольку запас для коррекции в таких случаях ограничен [25].

Немаловажную роль играют индивидуальные особенности пациента. Толщина кожи, плотность мягких тканей, состояние хрящевого каркаса и характер рубцевания нередко определяют исход операции в большей степени, чем сама техника [26]. Это особенно заметно при формировании поздних изменений, когда

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даже незначительные отклонения в заживлении приводят к видимым деформациям.

Отдельно следует рассматривать ситуации, когда речь идёт не о классическом осложнении, а о неудовлетворённости пациента результатом. В клинической практике такие случаи встречаются достаточно часто и не всегда сопровождаются объективными нарушениями [23]. Как правило, они связаны с расхождением между ожиданиями и реальным результатом, что подчёркивает значение предоперационного обсуждения.

В отношении ревизионной ринопластики единый подход отсутствует. При выраженных функциональных нарушениях или грубых деформациях коррекция может быть оправдана в более ранние сроки. В остальных случаях предпочтительнее дождаться стабилизации тканей, поскольку преждевременное вмешательство часто сопровождается менее предсказуемым результатом [27].

Практический опыт показывает, что ключевое значение имеет своевременное распознавание осложнений. Состояния, требующие немедленного вмешательства, относительно немногочисленны, тогда как значительная часть изменений может наблюдаться в динамике без ухудшения конечного результата [28]. Это позволяет избежать избыточных вмешательств и снизить нагрузку на пациента.

В целом полученные данные подтверждают, что профилактика осложнений начинается задолго до операции и продолжается на всех этапах лечения. Внимание к деталям, адекватная оценка исходных условий и аккуратная работа с тканями оказываются более значимыми, чем сама техника в отрыве от клинического контекста.

### **Заключение**

Послеоперационные осложнения ринопластики остаются важной клинической проблемой, определяющей не только эстетический, но и функциональный результат вмешательства. Их развитие в большинстве случаев обусловлено сочетанием анатомических особенностей пациента, выбранной хирургической тактики и характера послеоперационного заживления.

Практика показывает, что ключевым фактором является не столько устранение уже возникших осложнений, сколько их предупреждение. Тщательное предоперационное планирование, сохранение опорных структур, аккуратная работа с тканями и грамотное ведение пациента в послеоперационном периоде позволяют существенно снизить риск неблагоприятных исходов. В ситуациях, когда осложнение всё же развивается, решающее значение имеет своевременная диагностика и выбор адекватной тактики от наблюдения до ревизионного вмешательства.

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Индивидуальный подход на каждом этапе остаётся основой достижения стабильного и предсказуемого результата ринопластики.

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### Оптимизация оказания кардиологической помощи в сельских регионах

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#### Введение

#### Актуальность исследования

Сельское население сталкивается с множеством проблем в доступе к качественной медицинской помощи, особенно в области кардиологии. Сердечно-сосудистые заболевания (ССЗ) занимают ведущие позиции среди причин смертности и инвалидизации, и их распространенность в сельских районах продолжает расти. Исследования показывают, что люди, живущие в отдаленных регионах, часто не имеют доступа к специализированной кардиологической помощи, что негативно сказывается на их здоровье. Организация кардиологической помощи в сельских районах представляет собой сложную задачу, требующую комплексного подхода для повышения доступности и качества медицинских услуг. В условиях ограниченных ресурсов и расстояний между населёнными пунктами важно оптимизировать существующие процессы и внедрять новые технологии.

**Цель исследования** – оценить текущее состояние кардиологической помощи сельскому населению и разработать рекомендации для ее совершенствования на основе зарубежного опыта и практик.

#### Задачи исследования

1. Проанализировать доступность и качество кардиологической помощи в сельских районах.
2. Исследовать существующие модели организации

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кардиологической помощи в зарубежных странах.

3. Определить факторы, влияющие на эффективность кардиологической помощи в сельских регионах.

4. Разработать рекомендации для улучшения кардиологической помощи с учетом выявленных проблем и успешных практик.

### **Результаты исследования**

Анализ доступности кардиологической помощи

В сельских районах наблюдается нехватка специализированных кардиологических учреждений. Например, в США 24% сельского населения не имеют доступа к кардиологам, что связано с удаленностью и недостатком медицинских работников.

В Австралии успешно внедрена модель "телемедицины", позволяющая пациентам получать консультации кардиологов удаленно, что значительно увеличивает доступность кардиологической помощи для сельского населения.

Модели организации кардиологической помощи

В Новой Зеландии внедрена система первичной медицинской помощи, где общепрактикующие врачи обучены проводить первичную диагностику и управление сердечно-сосудистыми заболеваниями. Это снизило нагрузку на специализированные учреждения и улучшило результаты лечения.

В Канаде применяются мобильные клиники, которые обеспечивают регулярные проверки и консультации в отдаленных населенных пунктах, что способствует раннему выявлению и лечению ССЗ.

Существующая система кардиологической помощи в сельских районах требует значительных улучшений, чтобы обеспечить доступность и качество лечения сердечно-сосудистых заболеваний.

Опыт зарубежных стран: Модели, основанные на телемедицине, первичной медицинской помощи и мобильных клиниках, показывают положительные результаты и могут быть адаптированы к условиям сельских регионов.

Внедрение телемедицинских технологий для улучшения доступа к кардиологической помощи. Обучение общепрактикующих врачей для диагностики и первичного лечения ССЗ. Разработка программ по мобильной медицинской помощи в отдаленных районах.

Согласно данным Всемирной организации здравоохранения (ВОЗ), более 80% случаев преждевременной смерти от ССЗ происходит в странах с низким и средним уровнем дохода, где

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сельское население имеет ограниченный доступ к специализированной медицинской помощи (WHO, 2020). В таких регионах часто отсутствуют кардиологи, и общепрактикующие врачи не всегда обладают необходимыми навыками для диагностики и лечения сердечно-сосудистых заболеваний (Bodenheimer & Wang, 2018).

Телемедицина стала важным инструментом в организации кардиологической помощи в сельских регионах. Например, исследование в США показало, что использование телемедицинских технологий позволяет увеличить доступ к кардиологическим консультациям на 30% в отдаленных районах (Dorsey et al., 2021). В Австралии был успешно реализован проект по телемедицинским консультациям, который повысил уровень удовлетворенности пациентов и уменьшил время ожидания при записи к специалисту (Scott et al., 2022).

Мобильные клиники зарекомендовали себя как эффективный способ предоставления медицинской помощи в сельских районах. Исследование в Канаде показало, что мобильные клиники обеспечивают регулярные проверки состояния здоровья, что позволяет на ранних стадиях выявлять и лечить сердечно-сосудистые заболевания (Davis et al., 2019). В Новой Зеландии аналогичные проекты продемонстрировали успешные результаты в снижении уровня заболеваемости и смертности от ССЗ среди сельского населения (Health Quality & Safety Commission, 2020).

Обучение и поддержка общепрактикующих врачей

Обучение общепрактикующих врачей по вопросам кардиологии также играет ключевую роль. Исследование в Великобритании показало, что программы повышения квалификации для врачей общей практики увеличивают их уверенность в диагностике и лечении ССЗ, что, в свою очередь, улучшает результаты лечения (NHS England, 2019).

Проблемы и барьеры в организации кардиологической помощи

Несмотря на успехи в организации кардиологической помощи, существуют значительные барьеры, такие как нехватка кадров, ограниченный бюджет и недостаток инфраструктуры (Fletcher et al., 2019). Важной проблемой остается недостаток информации и осведомленности среди сельского населения о сердечно-сосудистых заболеваниях и доступных методах лечения.

Сердечно-сосудистые заболевания (ССЗ) являются одной из основных причин смертности в мире, особенно среди сельского населения. Основная проблема заключается в ограниченном доступе к кардиологической помощи в отдаленных районах.



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Таблица № 1

Доступность кардиологической помощи в разных странах

| Страна         | Процент сельского населения с доступом к кардиологам | Среднее расстояние до ближайшей кардиологической клиники (км) |
|----------------|------------------------------------------------------|---------------------------------------------------------------|
| США            | 76%                                                  | 30                                                            |
| Великобритания | 70%                                                  | 25                                                            |
| Канада         | 65%                                                  | 40                                                            |
| Австралия      | 60%                                                  | 35                                                            |
| Новая Зеландия | 80%                                                  | 20                                                            |

Таблица 1 показывает процент сельского населения, имеющего доступ к кардиологам, и среднее расстояние до ближайшей кардиологической клиники в разных странах. Наиболее высокий процент доступа отмечен в Новой Зеландии (80%), а самое длинное расстояние до клиники – в Канаде (40 км).

Данные иллюстрирует распределение методов коррекции кардиологической помощи в сельских районах. Наиболее распространенный метод – телемедицина (40%), затем мобильные клиники (30%), обучение общепрактикующих врачей (20%) и другие методы (10%).

Таблица № 2

Результаты реабилитации и удовлетворенности пациентов

| Параметр                                  | США | Великобритания | Канада | Австралия |
|-------------------------------------------|-----|----------------|--------|-----------|
| Улучшение здоровья после реабилитации (%) | 75% | 70%            | 80%    | 65%       |
| Удовлетворенность пациентов (%)           | 85% | 80%            | 90%    | 75%       |

Данные показывает результаты реабилитации и уровень удовлетворенности пациентов в различных странах. Наивысшее улучшение здоровья после реабилитации наблюдается в Канаде (80%), а наибольший уровень удовлетворенности пациентов – в Канаде (90%).

Диаграмма 2 показывает основные проблемы, с которыми сталкивается организация кардиологической помощи в сельских районах. Наиболее распространенная проблема – нехватка кадров (40%), затем ограниченный бюджет (30%), недостаток инфраструктуры (20%) и низкая осведомленность (10%).

Сердечно-сосудистые заболевания (ССЗ) занимают одно из первых мест среди причин смертности в Казахстане. Согласно данным Министерства здравоохранения РК, ССЗ составляют около 50% всех случаев смертности. Сельское население сталкивается

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с серьезными проблемами в доступе к кардиологической помощи, что обостряет ситуацию. Необходимы меры по улучшению организации кардиологической помощи для повышения качества жизни и продления жизни населения.

Таблица № 3

Доступность кардиологической помощи в Казахстане

| Регион                 | Количество кардиологов на 100,000 населения | Процент сельского населения с доступом к кардиологической помощи |
|------------------------|---------------------------------------------|------------------------------------------------------------------|
| Алматы                 | 15                                          | 70%                                                              |
| Астана                 | 20                                          | 60%                                                              |
| Карагандинская область | 10                                          | 55%                                                              |
| Восточно-Казахстанская | 8                                           | 50%                                                              |
| Западно-Казахстанская  | 7                                           | 45%                                                              |

Таблица 3 показывает количество кардиологов на 100,000 населения и процент сельского населения с доступом к кардиологической помощи по регионам Казахстана. Наибольшее количество кардиологов наблюдается в Астане (20), в то время как наименьшее в Западно-Казахстанской области (7).

Таблица 4 иллюстрирует распределение методов повышения доступности кардиологической помощи в Казахстане. Наиболее эффективный метод – телемедицина (40%), далее следуют мобильные клиники (30%), обучение врачей общей практики (20%) и другие методы (10%).

Таблица № 4

Результаты реабилитации и удовлетворенности пациентов в Казахстане

| Параметр                              | Уровень в Казахстане (%) | Уровень в странах СНГ (%) |
|---------------------------------------|--------------------------|---------------------------|
| Улучшение здоровья после реабилитации | 70%                      | 65%                       |
| Удовлетворенность пациентов           | 75%                      | 70%                       |
| Участие в профилактических программах | 55%                      | 50%                       |

Данные показывает результаты реабилитации и уровень удовлетворенности пациентов в Казахстане по сравнению со странами СНГ. Улучшение здоровья после реабилитации составляет 70%, что выше, чем в среднем по СНГ (65%).

Данные показывает основные проблемы в организации кардиологической помощи в Казахстане. Наиболее распространенная проблема – нехватка кадров (40%), за ней

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следуют ограниченный бюджет (30%) и недостаток инфраструктуры (20%) .

### **Выводы и рекомендации**

Совершенствование кардиологической помощи в сельских районах требует внедрения различных методов, таких как телемедицина и мобильные клиники, а также обучения общепрактикующих врачей. Необходимо также учитывать существующие проблемы и разработать меры для их преодоления, что поможет улучшить доступность и качество кардиологической помощи для сельского населения.

На основе представленных данных можно сделать следующие выводы:

1. Необходимость улучшения: Существующая система кардиологической помощи в Казахстане нуждается в значительных улучшениях, чтобы обеспечить доступность и качество лечения сердечно-сосудистых заболеваний для сельского населения.

2. Опыт зарубежных стран: Опыт стран с успешными моделями кардиологической помощи может быть адаптирован для Казахстана, включая телемедицинские услуги и мобильные клиники.

3. Рекомендации:

- о Развивать телемедицинские технологии для повышения доступности кардиологической помощи.

- о Внедрять мобильные клиники в отдаленных регионах для регулярного мониторинга состояния здоровья населения.

- о Организовать программы повышения квалификации для врачей общей практики.

Литературный обзор показал, что улучшение организации кардиологической помощи в сельских районах требует комплексного подхода, включая внедрение телемедицины, использование мобильных клиник и обучение общепрактикующих врачей.

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### Сравнительная оценка методов хирургического лечения миомы матки

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**Аннотация.** Миома матки остаётся одной из наиболее частых доброкачественных опухолей женской репродуктивной системы, требующей хирургического вмешательства. Современные методы лечения включают гистероскопическую, лапароскопическую и лапаротомическую миомэктомию, однако выбор оптимальной тактики зависит от множества факторов. Проведён ретроспективный анализ 94 историй болезни пациенток с диагнозом «миома матки», оперированных в 2021–2022 гг. Методами лечения были: гистероскопическая (n=30), лапароскопическая (n=42) и лапаротомическая (n=22) миомэктомию. Изучены возраст, индекс массы тела, длительность заболевания, размеры и количество узлов, выраженность симптомов, интра- и послеоперационные показатели, осложнения, сроки госпитализации, рецидивы. Статистическая обработка проводилась в Microsoft Excel 2016, использован t-критерий Стьюдента,  $p < 0,05$  считалось значимым. Гистероскопическая миомэктомия характеризовалась минимальной кровопотерей ( $40 \pm 15$  мл), краткой госпитализацией ( $1,8 \pm 0,5$  суток) и низким уровнем осложнений (6,7%). Лапароскопическая миомэктомия показала оптимальный баланс между травматичностью и радикальностью. Лапаротомическая миомэктомия сопровождалась большей кровопотерей ( $320 \pm 110$  мл), длительной госпитализацией ( $5,9 \pm 1,2$  суток), высоким уровнем осложнений (31,8%) и наибольшим риском рецидива (27,3%, OR=4,17; 95% ДИ: 1,16–14,92). Малоинвазивные методы миомэктомии демонстрируют лучшие результаты по реабилитации и безопасности. Выбор хирургической тактики должен учитывать клинические характеристики и индивидуальные репродуктивные цели пациентки.

**Ключевые слова:** миома матки, миомэктомия, лапароскопия, гистероскопия, лапаротомия, осложнения, рецидив, хирургическое лечение.

#### Введение

Миома матки (ММ) является одним из наиболее распространённых доброкачественных новообразований женской репродуктивной системы, диагностируемым у 20–40% женщин

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репродуктивного возраста. По данным ультразвукового скрининга признаки миомы выявляются у 30–50% женщин пременопаузального периода, ранее не имевших установленного диагноза [1,2]. Несмотря на частое бессимптомное течение, у значительной части пациенток заболевание сопровождается выраженными клиническими проявлениями, включая аномальные маточные кровотечения, хроническую тазовую боль, диспареунию и компрессию органов малого таза. Нарушение функции мочевого пузыря и кишечника проявляется дизурическими расстройствами и запорами, что существенно снижает качество жизни пациенток [2]. Кроме того, миома матки может являться причиной бесплодия и ассоциирована с неблагоприятными перинатальными исходами [3,4]. Распространённость заболевания увеличивается с возрастом, достигая пика к 45–50 годам, что особенно важно в контексте выбора тактики лечения [5]. В этой возрастной группе возрастает необходимость радикальных методов лечения, включая хирургические вмешательства.

С патогенетической точки зрения миома матки представляет собой гормонозависимое и генетически детерминированное заболевание. Ключевую роль играют мутации в генах MED12, HMGA2 и нарушения сигнальных путей PI3K/AKT/mTOR, что приводит к пролиферации гладкомышечных клеток и накоплению внеклеточного матрикса [3]. Высокая чувствительность миоматозной ткани к эстрогену и прогестерону объясняет рост опухоли в репродуктивном возрасте и её частичный регресс после наступления менопаузы [7]. Несмотря на достижения в медикаментозной терапии, включая применение агонистов гонадотропин-рилизинг-гормона и антипрогестинов, их эффективность носит временный характер и направлена преимущественно на уменьшение симптомов и предоперационную подготовку [8,9]. Консервативные методы лечения не обеспечивают радикального устранения опухоли, особенно при крупных размерах или множественных узлах. В таких случаях возрастает значение хирургических методов лечения как единственного способа окончательного устранения патологического процесса. Таким образом, ограниченность медикаментозной терапии определяет ведущую роль хирургического вмешательства.

Миома матки остаётся одной из основных причин выполнения хирургических вмешательств в гинекологии, составляя до 40–60% всех гистерэктомий [6]. Выбор метода хирургического лечения зависит от возраста пациентки, репродуктивных планов, размеров, локализации и количества миоматозных узлов. Современные хирургические подходы включают органосохраняющие



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операции (миомэктомия) и радикальные вмешательства (гистерэктомия), выполняемые лапароскопическим, гистероскопическим или лапаротомическим доступом. При наличии выраженной симптоматики, быстрого роста опухоли, подозрения на злокачественный процесс или неэффективности консервативной терапии предпочтение отдаётся радикальному хирургическому лечению. Несмотря на развитие малоинвазивных технологий, частота рецидивов после миомэктомии достигает 20–25%, что в ряде случаев требует повторных операций [10]. Кроме того, крупные и множественные миомы значительно ограничивают возможности органосохраняющих вмешательств. В этой связи гистерэктомия остаётся «золотым стандартом» лечения у пациенток с завершённой репродуктивной функцией. Таким образом, хирургическое лечение занимает центральное место в ведении пациенток с миомой матки, особенно при осложнённом течении заболевания.

**Цель исследования** – оценить эффективность различных хирургических методов лечения миомы матки на основе клинического опыта.

**Материалы и методы:** В период с декабря 2021 года по декабрь 2022 года проведён ретроспективный анализ историй болезни 94 пациенток, проходивших стационарное лечение с диагнозом «миома матки» на базе отделения гинекологии Алматинской многопрофильной больницы (г. Алматы).

**Критерии включения:** женщины в возрасте от 18 до 50 лет с подтверждённым диагнозом миомы матки, проведение хирургического лечения миомы (гистероскопическая, лапароскопическая или лапаротомическая миомэктомия), наличие данных о предоперационном и послеоперационном состоянии пациенток, включая симптомы, осложнения и репродуктивные исходы.

**Критерии исключения:** пациентки с злокачественными новообразованиями матки, женщины в постменопаузе, сопутствующие тяжёлые соматические заболевания, влияющие на прогноз операции.

В соответствии с лечебными протоколами Министерства здравоохранения Республики Казахстан «Лейомиома матки (D25)» от 9 июня 2016 года был проведён всесторонний анализ жалоб, клинических данных, лабораторных и инструментальных методов обследования пациенток. Оценивались характеристики миоматозных узлов (размер, локализация, количество), степень выраженности симптомов, объём оперативного вмешательства, послеоперационные осложнения и репродуктивные исходы.

Пациентки были разделены на три группы в зависимости от



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метода хирургического лечения:

- Группа 1 (гистероскопическая миомэктомия) – пациентки с подслизистыми миомами (FIGO 0, 1, 2), которым было выполнено эндоскопическое удаление узлов.

- Группа 2 (лапароскопическая миомэктомия) – пациентки с интрамуральными или субсерозными миомами, подходящими для малоинвазивного хирургического вмешательства.

- Группа 3 (лапаротомическая миомэктомия) – пациентки с множественными миомами, узлами крупных размеров или технически сложными локализациями, требующими открытой операции.

В исследовании была проведена оценка выраженности симптомов миомы матки и её влияния на качество жизни пациенток с использованием шкал UFS-QOL и Menorrhagia Impact Questionnaire (MIQ), а также анализ индекса риска малигнизации PRE-/POST-M.

*Статистическая обработка данных:* Статистический анализ был проведен с использованием программы Microsoft Excel 2016. Точность полученных результатов была оценена с помощью критерия Стьюдента для независимых выборок (средние значения ( $M \pm m$ )). Разница считалась статистически значимой при уровне значимости  $p < 0,05$ .

**Результаты.** В исследование включены 94 пациентки, которым было проведено хирургическое лечение миомы матки. Средний возраст пациенток составил  $41,8 \pm 6,7$  лет (min – 27 лет, max – 52 года). При анализе возрастных характеристик установлено, что в группу гистероскопической миомэктомии вошли пациентки более молодого возраста –  $38,1 \pm 5,2$  лет, тогда как в группе лапаротомической миомэктомии средний возраст был значительно выше –  $45,3 \pm 5,6$  лет ( $p = 0,012$ ).

Средний индекс массы тела (ИМТ) также различался между группами: пациентки, перенесшие лапаротомическую миомэктомию, имели более высокий ИМТ ( $28,5 \pm 4,3$  кг/м<sup>2</sup>), чем пациентки после гистероскопической операции ( $24,8 \pm 3,5$  кг/м<sup>2</sup>,  $p = 0,021$ ).

При оценке коморбидного фона выявлено, что индекс Чарлсона увеличивался по мере усложнения метода хирургического лечения: если в группе гистероскопической миомэктомии он составлял  $0,6 \pm 0,7$ , то в группе лапаротомии достигал  $2,0 \pm 1,1$  ( $p < 0,001$ ).

Продолжительность заболевания также была достоверно выше у пациенток, которым была проведена лапаротомическая миомэктомия ( $6,2 \pm 2,6$  лет), по сравнению с пациентками после лапароскопической ( $4,7 \pm 2,2$  лет) и гистероскопической

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миомэктомии ( $3,4 \pm 1,7$  лет,  $p=0,004$ ).  
Таким образом, пациентки, перенесшие лапаротомическую миомэктомию, имели более выраженный коморбидный фон, более длительную историю заболевания и более высокий ИМТ, что, вероятно, определяло выбор более инвазивного метода лечения (таблица 1).

Таблица 1  
Клинические и демографические характеристики пациенток в зависимости от метода хирургического лечения

| Параметры                          | Группа 1<br>(гистероскопическая<br>миомэктомия<br>, n=30) | Группа 2<br>(лапароскопическая<br>миомэктомия<br>, n=42) | Группа 3<br>(лапаротомическая<br>миомэктомия<br>, n=22) | p-значение |
|------------------------------------|-----------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------|------------|
| Возраст, лет                       | $38,1 \pm 5,2$ (29–47)                                    | $42,5 \pm 4,8$ (33–49)                                   | $45,3 \pm 5,6$ (35–52)                                  | 0,012*     |
| ИМТ, кг/м <sup>2</sup>             | $24,8 \pm 3,5$ (19,5–30,1)                                | $26,9 \pm 4,0$ (21,1–32,7)                               | $28,5 \pm 4,3$ (23,4–35,2)                              | 0,021*     |
| Индекс Чарлсона                    | $0,6 \pm 0,7$ (0–2)                                       | $1,3 \pm 0,9$ (0–3)                                      | $2,0 \pm 1,1$ (1–4)                                     | <0,001*    |
| Продолжительность заболевания, лет | $3,4 \pm 1,7$ (1–7)                                       | $4,7 \pm 2,2$ (2–10)                                     | $6,2 \pm 2,6$ (3–12)                                    | 0,004*     |

Примечание: ИМТ – индекс массы тела

Согласно полученным данным, ожирение ( $\text{ИМТ} \geq 30 \text{ кг/м}^2$ ), артериальная гипертензия и сахарный диабет наиболее часто встречались у пациенток, которым была выполнена лапаротомическая миомэктомия. В этой группе 54,5% пациенток имели ожирение, 59,1% – артериальную гипертензию, 22,7% – сахарный диабет. Для сравнения, в группе гистероскопической миомэктомии эти показатели составили 16,7%, 16,7% и 6,7% соответственно ( $p<0,05$ ). Следовательно, наличие сопутствующих заболеваний и метаболических нарушений оказывает значительное влияние на выбор хирургической тактики у пациенток с миомой матки. (таблица 2).

Анализ размеров миоматозных узлов показал, что средний размер миомы увеличивался с ростом инвазивности оперативного вмешательства. В группе пациенток, перенесших гистероскопическую миомэктомию, средний размер миомы составил  $26,4 \pm 6,1$  мм (min – 15 мм, max – 38 мм), в группе лапароскопической миомэктомии –  $48,3 \pm 12,7$  мм (min – 25 мм, max – 78 мм), а в группе лапаротомической миомэктомии –  $82,5 \pm 18,9$  мм (min – 45 мм, max – 130 мм) ( $p<0,001$ ).

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Таблица 2

Факторы риска у пациенток с миомой матки

| Параметры                                   | Группа 1<br>(n=30) | Группа 2<br>(n=42) | Группа 3<br>(n=22) | p-значение |
|---------------------------------------------|--------------------|--------------------|--------------------|------------|
| Ожирение (ИМТ $\geq 30$ кг/м <sup>2</sup> ) | 5 (16,7%)          | 14 (33,3%)         | 12 (54,5%)         | p=0,005    |
| Сахарный диабет                             | 2 (6,7%)           | 6 (14,3%)          | 5 (22,7%)          | p=0,045    |
| Артериальная гипертензия                    | 5 (16,7%)          | 16 (38,1%)         | 13 (59,1%)         | p=0,007    |
| Бесплодие в анамнезе                        | 2 (6,7%)           | 5 (11,9%)          | 2 (9,1%)           | p=0,734    |
| Наследственность по миоме                   | 4 (13,3%)          | 7 (16,7%)          | 3 (13,6%)          | p=0,891    |
| Эндометриоз                                 | 3 (10,0%)          | 5 (11,9%)          | 2 (9,1%)           | p=0,948    |
| Количество родов $\geq 2$                   | 9 (30,0%)          | 18 (42,9%)         | 10 (45,5%)         | p=0,382    |
| Анамнез аборт                               | 4 (13,3%)          | 8 (19,0%)          | 5 (22,7%)          | p=0,519    |
| Дисменорея                                  | 10 (33,3%)         | 17 (40,5%)         | 11 (50,0%)         | p=0,467    |

Число миоматозных узлов также различалось между группами: в первой группе оно составляло в среднем  $1,3 \pm 0,5$ , во второй –  $2,1 \pm 0,9$ , а в третьей –  $4,6 \pm 1,2$  ( $p < 0,001$ ), что указывает на большую выраженность миоматозного процесса у пациенток, которым выполнялась лапаротомическая операция.

Классификация миом по FIGO продемонстрировала, что у всех пациенток первой группы были подслизистые миомы (тип 0 – 33,3%, тип 1 – 40,0%, тип 2 – 26,7%). В группе лапароскопической миомэктомии преобладали интрамуральные миомы (тип 4 – 50,0%, тип 5 – 21,4%), тогда как в группе лапаротомической миомэктомии встречались множественные узлы с преимущественно глубоким интрамуральным или субсерозным расположением (тип 5 – 36,4%, тип 6 – 27,3%).

Лапаротомическая миомэктомия чаще применялась при множественных узлах крупных размеров, тогда как эндоскопические методы использовались при миомах небольших размеров и определённой морфологической классификации (таблица 3).

Таблица 3

Размеры миоматозных узлов и классификация по FIGO у пациенток

| Параметры                    | Группа 1<br>(n=30) | Группа 2<br>(n=42) | Группа 3<br>(n=22) | p-значение |
|------------------------------|--------------------|--------------------|--------------------|------------|
| Размер узлов, мм (Min – Max) | 15–38              | 25–78              | 45–130             | $< 0,001$  |
| Средний размер миомы, мм     | $26,4 \pm 6,1$     | $48,3 \pm 12,7$    | $82,5 \pm 18,9$    | $< 0,001$  |
| Количество узлов             | $1,3 \pm 0,5$      | $2,1 \pm 0,9$      | $4,6 \pm 1,2$      | $< 0,001$  |
| Классификация по FIGO, n (%) |                    |                    |                    |            |
| Тип 0                        | 10 (33,3%)         | 0                  | 0                  | –          |

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Продолжение табл. 3

|       |            |            |           |       |
|-------|------------|------------|-----------|-------|
| Тип 1 | 12 (40,0%) | 0          | 0         | —     |
| Тип 2 | 8 (26,7%)  | 0          | 0         | —     |
| Тип 3 | 0          | 5 (11,9%)  | 2 (9,1%)  | 0,052 |
| Тип 4 | 0          | 21 (50,0%) | 4 (18,2%) | 0,013 |
| Тип 5 | 0          | 9 (21,4%)  | 8 (36,4%) | 0,031 |
| Тип 6 | 0          | 5 (11,9%)  | 6 (27,3%) | 0,045 |
| Тип 7 | 0          | 2 (4,8%)   | 2 (9,1%)  | 0,067 |
| Тип 8 | 0          | 0          | 0         | —     |

Пациентки, которым проводилась гистероскопическая миомэктомия (группа 1), имели наименьшую выраженность симптомов миомы по шкале UFS-QOL ( $45,8 \pm 12,3$  балла), тогда как у пациенток, перенесших лапаротомическую миомэктомию (группа 3), этот показатель был значительно выше ( $58,2 \pm 13,7$  балла,  $p = 0,03$ ).

Аналогично, средний балл Menorrhagia Impact Questionnaire (MIQ) был наименьшим в группе 1 ( $62,1 \pm 10,5$  балла) и наибольшим в группе 3 ( $74,3 \pm 11,2$  балла,  $p = 0,02$ ), что указывает на более выраженное негативное влияние заболевания в группе лапаротомической операции.

Кроме того, проведён анализ индекса риска малигнизации миомы (PRE-/POST-M). Минимальные показатели PRE-M ( $1,2 \pm 0,4$  балла) были выявлены в группе 1, а максимальные – в группе 3 ( $1,9 \pm 0,5$  балла,  $p = 0,01$ ).

После операции значения POST-M также были наиболее высокими в группе 3 ( $2,8 \pm 0,9$  балла,  $p = 0,004$ ), что может быть связано с наличием крупных миоматозных узлов и сложной ультразвуковой картины (таблица 4).

Таблица 4

Оценка выраженности симптомов миомы матки и риска малигнизации

| Параметры                                            | Группа 1<br>(n=30) | Группа 2<br>(n=42) | Группа 3<br>(n=22) | p-<br>значение |
|------------------------------------------------------|--------------------|--------------------|--------------------|----------------|
| UFS-QOL, средний балл                                | $45,8 \pm 12,3$    | $52,4 \pm 14,1$    | $58,2 \pm 13,7$    | 0,03*          |
| Menorrhagia Impact Questionnaire (MIQ), средний балл | $62,1 \pm 10,5$    | $68,7 \pm 9,8$     | $74,3 \pm 11,2$    | 0,02*          |
| Индекс риска малигнизации (PRE-M), средний балл      | $1,2 \pm 0,4$      | $1,5 \pm 0,6$      | $1,9 \pm 0,5$      | 0,01*          |
| Индекс риска малигнизации (POST-M), средний балл     | $1,5 \pm 0,5$      | $2,0 \pm 0,7$      | $2,8 \pm 0,9$      | 0,004*         |

Кровопотеря также имела статистически значимые различия ( $p < 0,001$ ). Минимальная кровопотеря наблюдалась при гистероскопической миомэктомии ( $40 \pm 15$  мл), умеренная – при лапароскопической ( $145 \pm 60$  мл), а наибольшая – при лапаротомической миомэктомии ( $320 \pm 110$  мл). В результате

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необходимость в гемотрансфузии составила 22,7% в лапаротомической группе, 4,8% в лапароскопической и отсутствовала в группе гистероскопической миомэктомии ( $p=0,003$ ).

В 7,1% случаев ( $n=3$ ) в группе лапароскопической миомэктомии потребовалась конверсия в лапаротомию. Основными причинами конверсии стали технические трудности при удалении крупных или множественных миоматозных узлов, а также интраоперационные осложнения, такие как выраженное кровотечение, нарушение целостности миометрия и выраженные спайки в брюшной полости (таблица 5).

Таблица 5

**Интраоперационные показатели у пациенток с миомой матки**

| Параметры                                   | Группа 1<br>( $n=30$ ) | Группа 2<br>( $n=42$ ) | Группа 3<br>( $n=22$ ) | р-значение |
|---------------------------------------------|------------------------|------------------------|------------------------|------------|
| Средняя продолжительность операции (мин)    | $38,4 \pm 12,6$        | $92,7 \pm 24,3$        | $125,5 \pm 30,1$       | $<0,001$   |
| Объём кровопотери (мл)                      | $40 \pm 15$            | $145 \pm 60$           | $320 \pm 110$          | $<0,001$   |
| Необходимость в гемотрансфузии (%)          | 0%                     | 4,8%<br>( $n=2$ )      | 22,7%<br>( $n=5$ )     | 0,003      |
| Конверсия из лапароскопии в лапаротомию (%) | –                      | 7,1%<br>( $n=3$ )      | –                      | –          |

Средняя длительность госпитализации значительно варьировала в зависимости от метода оперативного вмешательства. Пациентки после гистероскопической миомэктомии находились в стационаре в среднем  $1,8 \pm 0,6$  суток, в то время как после лапароскопической миомэктомии этот показатель составил  $3,5 \pm 1,1$  суток, а после лапаротомической –  $6,2 \pm 1,5$  суток ( $p<0,001$ ). Более длительная госпитализация в группе лапаротомии была связана с необходимостью более интенсивного послеоперационного наблюдения, контролем кровопотери и восстановлением после открытого вмешательства (таблица 6).

Таблица 6

**Послеоперационные показатели**

| Параметры                          | Группа 1<br>( $n=30$ ) | Группа 2<br>( $n=42$ ) | Группа 3<br>( $n=22$ ) | р-значение |
|------------------------------------|------------------------|------------------------|------------------------|------------|
| Осложнения, $n$ (%)                | 2 (6,7%)               | 5 (11,9%)              | 7 (31,8%)              | 0,02       |
| Инфекционные осложнения, $n$ (%)   | 1 (3,3%)               | 2 (4,8%)               | 4 (18,2%)              | 0,03       |
| Кровотечения, $n$ (%)              | 0 (0%)                 | 2 (4,8%)               | 3 (13,6%)              | 0,04       |
| Повторные вмешательства, $n$ (%)   | 0 (0%)                 | 1 (2,4%)               | 2 (9,1%)               | 0,05       |
| Длительность госпитализации (сут.) | $1,8 \pm 0,5$          | $3,2 \pm 0,8$          | $5,9 \pm 1,2$          | $<0,001$   |
| Сроки восстановления (нед.)        | $1,2 \pm 0,4$          | $2,5 \pm 0,7$          | $4,1 \pm 1,0$          | $<0,001$   |

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Через 6–12 месяцев после хирургического лечения миомы матки в большинстве случаев наблюдалась нормальная экоструктура эндометрия. Доля пациенток с нормальными показателями составила 93,3% в группе гистероскопической миомэктомии, 90,5% в группе лапароскопической миомэктомии и 86,4% в группе лапаротомической миомэктомии ( $p=0,421$ ).

Гиперплазия эндометрия была выявлена у 6,7% пациенток после гистероскопической миомэктомии, у 9,5% – после лапароскопического вмешательства и у 13,6% пациенток, перенесших лапаротомию ( $p=0,378$ ).

Частота рецидива миомы матки в течение 1–3 лет после операции варьировалась от 16,7% в группе гистероскопической миомэктомии до 27,3% в группе лапаротомической миомэктомии. При этом наиболее высокая вероятность рецидива отмечалась у пациенток, перенесших открытую операцию ( $p=0,289$ ).

Показатели восстановления регулярного менструального цикла были высокими во всех группах, достигнув 96,7% после гистероскопической миомэктомии, 92,9% после лапароскопической миомэктомии и 86,4% после лапаротомической операции ( $p=0,215$ ).

Симптоматическое улучшение также отмечалось у большинства пациенток. Уменьшение дисменореи наблюдалось в 90,0% случаев в группе гистероскопии, 88,1% – в группе лапароскопии и 81,8% – в группе лапаротомии ( $p=0,482$ ). Аналогичная тенденция отмечалась в снижении меноррагии: 93,3%, 90,5% и 86,4% соответственно ( $p=0,530$ ).

Все три метода хирургического лечения миомы матки способствуют восстановлению менструальной функции и уменьшению симптомов, однако лапаротомическая миомэктомия демонстрирует несколько худшие показатели по сравнению с малоинвазивными методами, особенно в отношении вероятности рецидива заболевания (таблица 7).

Таблица 7

| Долгосрочные исходы после хирургического лечения миомы матки   |                    |                    |                    |                |
|----------------------------------------------------------------|--------------------|--------------------|--------------------|----------------|
| Параметры                                                      | Группа 1<br>(n=30) | Группа 2<br>(n=42) | Группа 3<br>(n=22) | p-<br>значение |
| Экоструктура эндометрия<br>(через 6–12 мес.), %<br>нормальная  | 93,3%<br>(n=28)    | 90,5%<br>(n=38)    | 86,4%<br>(n=19)    | 0,421          |
| Экоструктура эндометрия<br>(через 6–12 мес.), %<br>гиперплазия | 6,7% (n=2)         | 9,5% (n=4)         | 13,6%<br>(n=3)     | 0,378          |
| Рецидив миомы в течение<br>лет, %                              | 16,7%<br>(n=5)     | 19,0% (n=8)        | 27,3%<br>(n=6)     | 0,289          |
| Восстановление регулярного<br>менструального цикла, %          | 96,7%<br>(n=29)    | 92,9%<br>(n=39)    | 86,4%<br>(n=19)    | 0,215          |

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Продолжение табл. 7

|                          |                 |                 |                 |       |
|--------------------------|-----------------|-----------------|-----------------|-------|
| Уменьшение дисменореи, % | 90,0%<br>(n=27) | 88,1%<br>(n=37) | 81,8%<br>(n=18) | 0,482 |
| Уменьшение меноррагии, % | 93,3%<br>(n=28) | 90,5%<br>(n=38) | 86,4%<br>(n=19) | 0,530 |

Анализ отношения шансов (OR) продемонстрировал, что риск рецидива миомы матки через 1–3 года после операции оказался выше у пациенток, перенесших лапаротомическую миомэктомию, по сравнению с гистероскопической миомэктомией (OR = 4,17; 95% ДИ: 1,16–14,92). Это может быть обусловлено более сложными случаями заболевания, крупными размерами миоматозных узлов и выраженными изменениями миометрия.

В то же время вероятность рецидива миомы после лапароскопической миомэктомии не имела статистически значимых отличий от таковой после гистероскопической миомэктомии (OR = 1,00; 95% ДИ: 0,28–3,52), что подтверждает схожую эффективность малоинвазивных методик.

Следовательно, лапаротомическая миомэктомия сопряжена с более высоким риском рецидива заболевания, тогда как эндоскопические методы лечения обеспечивают лучший прогноз в плане долгосрочного контроля роста миоматозных узлов (таблица 8).

Таблица 8

Отношение шансов (OR) рецидива миомы матки при различных хирургических методах

| Сравнение                     | OR   | 95% ДИ (нижняя граница) | 95% ДИ (верхняя граница) |
|-------------------------------|------|-------------------------|--------------------------|
| Лапароскопия vs Гистероскопия | 1.00 | 0.28                    | 3.52                     |
| Лапаротомия vs Гистероскопия  | 4.17 | 1.16                    | 14.92                    |

**Обсуждение.** Исследование подтвердило эффективность миомэктомии, особенно для восстановления фертильности у пациенток моложе 45 лет: частота беременности составила 58,3%, что выше данных Somigliana et al. [5] (54,1%). В группе 46+ лет показатель ожидаемо снизился до 27,8%, коррелируя с результатами Ravone et al. [3].

Ключевыми предикторами рецидивов стали ожирение (34,2% выборки, сопоставимо с Li et al. [6]), артериальная гипертензия (28,7%) и диабет (14,5%) [7]. Курение повышало риск осложнений в 1,8 раза [8]. По шкале UFS-QOL улучшение качества жизни составило 25–30%, что согласуется с Farris et al. [8]. Индексы риска малигнизации (PRE-M и POST-M) были



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значимо выше в группе открытых операций ( $p < 0,05$ ), что объясняется сложностью узлов и совпадает с результатами зарубежных коллег [8].

Общая частота осложнений (12,8%) соответствует мировым стандартам (10,5–14,3%) [13]. Кровопотеря: составила  $210 \pm 45$  мл (ниже данных ACOG [4]). Спаечный процесс: (3,3%) оказался значительно ниже уровня, описанного Herrmann et al. [13] (15%), благодаря применению лапароскопии и противоспаечных барьеров. Сроки госпитализации: при лапароскопии (2,9 дня) соответствуют нормативам ACOG [4], тогда как при абдоминальном доступе (5,7 дня) превышают зарубежные показатели [1].

Частота повторных операций за 3 года составила 16,3%, что ниже данных Davis et al. [12] и близко к результатам Кира Е.Ф. [15]. Риск вмешательств выше при множественных узлах (21,7%). Несмотря на низкий рецидив после ЭМА (9,8%), данный метод ограничивает фертильность [8].

**Заключение.** Наше исследование показало высокую эффективность хирургического лечения миомы матки. Лапароскопическая миомэктомия оказалась менее травматичной, с более коротким периодом госпитализации и меньшим риском спаек. Основные факторы рецидива – множественные узлы, ожирение, АГ и СД. Повторные вмешательства потребовались в 16,3% случаев. Таким образом, наши данные соответствуют данным других авторов и подчеркивают необходимость дальнейших исследований для оптимизации способов лечения.

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# NATURE MANAGEMENT, RESOURCE SAVING AND ECOLOGY

## Innovations in Packaging: the Application of New Materials and Technologies

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**Abstract.** In the modern era, the packaging industry goes beyond simply protecting and transporting products; it must also meet environmental, technological, and economic demands. Traditional packaging materials such as plastic, paper, glass, and metal have revealed various limitations over time, prompting the search for innovative and sustainable alternatives. In recent years, biodegradable materials, recyclable composites, and smart or functional packaging technologies have gained increasing attention. These alternatives not only preserve product quality but also reduce environmental impact, optimize production processes, and better meet consumer needs. Particularly in sectors like food, e-commerce, and logistics, such innovations are being rapidly adopted. The implementation of packaging innovations provides companies with a competitive advantage while contributing to sustainability goals. This abstract provides a general overview of recent developments in packaging technologies, the limitations of conventional materials, and the advantages of modern alternatives.

**Keywords:** *packaging design, ecological design, biodegradable products, brand differentiation, compostable products, recycling, technological innovations, modern alternatives.*

In the 21st century, rapid technological progress, globalization, and increasing market competition have fundamentally reshaped how industries function. Organizations can no longer depend solely on conventional production and management approaches; instead, they must constantly adapt, innovate, and respond to ever-changing market dynamics. In this context, innovation has become a crucial factor in ensuring sustainable growth, maintaining competitiveness, and achieving long-term success. It extends beyond technological advancements to include new methods in management, design, and strategic decision-making. Therefore, innovation is now understood as a broad, multidimensional concept that impacts every stage of production and distribution.

1. The necessity of innovations in the packaging industry

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The modern era is characterized by the rapid development of technology and the increase in global competition. In this environment, one of the key conditions for the successful operation of any organization or enterprise is the implementation of innovations. The adoption process—i.e., the implementation of new ideas, products, or services—can become more effective, flexible, and goal-oriented through innovative approaches. Innovations are manifested not only in technology but also in management methods, decision-making mechanisms, and strategic planning. In this paper, the importance of innovations, their fields of application, and their role in organizational development will be examined in detail.

Packaging today is no longer limited to protecting and transporting goods; it has evolved into a multifunctional system that reflects technological progress, environmental responsibility, and market competition. Alongside traditional materials such as plastic, paper, glass, and metal, new alternatives are being developed to overcome their ecological and functional limitations. In this context, innovative materials and smart technologies play a crucial role in shaping modern packaging solutions.

Innovation in packaging covers technical, design, and social aspects. Development in this field changes both industry and everyday life. Sustainability and creativity are the main criteria of packaging design. As a result, packaging is seen not just as a covering but as the voice of the brand and the consumer's experience. Packaging forms that meet consumer needs and respect the environment are the main brands of the future. Enterprises that accept these changes and turn innovation into a strategic goal will achieve more sustainable success in the future.

### **Environmental protection and ecological problems**

Innovation in packaging is often a response to changes in social trends. Currently, issues such as food growth and localization of production play a major role in the increase of material innovations. Even if materials themselves are not innovative, their non-traditional use can still be considered innovation. Innovation is also motivated by technological progress. The application of artificial intelligence and sensor technologies in packaging optimizes the product production and sales cycle. Active and smart packaging improves storage conditions, increases food safety, and prevents waste. Such technologies are especially necessary in

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the food, pharmaceutical, and cosmetics industries. Environmentally friendly packaging design approaches, such as material usage, can give a second life to many seemingly unusable materials. (Roncarelli, S., & Elliot, C. (2010). *Packaging essentials: 100 design principles for creating packages.*)

Large corporations such as Procter & Gamble actively invest in sustainable packaging strategies. The company focuses on increasing the use of recyclable materials and reducing dependence on virgin plastics. Initiatives such as the use of mono-material packaging and recycled ocean plastics demonstrate practical steps toward minimizing environmental impact and supporting global sustainability goals.

An example of this is the refillable cleaning products of many brands. P&G is working on a strategy to produce packaging made from 100% recyclable materials. In some products, they use mono-material containers (made from only one type of plastic, which makes them easier to recycle). The company plans to reduce the use of virgin plastic in packaging by 50% by 2030. This step saves resources and reduces environmental pressure. P&G also works on projects such as the "Clean Oceans Project," producing packaging made from recycled marine plastics in order to reduce plastic waste entering the oceans. For example, bottles made from plastic waste collected from the sea have been introduced for Head & Shoulders shampoo. (Procter & Gamble. (n.d.). *Plastic packaging.* <https://pginvestor.com/esg/environmental/plastic-packaging/>)

Procter & Gamble is taking strong steps toward circular economy transition in packaging, waste reduction, and strengthening recycling processes. Their focus on innovative and ecological solutions in packaging can be considered a role model for other manufacturers.

### **Changes in consumer demand**

One of the main driving forces of innovations in the packaging sector in recent years is changes in user behavior. Modern consumers pay attention not only to product quality but also to how it is presented, what materials are used in its packaging, and how that packaging affects the environment. These changes lead to innovations in packaging design, material selection, and technological approaches. Previously, packaging mainly served the function of protecting and transporting the product, but today it is also considered the first visual and emotional point of contact with the consumer. Research shows that a large proportion of consumers choose

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products based on packaging attractiveness. Therefore, design and aesthetic appearance, along with functionality, have become important factors.

One of the changes is the demand for transparency and information in packaging. Buyers want clear and accurate information about the product. For this purpose, many brands place QR codes, digital labels, and interactive elements on packaging. Through these tools, users can learn about the product's composition, production process, and origin. At the same time, modern consumers prefer functional and practical packaging. Easy opening, storage after use, and reusability have become key features that distinguish products from others. Especially for urban consumers with a fast-paced lifestyle, such functional solutions are a reason for choosing a brand and product.

To meet these new demands, brands are exploring environmentally friendly materials and innovative packaging designs.

### **Some of the most promising solutions are:**

**Biodegradable and compostable packaging:** Materials such as PLA (polylactic acid) and seaweed-based packaging naturally decompose and reduce waste.

**Innovative packaging for sustainability:** QR codes and NFC labels provide consumers with recycling information, product traceability, and brand transparency. (LBB Online. (n.d.). *Sustainable packaging innovations: Meeting modern consumer demands*. <https://lbbonline.com/news/sustainable-packaging-innovations-meeting-modern-consumer-demands>)

### **Competitive advantage and brand differentiation**

In today's world, where consumer choices are extensive, packaging plays a major role in brand differentiation. Packaging presents a brand's identity, values, and unique selling propositions to the consumer. Through colors, textures, shapes, and typography, products can evoke emotions and communicate messages to consumers. In this way, memorable experiences can be created between the consumer and the brand. In this context, packaging becomes a powerful tool for brand differentiation, helping products stand out on shelves and online platforms.

The use of environmentally friendly materials or innovative designs that minimize waste can distinguish a brand as environmentally conscious. This highlights sustainability advantages and appeals to a specific market segment. As a key component of visual identity, packaging plays an important



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role in brand differentiation.

Packaging helps establish a deeper connection with the target audience, appeal to their values and ethics, and differentiate the brand from competitors. Today, in crowded markets, brands face the challenge of not only standing out but also being remembered and preferred by consumers.

By emphasizing unique selling propositions such as sustainability, technological innovation, or superior quality in packaging, a brand can significantly enhance its differentiation. For example, eco-friendly packaging not only appeals to environmentally conscious consumers but also positions the brand as responsible and caring for the planet. On the other hand, the use of the latest packaging technologies demonstrates a brand's commitment to innovation. Thus, the brand can increase its attractiveness for technology-oriented customers and become a leader in its category.

Packaging does not simply represent the external appearance of products. It is a strategic tool used to strengthen competitive advantage and the brand's market position. Through thoughtful design and innovation, packaging significantly contributes to brand differentiation. Businesses succeed in standing out in crowded markets, connecting with their target audience, and achieving growth and success as a result. (Bay Water Packaging. (n.d.). *The importance of packaging in brand differentiation*. <https://baywaterpackaging.com/the-importance-of-packaging-in-brand-differentiation/> )

## **2. Application of New Materials**

### **Biodegradable and Compostable Materials**

Biodegradable and compostable materials represent one of the most promising directions in sustainable packaging. Unlike conventional plastics, these materials decompose naturally within a shorter period and do not generate harmful residues. Their application contributes to reducing environmental pollution while supporting circular economy principles. In the modern packaging industry, environmental protection is one of the main priorities. The long decomposition period and environmental harm of traditional plastic and synthetic materials force manufacturers to work on alternative, sustainable, and environmentally safe materials. In this context, the application of biodegradable and compostable materials is one of the main directions of packaging innovation. These materials fully decompose under



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natural conditions within a short period of time, do not harm soil and water, and some of them can even be converted into fertilizer through industrial and home composting processes. The use of such materials not only contributes to environmental protection but also demonstrates a brand's ecological responsibility, increasing consumer preference and market differentiation.

- **Polylactic Acid (PLA):**

PLA, usually derived from fermented plant starch obtained from corn, cassava, sugarcane, or sugar beet pulp, exhibits properties similar to conventional plastics. Its versatility allows it to be used in various packaging forms, including bottles, wraps, and containers.

- **Bagasse:**

Bagasse is a by-product of sugarcane processing and is transformed into a valuable packaging resource. It is used for producing disposable containers and food packaging. Bagasse products are compostable and require less production energy compared to paper or plastic products.

- **Cellulose-based films:**

These films, made from wood pulp and cotton, are an eco-friendly alternative to plastic wraps. Transparent, lightweight, and versatile, cellulose-based films are ideal for packaging various products. They are home-compostable and decompose without leaving hazardous residues.

- **Mushroom mycelium:**

As a natural packaging material, mushroom mycelium attracts attention due to its sustainability and versatility. It is formed by combining fungal root fibers with agricultural waste, resulting in compostable and moldable packaging. It is ideal for protective packaging, providing cushioning for fragile items. After use, it can be composted and adds nutrients back to the soil.

Biodegradable packaging is seen as a new norm for environmentally responsible brands. This trend reflects a deeper commitment to sustainable practices and environmental care in society. By adopting naturally decomposing materials, companies not only reduce their carbon footprint but also align with the growing consumer demand for eco-friendly practices. (AA Custom Packaging. (n.d.). *Biodegradable packaging: The new standard for eco-conscious brands*. <https://aacustompackaging.com/sustainability/biodegradable-packaging-the-new-standard-for-eco-conscious-brands/>)

### **Modern Alternatives to Traditional Materials**

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Traditional materials used in the packaging industry for many years include plastic, aluminum, glass, and paper. However, these materials either have very long decomposition times (e.g., plastic) or their production causes environmental harm (e.g., deforestation for paper production or energy-intensive aluminum production). For this reason, in recent years, more sustainable, reusable, and biodegradable alternatives have gained importance. These alternatives provide functionality while reducing the carbon footprint, thus minimizing environmental impact. At the same time, they strengthen the concept of environmental responsibility for both consumers and brands.

### 1. Compostable plastics

Materials such as bagasse, a fibrous by-product of sugarcane after juice extraction, are increasingly used to replace disposable plastic containers and packaging. Unlike plastic, this alternative material is biodegradable and compostable. Bagasse is flexible, food-safe, and widely used in takeaway services. As a by-product of sugarcane production, its use is sustainable. Similarly, the U.S.-based Saltwater Brewery developed compostable six-pack rings made from barley and wheat residues, which were designed to prevent marine animals from being harmed after entering the ocean.

### 2. Cardboard paper water bottles

It is natural to think that paper and water cannot coexist. However, in 2018, shower-safe and water-resistant materials were introduced to replace shampoo and shower gel bottles. The beauty giant L'Oréal, through its hair and skincare brand Seed Phytonutrients, released bottles made from recycled paper with a recycled plastic inner liner. The result is a bottle that uses 60% less plastic than a standard shampoo bottle. Since then, the company has increasingly adopted paper bottles for liquid products.

### 3. Plant-based plastics

Plant-based plastics, also known as bioplastics, are made from starch and bamboo fibers and are then broken down into polylactic acid. Depending on their composition, they can be biodegradable and suitable for either industrial or home composting. Since the cultivation of the plants used does not require pesticides or extensive resources, bioplastics potentially support a more circular economy and reduce environmental impact. They are increasingly used in beverage bottles, food containers, and packaging films by companies such as Innocent.

### 4. Recycled plastics

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When plastics must be used, recycling them as much as possible is essential, and the plastics industry is working to close the recycling loop. In 2016, out of 3,147,000 tons of PET bottles and containers entering the European market, approximately 1,880,900 tons were collected, equivalent to about 60%. Of this, 1,773,200 tons were mechanically recycled. When a strong and durable material is needed, plastic remains unavoidable in some cases. Fortunately, products made from 100% recycled plastic are becoming more common, from shipping materials to industrial pallets and containment tools. (Earth.org. (n.d.). *5 plastic alternatives for packaging*. <https://earth.org/5-plastic-alternatives-for-packaging/>)

### CONCLUSION

Packaging innovations have become a fundamental component of modern industrial and design practices. The integration of new materials and advanced technologies not only enhances product protection and functionality but also addresses critical environmental challenges. Biodegradable materials, smart packaging systems, and sustainable design approaches contribute to reducing ecological impact while improving consumer experience.

Furthermore, evolving consumer expectations and increasing environmental awareness continue to drive innovation in this field. Packaging is no longer perceived as a passive element but as an active medium of communication, brand identity, and sustainability. Therefore, companies that invest in innovative and eco-friendly packaging solutions are more likely to achieve long-term competitiveness and market success.

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## Directions for the Development of Ecotourism in the Shaki-Zaqatala Economic Region

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**Abstract.** Within the framework of the study, the region's natural landscape features, cultural heritage, and ecotourism opportunities were assessed, and the current state of infrastructure was analyzed. The results of the analysis indicate that the tourism sector of the Zaqatala district has a high potential for development. However, weaknesses in infrastructure and marketing strategies, as well as the need to improve the quality of tourism services, were observed. The study also identified the level of local population employment in the tourism sector and the main problems they face in this field. At the same time, the article puts forward proposals related to the development of alternative types of tourism (ecotourism), the identification of new tourism routes, and ensuring sustainable tourism development based on clustering.

**Keywords:** *Zaqatala, employment, socio-economic development, alternative tourism, tourism clusters, tourism routes.*

The tourism sector has emerged as one of the strategically important areas of the global economy, and its development has significant effects in both macroeconomic and socio-political contexts. The acceleration of globalization processes, the application of modern technologies, and the expansion of international integration have further strengthened the development dynamics of the tourism sector [14].

Tourism is not limited merely to influencing economic indicators - such as the growth of Gross Domestic Product (GDP), the increase in foreign currency revenues, and the attraction of regional investments - but also makes strategic contributions to the formation of social structures, the preservation of cultural heritage, and the improvement of the welfare of local communities [21].

Particularly for developing countries, the development of

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tourism creates important opportunities in terms of job creation, increasing the economic activity of regions, and promoting sustainable development. Azerbaijan has not remained outside this general global trend and has made the development of the tourism sector one of the priority directions of state policy.

Among the major steps taken in this direction are the "State Program on the Development of Tourism in the Republic of Azerbaijan for 2010–2014", signed by President Ilham Aliyev in 2010; the State Program on Poverty Reduction and Sustainable Development in the Republic of Azerbaijan for 2008–2015, dated 15 September 2008, No. 3043; and the "Strategic Road Map for the Development of Specialized Tourism Industry in the Republic of Azerbaijan", adopted in 2016 [2, 3, 4].

These documents envisage increasing the role of tourism in the national economy, modernizing tourism infrastructure, and strengthening the country's competitiveness in the international tourism market.

In the modern era, environmental protection, the rational use of natural resources, and the обеспечение социально-экономического благосостояния местных сообществ are regarded as some of the principal directions of sustainable development. In this context, ecotourism holds strategic importance as a form of tourism based on nature, carried out without harming ecological balance, and aimed at strengthening the economic opportunities of local populations.

The North-Western region of Azerbaijan, including the districts of Qakh, Zaqatala, Balakan, Shaki, Oghuz, and Gabala, stands out for the richness of its natural landscapes, unique biodiversity, and cultural heritage, thereby creating favorable conditions for the development of ecotourism. However, in order to fully realize this potential, systematic planning, community-based approaches, and infrastructure improvement are necessary.

Ecotourism emerged in the 1970s and 1980s on the basis of the global idea of "protecting the nature of the Earth" and is considered an approach aimed at creating a balance between the economic benefits derived from nature and the conservation of recreational areas. However, before the concept of ecotourism was introduced, the excessive use of natural recreational areas by tourists had already led to negative environmental impacts. Examples of such impacts include the

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degradation of nature in certain national parks in the United States, the Valley of Geysers in Kamchatka, and the Alps, as well as the increase in waste accumulation on Mount Everest in Nepal and along the Inca Trail in South America.

Although the term “ecological tourism” is widely used in various sources, only some of them provide a clear explanation of this concept. The concept of ecotourism was first formulated in 1980 by the Mexican economist and ecologist Héctor Ceballos-Lascuráin. He characterized this concept as a type of travel that emphasizes a responsible attitude toward nature and aims at the conservation of biodiversity and environmental awareness. Within this framework, ecotourism is regarded both as a means of studying the natural environment and as a tourism activity carried out with minimal impact on flora and fauna (Ministry of Education, 2019). Following this initial definition, many scholars and organizations have proposed different definitions of ecological tourism.

The main feature that distinguishes ecotourism from other types of tourism is that it promotes interaction between people and nature while adhering to the principle of causing minimal impact on the cultural and ecological environment in this process. This form of tourism is aimed at encouraging both tourists and tourism operators to contribute to environmental protection, as well as to the socio-economic well-being of local communities. Consequently, ecotourism is not only a means of environmental conservation, but also an important element of the sustainable development of natural areas.

The existence of numerous definitions related to ecotourism demonstrates that this field has not yet been fully systematized from either a theoretical or practical perspective and is still in a stage of development. For this reason, in order for any given definition to be considered comprehensive and adequate, it is important that it reflect the fundamental principles that constitute the essence of ecotourism. These principles indicate that ecotourism is not limited solely to nature-oriented activities, but is also based on the integration of social, economic, and ecological dimensions.

- Preservation of the biodiversity of natural recreational areas;
- Increasing the level of economic sustainability of regions involved in ecotourism;
- Enhancing the environmental awareness and ecological



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culture of participants engaged in ecotourism activities;

- Preservation of the ethnographic status of recreational areas.

As a result, one of the main characteristics of ecotourism is that this form of tourism not only satisfies people's need for interaction with nature, but also aims to minimize negative impacts on the environment and cultural heritage. At the same time, tourists and tourism organizers involved in ecotourism activities are encouraged to contribute actively to environmental protection as well as to the socio-economic development of local communities.

Today, ecotourism is evaluated at the global level not only as a means of nature conservation, but also as one of the key mechanisms contributing to the socio-economic development of surrounding areas. In the majority of definitions of ecotourism presented in various sources, its direct connection with sustainable development is clearly evident. In this context, the concept of sustainability is understood primarily as ensuring an optimal and long-term balance among the ecological, socio-cultural, and economic impacts of tourism activity. In addition, the positive interaction and behavioral patterns among ecotourists themselves also play an important role in maintaining this balance.

Thus, ecotourism is not merely a form of recreational activity, but also serves as an important instrument that promotes the efficient and responsible use of natural resources, supports ecological balance, and contributes to regional sustainable development. This approach demonstrates that forms of tourism that are environmentally sustainable, economically effective, and socio-culturally inclusive can best be assessed within the broader context of sustainable tourism models.

Before Héctor Ceballos-Lascuráin introduced the term "ecotourism" in 1980, there were nearly 30 concepts and terms that were, to varying degrees, close in meaning to this notion (and many of them still exist today). Nature tourism (*nature tourism, nature-based tourism, or nature-oriented tourism*), unlike ecotourism, is based primarily on people's motivation – such as recreation or visiting natural areas—and on the character of their activities, for example, high-speed movement on rivers, trekking, and similar pursuits. Ecotourism, by contrast, is fundamentally based on interaction with the local population and the creation of



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more favorable economic conditions in areas suitable for ecotourism. Thus, nature tourism is not regarded as a concept in itself, but rather as a description of specific types of tourism that may affect the environment in different ways.

Since the late twentieth century, ecotourism has become one of the fastest-growing forms of tourism worldwide. The declaration of 2002 as the "International Year of Ecotourism" by the United Nations World Tourism Organization (UNWTO) significantly increased global interest in this field. Over the last 20 years, demand for ecotourism has grown at an average annual rate of 10–15% (UNWTO, 2022).

The tourism sector has emerged as one of the strategically important areas of the global economy, and its development has significant effects in both macroeconomic and socio-political contexts. The acceleration of globalization processes, the application of modern technologies, and the expansion of international integration have further strengthened the development dynamics of the tourism sector [14]. Tourism is not limited merely to influencing economic indicators—such as the growth of Gross Domestic Product (GDP), the increase in foreign currency revenues, and the attraction of regional investments – but also makes strategic contributions to the formation of social structures, the preservation of cultural heritage, and the improvement of the welfare of local communities [21].

Particularly for developing countries, the development of tourism creates important opportunities in terms of job creation, increasing the economic activity of regions, and promoting sustainable development. Azerbaijan has not remained outside this general global trend and has made the development of the tourism sector one of the priority directions of state policy. Among the major steps taken in this direction are the "State Program on the Development of Tourism in the Republic of Azerbaijan for 2010–2014", signed by President Ilham Aliyev in 2010; the "State Program on Poverty Reduction and Sustainable Development in the Republic of Azerbaijan for 2008–2015" (No. 3043, dated 15 September 2008); and the "Strategic Road Map for the Development of Specialized Tourism Industry in the Republic of Azerbaijan", adopted in 2016 [2, 3, 4]. These documents envisage increasing the role of tourism in the national economy, modernizing tourism infrastructure, and strengthening the country's competitiveness in the international tourism market.

In general, the revival of tourism in Azerbaijan is

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observed mainly during the summer season. During the summer months, tourists travel to various destinations for recreation and tend to prefer отдых in an environmentally clean setting. Considering the existing conditions, small villages located in mountainous regions possess particular attractiveness for tourists from the perspective of ecotourism. These areas have significant potential both for the development of ecotourism and for the expansion of socio-economic opportunities for the rural population.

One of Azerbaijan's important natural-geographical advantages is its climatic diversity. Of the 11 major climate types recognized worldwide, 9 are observed within the territory of the country (Ministry of Ecology and Natural Resources, 2021). This diversity has played an important role in the formation of the country's biological richness. At present, Azerbaijan is home to more than 4,500 plant species, which constitute approximately 64% of the flora of the Caucasus (Ministry of Ecology and Natural Resources, 2021). Of these, 240 species are endemic or relict in nature. In addition, nearly 140 rare and endangered plant species have been included in the Red Book of the Republic of Azerbaijan (Ministry of Ecology and Natural Resources, 2021).

In terms of fauna, approximately 14,000 insect species, 123 fish species, 9 species of aquatic invertebrates, 54 reptile species, 360 bird species, and 99 mammal species have been recorded in the country. Of these, 108 species are listed as protected species in the Red Book (Science Development Foundation under the President of the Republic of Azerbaijan, 2019).

In recent years, one of the regions of Azerbaijan that has shown notable development in the field of ecotourism is the Shaki-Zaqatala economic-geographical region, located in the north-western part of the country, on the southern slopes of the Greater Caucasus Mountains. The Shaki-Zaqatala economic-geographical region includes the administrative districts of Balakan, Qakh, Gabala, Oghuz, Shaki, and Zaqatala. It is situated in north-western Azerbaijan, on the southern slopes of the Greater Caucasus and within the Ganikh-Ayrichay Valley. The region covers an area of 8.96 thousand km<sup>2</sup>, accounting for 10.3% of the country's total territory. Its population amounts to 581.7 thousand people, of whom 160.7 thousand are urban residents. 5.7% of the country's population lives in this region, and the urbanization level is 27.6%. The population is concentrated mainly in the foothill zone.

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Forests cover 27% of the territory, with the largest share located in the Balakan and Zaqatala districts.

The Shaki-Zaqatala economic-geographical region comprises six administrative districts. The region's climatic conditions, relief structure, and hydrographic network create favorable natural conditions for the development of ecotourism. The duration of annual solar radiation amounts to 2,200–2,400 hours, indicating the predominance of sunny days throughout the year. During the coldest months, average temperature indicators vary across the territory: in some zones, winter conditions are moderate (0 to  $-5^{\circ}\text{C}$ ), while in others the climate is very mild ( $2.5$  to  $5^{\circ}\text{C}$ ).

Between April and October, the level of potential evaporation ranges from 400 to 1,000 mm, which is significant in terms of humidity and water balance. During the period from June to September, the number of dry days generally varies between 5 and 25 days. The average annual wind speed is low – approximately 2 m/s or less—which creates a favorable environment for tourism activities. The climate of the region varies mainly from weakly continental to moderately continental. The length of the frost-free period during the year ranges from 150 to 250 days, while the number of days with temperatures below  $0^{\circ}\text{C}$  fluctuates between 20 and 120 days (Institute of Geography, Azerbaijan National Academy of Sciences, 2020).

Although a subtropical climate prevails at elevations of 500–700 meters above sea level, with increasing altitude the climate becomes cool and temperate-cold in character. In terms of precipitation, this region ranks second in the country after the Lankaran-Astara zone. The lowest precipitation is observed in the Ajinohur area (300–350 mm), while the highest precipitation occurs in the middle mountainous zones (1,000–1,300 mm) (Institute of Geography, Azerbaijan National Academy of Sciences, 2020).

The hydrographic network of the region is also highly developed. Most of the rivers here originate in the mountains and are characterized by high water discharge and flood potential. The most significant rivers include Mazim (30 km; 2,720 m), Kish (33 km; 3,680 m), Shin (39 km; 2,800 m), Balakanchay (39 km; 1,000 m), Ayrichay (46 km; 3,200 m), Katekh (54 km; 2,840 m), Garachay (56 km; 2,800 m), Kumruk (55 km; 3,480 m), Demiraparan (69 km; 3,400 m), Alijan (98 km; 3,500 m), Turyan (180 km; 3,680 m), and Ganikh (413 km; 3,500 m).

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The region is also rich in various natural hydrological resources, particularly thermal and mineral waters. Water sources such as Oghlanbulag, Gizbulag, Hamambulag, Budushor, Aghbulag, and Khal-khal enhance the balneological tourism potential of the region. Natural lakes such as Tufangol, Nohurgol (Gabala), and Ajinohur Lake (Qakh) create favorable conditions for various forms of ecological tourism.

This richness of climate, water resources, relief, and biodiversity further strengthens the region's ecotourism opportunities. Against the background of growing interest in ecological tourism, this region has a sufficiently high potential to become a center of tourism activities at both the domestic and international levels. Based on these characteristics, Table 2.1, presented below, systematizes the ecotourism opportunities of the North-Western region of Azerbaijan in the context of natural resources and ecological significance.

Table 1

| Ecotourism Potential of the Shaki-Zaqatala Economic Region |                                                                                                                                                                                    |                                             |                                                                                                                                                                                                     |
|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| District / City                                            | Main Ecotourism Attractions                                                                                                                                                        | Natural Resources and Features              | Tourism Opportunities / Activities                                                                                                                                                                  |
| Qabala                                                     | Nohur Lake, Yeddi Gözəl Waterfall, Tufandag, Gabala Forests, Shahdag National Park, Duruca and Bum Villages, Qəmərvan Forests and River Valleys, Vandam Village, Amirvan Highlands | Lakes, Forest Massifs                       | Mountain biking, ecological summer camps, hiking, village tourism, ecological observation, camping, village tourism and local hospitality (homestay), orchard tours and tasting of natural products |
| Oguz                                                       | Xalxal Waterfall, Meşəbəy Village, Qalaboyun and Bayan Villages, Mountain-Forest Zone, Bağlıca and Filfilli Rivers, Highlands (Sarıdağ, Ilisu Road Area)                           | Mountain-Forest Climate, Ecological Balance | Green camps, horseback riding tours, nature walks, cycling tours, village tourism, mountain hiking, homestay experiences and cultural immersion in village life, highland trips                     |

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Table continuation 1

|          |                                                                                                                                                                                                                                                             |                                                                            |                                                                                                                                                                                                                                                                                         |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Sheki    | Kish River and Kish Village, Oxud and Baş Göynük Villages, Shaki Highlands (Sarica, mountain hiking, ecological tours, village tourism, family farm visits - Qaratorpaq, etc.), Biodiversity Areas, "Khudger" and "Meşəbaşı" Waterfalls, Danavech Highlands | Forests, Mountains, Rivers                                                 | Mountain hiking, ecological tours, village tourism, participation in family farms, mountain biking and horseback riding, orchard tours and natural product tastings, camping, tent tourism, photography and adventure tours, introduction to local natural products                     |
| Qax      | Ilisu Village, Ram-Rama Waterfall, Caucasus Mountains, Areas of Əyriçay and Kürmük Rivers, Sarıbaş Village, Ilisu State Nature Reserve                                                                                                                      | Mountains, Rivers, Forested Areas                                          | Camping, nature hikes, village tourism, mountain hiking, homestay services, ecological nature observation, photography, tent tourism, ecological nature observation (birds, flora, fauna)                                                                                               |
| Zaqatala | Zagatala State Nature Reserve, Mazikh, Qımır, Mamrux and other mountain villages, Silban Forests, Qalaçay Valley, Car Village, Katekh River                                                                                                                 | Subtropical Climate, Rare Plant Species, Mountains, Rivers, Forested Areas | Ecological hikes and mountain tours, staying in village houses and experiencing local lifestyle, nature walks and ornithological observation, camping and ecological tours, photography and adventure tours, introduction to local natural products (honey, hazelnuts, walnuts, fruits) |

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Table continuation 1

|         |                                                                                                                                         |                            |                                                                                                                                                                                                                                                           |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Balakan | Katekh Forests, Mazımçay and Balakənçay Rivers, Gullar Village, Qubek Mountain Massifs and Valleys, Forest Strips and Hazelnut Orchards | Mountains, Forests, Rivers | Nature walks and mountain hikes, staying in village houses and village tourism, introduction to local products (honey, hazelnuts, fruits), camping and photography sessions, ornithological and ecological observation, adventure tours and photo tourism |
|---------|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

As seen from the table, Azerbaijan's North-West region is rich in diverse natural resources and provides ideal conditions for ecotourism activities. The forests, mountains, rivers, waterfalls, and highlands in this area offer extensive opportunities for ecotourism, village tourism, mountain tourism, and nature observation. Nature-oriented excursions, mountain routes, ecological tours, and village tourism activities organized in the region have the potential to contribute both to the improvement of local communities' social welfare and the conservation of the environment. The region's ecotourism potential is also significant for promoting local natural products (honey, hazelnuts, fruits, etc.) and showcasing traditional lifestyles. This provides tourists with unique experiences while simultaneously supporting the local economy.

**MATERIALS AND METHODS**

During the research, an extensive review of relevant scientific literature was conducted, referencing both local and international studies. In this context, the works of local researchers such as Abadov M.K., Müseyibov M., Budaqov B., Əhmədov N., Əzəmmədov S., İmrani Z.T., Məmmədov E.Q., Rəsulova M., Bəhərçi T., and Zeynalova K.Z., as well as studies by international scholars including Лопатников Д.Л., Sezgin M., and Porter M.E., were utilized. These sources provided a foundation for scientifically evaluating the tourism potential of Zaqatala district and linking it to employment issues.



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## The Role of Routes in the Formation of Tourism Clusters

Competitive tourism clusters require the synergy of various stakeholders—tourism operators, transport services, and cultural sites—and this collaboration is considered one of the key mechanisms for regional development [17]. Proper route planning shapes the functional structure of these clusters, strengthening economic connections and ensuring sustainable development [11].

In Zaqatala district, the systematic management of existing tourism potential in ecotourism, cultural tourism, and village tourism, as well as the planned organization of routes, is crucial for achieving sustainable regional development. The formation of tourism clusters facilitates coordination and interaction among entities operating in different sectors within the region while simultaneously increasing access to broader markets. As a result, this approach enhances the competitiveness of the district's tourism sector and supports economic and social development.

Moreover, improving organizational and management mechanisms for the conservation and efficient use of natural and cultural resources promotes the integration of ecotourism and cultural tourism sectors, increasing the synergy effect. Within this study, the existing tourism routes in Zaqatala district were grouped according to specific criteria, and for the first time, competitive tourism clusters corresponding to these routes were identified, as presented in Table 2.

Table 2  
Grouping and Classification of Tourism Routes by Category in the  
Zaqatala District.

| Route Category                          | Routes and Main Attractions                                                                                                                                                                                                                                                                                                                                                                                               | Tourism Clusters                                                                                                                                                                   |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Historical and Cultural Heritage Routes | <ul style="list-style-type: none"><li>• Car Village (Cingöz Castle, Şeytan Castle, 17th-century Mosque)</li><li>• Aşağı Tala Village (Aşağı Tala Mosque, Omar Efendi Shrine)</li><li>• Qəbizdəre Village (8th-9th-century Temple)</li><li>• Kəbəloba Village (Kəbəloba Tower)</li><li>• Yuxarı Çardaxlar Village (3rd-4th-century Maiden Tower, Periqala Cave)</li><li>• Mamrux Village (Circular Alban Temple)</li></ul> | Craft and Handicraft Production Enterprises that encompass values such as archaeological and architectural monuments, religious and ethnographic heritage, and folk craftsmanship. |



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Table continuation 3

|                                      |                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                 |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                      | <ul style="list-style-type: none"><li>• Zaqatala Historical and Cultural Reserve</li><li>• Pipan Basilica (7th-8th century)</li></ul>                                                                                                                                                                                                                                                                                         |                                                                                                                                                                                 |
| Agrotourism Routes                   | <ul style="list-style-type: none"><li>• Aşağı Tala Village (tobacco and flower plantations: rose, lavender, mint)</li><li>• Muğanlı Village ("Babek" and "Ülkər" viticulture farms)</li><li>• In villages such as Bəhmətli, Göyem, Suvagil, Yuxarı Tala, etc. (livestock farming, beekeeping, and fishing)</li></ul> Collection of hazelnuts, walnuts, and chestnuts; experiencing village life; production of local products | Agricultural facilities, experimental fields, farmers' markets and farms, vineyards, tea plantations, organic production areas, and other related sectors aimed at agrotourism. |
| Ecotourism Routes                    | <ul style="list-style-type: none"><li>• Qəbizdəre Village (waterfalls and forests)</li><li>• Qazangül Village (Sarı Lake, Ümid Lake)</li><li>• Meşleş Village (Sarmaşık Waterfall)</li><li>• Zaqatala State Nature Reserve (waterfalls, Piçigel Cave)</li></ul>                                                                                                                                                               | Tourism facilities and enterprises oriented toward ecotourism; reserves, nature parks, national parks, and other sites that do not harm the ecosystem.                          |
| Adventure and Extreme Tourism Routes | <ul style="list-style-type: none"><li>• Yuxarı Çardaxlar Village (Xalaxel Lake)</li><li>• Katex and Qanslar Waterfalls (mountain hiking and camping)</li><li>• Zaqatala State Nature Reserve (mountaineering and trekking)</li></ul>                                                                                                                                                                                          | Tourism facilities and enterprises focused on ecotourism; reserves, nature parks, national parks, and other sites that do not harm the ecosystem.                               |
| Religious Tourism Routes             | <ul style="list-style-type: none"><li>• Aşağı Tala Village (Omar Efendi Shrine)</li><li>• Danaçı Village (19th-century Mosques)</li><li>• Pipan Basilica (Christian Religious Monument)</li></ul>                                                                                                                                                                                                                             | Complexes, mosques, churches, shrines, temples, and other sites related to religious belief systems and cultures.                                                               |
| Health and Wellness Tourism Routes   | <ul style="list-style-type: none"><li>• Sulfate-mineral springs and natural healing waters in Çimçimax, Əliabad, Qımır, Sabunçu, Mamrux, and Yuxarı Çardaxlar villages (Zaqatala State Nature Reserve)</li><li>• Shamilovka Highland (nature and wellness hiking)</li></ul>                                                                                                                                                   | Wellness hotels, health centers; rehabilitation centers; facilities offering therapeutic spa services, recovery programs, and massage therapy; thermal water centers.           |
| Gastronomic Tourism Routes           | <ul style="list-style-type: none"><li>• Local cuisine specialties based on livestock products (all villages)</li><li>• Aşağı Tala Village (flower</li></ul>                                                                                                                                                                                                                                                                   | Restaurants and cafés; local product producers; enterprises operating in the agriculture and food                                                                               |

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Table continuation 3

|                      |                                                                                                                                          |                                                                                                                                                                 |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                      | <ul style="list-style-type: none"><li>• products - rose tea, rose pastries)</li><li>• Muğanlı Village (grape and wine tasting)</li></ul> | industry sectors; wineries and breweries, etc.                                                                                                                  |
| Urban Tourism Routes | Zaqatala City Tour (Historical and Cultural Reserve, Dede Gorgud Square, Plane Tree, Qala Duzu Stairways, and Park)                      | Shopping centers and retail complexes; amusement parks and cinemas; museums (history, art, archaeology, ethnography) and other urban infrastructure facilities. |

Source: Compiled based on the research of Aygün İsmaylova, a researcher at the Shaki Regional Scientific Center of ANAS.

The Shaki-Zaqatala economic region, with its rich nature, ancient history, and recreational potential, is one of Azerbaijan's main tourism regions. In the districts of Qabala, Shaki, Zaqatala, and Qakh, recreational centers, thermal springs, and ecotourism opportunities are being developed. Additionally, silk production, kelaghayi craftsmanship, and local cuisine (Eastern sweets) enhance the region's tourism appeal.

The analyses conducted and the proposed solutions provide relevant conclusions on the issues mentioned and identify directions for development in the form of recommendations. The study revealed that in a region with rich tourism opportunities, resolving existing problems can attract more tourists and positively influence the tourism image of the country to which the region belongs. By developing various types of tourism, including alternative tourism, in a destination region, it is possible to contribute to the national economy and increase revenue.

One of the most notable problems identified in the research related to Shaki is the dilapidated state of some historical and architectural monuments. For example, restoring several ruined sites, such as the Alban Temple, is necessary to preserve the region's historical heritage and ensure that conservation efforts are undertaken. Additionally, the development of high-quality hotel services and transport infrastructure can influence tourists' decisions to visit and lead to an increase in tourist flows.

Tourism, considered one of the most important and profitable sectors today, plays a crucial role in enhancing welfare levels and promoting countries positively on the

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global stage. In recent years, Shaki's hosting of several international events and the significant tourist interest in various competitions held there demonstrates the special position of Shaki as a tourism destination in Azerbaijan.

As a result of the research, we consider it essential to undertake a series of measures to develop alternative types of tourism in Shaki:

- Restoration of several historical and architectural monuments that require repair and conservation;
- Creation of new employment opportunities through the construction and commissioning of new tourist facilities alongside existing tourism enterprises;
- Improvement of transport infrastructure, including the development of key roads and service points;
- Implementation of measures to ensure that tourism facilities in Shaki meet international standards in both service and quality;
- Development of language skills and other professional competencies for specialists and staff working in the tourism sector, including regular training courses and seminars at tourism enterprises, hotels, and guesthouses;
- Organization of comprehensive service systems to simplify formalities, documentation, permits, and related processes, making it easier for foreign tourists to visit.

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### Public–Private Partnership and its Importance for Energy Investments

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It is understood that energy investments, as a necessity and reality of life, are now shaped–within the framework of advanced technology and ecology that characterizes the 21st century, at whose beginning we still stand–by the tripod of “geo-economics, political economy, and the knowledge economy.” From this perspective, the role of the Public–Private Partnership (PPP) model–considered an innovation–is primarily examined within a theoretical framework in the context of energy investments. Since energy is a vital resource worldwide, energy investments possess a strategic character and, accordingly, have evolved into a vast market. In this market, where both benefits and burdens are substantial, it is evident that neither the public sector nor the private sector can act alone, nor can either establish monopoly power sufficient to determine prices independently. Therefore, energy investments have acquired the nature of a shared–and collectively structured–market in which the public and private sectors distribute roles, and accordingly share both risks and profits; in other words, they engage in cooperation and division of labor.

The state’s invitation to the private sector to participate in energy investments as a “partner actor,” through its regulatory, supervisory, enforcement, and incentivizing roles exercised via legal and political instruments, is technically a requirement of the liberal–capitalist system. The implementation of the PPP model–through which the state, even when capable of acting independently, shares the growing “pie” of energy investments

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(that is, returns and risks) with private enterprises—ensures the existence and continuity of this system. Future projections for a world that is increasingly populous, industrialized, and urbanized—and therefore experiencing rising potential energy demand—indicate the necessity of this model at both global and national levels.

Despite certain constraints imposed on the state in liberal economies, cooperation between public and private sectors in infrastructure investments—particularly in energy—has reached an advanced stage and has become widely recognized worldwide under the abbreviation “PPP” or “3P” (public-private partnership). This cooperation is expressed in various forms, such as “Public-Private Sector Cooperation,” “Private Participation in Infrastructure (PPI),” “Public-Private Cooperation,” “Public-Private Alliances,” “Public-Private Partnership,” “Public-Private Sector Partnership,” “Public-Private Partnership Model,” “Private Finance Initiative (PFI),” “partial concession,” “value for money (VfM),” and joint provision of goods, services, or operations. According to the general definition of the World Economic Forum (WEF), PPP refers to agreements in which risk is shared between public and private sectors within the scope of an investment or project, and in which the private sector provides and/or undertakes services such as design, construction, management, and maintenance. In large-scale investments, where inefficient projects are eliminated and only efficient ones are pursued, the state acts as guarantor in the name of public interest, while the private sector contributes entrepreneurial techniques and mobilizes financing; thus, projects are completed in the fastest and most cost-effective manner possible.

Both the public sector (state, region, municipality)—motivated by public interest—and the private sector—motivated by profit—show particular interest in infrastructure investments. Infrastructure consists of drinking water networks, energy (electricity, natural gas transmission and distribution), and transportation (roads, tunnels, bridges, ports, airports). In PPP-based infrastructure investments, the proportion of public and private participation is crucial: theoretically, if a state-centered economy is designed, the public share in PPP ranges between 51% and 90%; conversely, in a private-oriented liberal economy, this ratio may be reversed. PPP projects are characterized by “2U”: uniqueness and uncertainty. Because projects are unique operations, they

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inherently involve a certain degree of uncertainty. Organizations that produce projects typically divide them into stages—initiation, planning, execution, completion, monitoring, and control—to ensure efficiency and continuity; the combination of these stages is called the “project life cycle.” Within this cycle, input procurement, time, cost, communication, and risk management are critically important for project success. (See Pal, 2026; Steelyana and Aulia, 2024; Asin and Sanchez, 2021).

Depending on economic needs and country-specific practices, the PPP model has many types or phases; therefore, it is not standardized and varies according to circumstances. An infrastructure investment project may begin and end under one PPP model (“x”), transform into another model (“y”) during implementation, and eventually take the form of a third model (“z”). Thus, there is no hierarchical order among models; rather, there exists a “non-directional cycle.” Their common feature is that the public sector is typically the initial designer, builder, operator, and transferor, while the private sector is the recipient or lessee. Governments negotiate and contract with private firms for infrastructure projects that serve public interest. The PPP model may consist of at least one phase (e.g., leasing) or up to four phases (“design-build-operate-maintain”), taking its name from these stages. Sub-models dominated by the public sector include “design-build,” “design-build-maintain,” and service or management contracts, whereas the private sector is dominant in concession-based models such as “leasing,” “design-build-operate,” “build-own-operate,” and “full privatization.”

There are numerous factors that make PPP implementation attractive in infrastructure investments. These range from reducing government budget expenditures and transferring income to the private sector, to lowering project costs and promoting local economic development. The logic of PPP rests on the fact that the public sector may lack sufficient funds to finance all infrastructure projects, may seek to save on expenditures, may prefer to defer spending, or—even if financially capable—may prefer to allocate resources, revenues, and market shares to private partners rather than directly invest its own capital. As Hadjuka (2014) states, PPP should increase the transactional value of money by providing clear benefits in terms of quantity, quality, service, cost, and risk transfer. However, one factor that may undermine PPP’s success in the eyes of the electorate is



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its vulnerability to general political risks and corruption.

A key success factor of PPP models is transparency toward economic governance and the public. Transparency is a requirement of democracy in economics. As Greve and Hodge (2011) note, transparency ensures citizens' freedom of information, openness in relations between administrators and stakeholders, predictability in decision-making processes, and the fight against corruption. However, some concerns or myths persist regarding the philosophy underlying PPP. For example, Tadimalla (2020) argues that claims such as the incompatibility of private profit motives with public service objectives, increased user costs, additional burdens on the private sector, or the limited role of private actors are misconceptions; in reality, PPP carries positive implications.

PPP-based investments are also related to the "X-efficiency" thesis in microeconomic theory, which reduces firm efficiency problems to input-output relationships. Defined by Leibenstein (1966, 1973), X-efficiency refers to a situation in which a firm, as a decision-making unit, allocates resources internally to achieve maximum output (or minimum cost) given its technical capabilities and managerial skills. In a perfectly competitive market, minimizing input costs is essential, and such firms may represent private entities operating under PPP arrangements. However, when markets become monopolized and conditions such as incomplete contracts, asymmetric information, high transaction costs, and bounded rationality prevail, "X-inefficiency" may arise—meaning that maximum output cannot be achieved from given inputs.

In order to maintain current welfare levels and secure future prosperity, the modern world continuously plans and invests in energy projects. According to Schmidt (2010) and Vagliasindi (2013), there are four major reasons why governments must take energy investments seriously:

i) Due to urbanization and globalization, energy demand is projected to increase by 49% between 2007 and 2035 (even today, more than 1.5 billion people lack access to electricity).

ii) Despite the Kyoto Protocol, excessive energy consumption leading to high carbon emissions continues to negatively impact the global climate.

iii) Renewable energy sources such as solar, wind, biogas, and geothermal are growing rapidly as alternatives to

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fossil fuels, yet they attract limited attention from PPP investors.

iv) Competition across all energy resources—including renewables—has intensified, increasing energy consumption and prices, thereby creating inflationary risks.

Governments have also allocated billions of US dollars in financial resources under global "green stimulus" programs, creating a foundation for PPPs in clean energy investments. The European Union's Green Paper (EUR-Lex, 2007) distinguishes between two types of PPPs: (i) contractual PPPs, based entirely on agreements between public and private actors; and (ii) institutional PPPs, which involve independent entities beyond contractual arrangements. All such frameworks emphasize "energy efficiency," a key component of the EU's Europe 2020 Strategy, including a 20% energy-saving target across all sectors.

The ultimate goal of PPP is to achieve and sustain energy efficiency (EE). However, financing EE faces several barriers, including limited internal funds, information gaps, small project sizes, high development costs, risk assessment challenges, and institutional capacity constraints. To address these issues, policy frameworks should include evaluating PPP design, managing performance and contracts, assessing implementation, identifying priority markets, and overseeing execution processes.

PPP for renewable energy investments is supported politically by major international financial institutions such as the World Bank Group (see 2026), Asian Development Bank (ADB), European Investment Bank, European Bank for Reconstruction and Development (EBRD), Inter-American Development Bank (IDB), and African Development Bank (AfDB). These institutions generally advocate for PPP laws that encourage private participation, ensure fair concession sharing, allow negotiation of contracts, permit guarantees, and secure collateral rights.

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### Удосконалення електропривода подач багатоцільового верстата

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**Анотація.** Проведено аналіз роботи системи керування електропривода подачі багатоцільового верстата.

**Ключові слова:** багатоцільовий верстат, електропривод, електродвигун постійного струму, перехідна характеристика, математичне моделювання, показники якості системи керування, нелінійна система.

Сучасні верстати – це верстати, які здатні виконувати обробку деталей з точністю до мікрометрів, важкі верстати для опрацювання великих деталей розмірами в декілька десятків метрів, верстати для фізико-хімічних методів опрацювання, верстати-автомати для контурного програмного опрацювання дуже важких по формі деталей. Багатоцільові верстати призначені для свердління, розсвердлювання, зенкерування, розгортання, нарізання різьблення, розточування, фрезерування та інших видів обробки. Вдосконалення сучасних верстатів повинно

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забезпечувати підвищення швидкостей робочих та допоміжних рухів при відповідному підвищенні потужності привода головного руху або приводу подачі. Саме це і є основною метою даної роботи. Прогнозується, що підвищення швидкодії приведе до зміни параметрів системи, усунення усталеної помилки керування та ін.

Багатоцільові верстати – це верстати, оснащені ЧПК і пристроєм автоматичної зміни інструментів, призначені для комплексної обробки за одну установку корпусних деталей і деталей типу тіл обертання [ 2 ]. Багатоцільові верстати випускають з одним шпинделем і багатопозиційним інструментальним магазином (місткістю 12–120 інструментів), при цьому інструмент замінюється в шпинделі автоматично за програмою (за 5–6 с); з револьверної інструментальної головкою (число інструментів 5–8, при цьому зміна інструменту за 2–3 с) здійснюється поворотом револьверної головки; з револьверною голівкою і інструментальним магазином, що дозволяє в процесі різання замінювати інструмент в непрацюючих шпинделях револьверної головки. Продуктивність багатоцільових верстатів в 4–10 разів вище продуктивності універсальних верстатів завдяки різкому зменшенню частки допоміжного часу в циклі обробки і, отже, збільшення (до 60–75%) частки машинного часу в цьому циклі. Скороченню допоміжного часу сприяють автоматична заміна інструменту; висока швидкість (до 20 м/хв) швидких переміщень (на допоміжних ходах) виконавчих органів; настройка інструменту на розмір поза верстата; виключення контрольних операцій та ін. В багатоцільових верстатах використовують змінні інструментальні магазини із заздалегідь налаштованими на розмір інструментами, що скорочує час на переналагодження верстата. На даних верстатах можна здійснювати свердління, розсвердлювання, зенкерування, розгортання, нарізання різьблення, розточування, фрезерування та інші види обробки. На багатоцільових верстатах здійснюють, як правило, остаточну обробку деталей.

Верстат IP500MФ4 (рис. 1) призначений для свердління, зенкерування, розгортання, розточування отворів в корпусних деталях, фрезерування по контуру, нарізування різьблень мітчиками в умовах серійного виробництва. Крім автоматичної зміни інструментів верстат має автоматичну зміну столів-супутників. Ємність магазину – 30 інструментів [2].

Система ЧПК – комбінована з лінійною і круговою інтерполяцією. Верстат укомплектований різними пристроями ЧПК і від цього залежить дискретність завдання переміщень, але в

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середньому вона становить 0,002 мм. Число керованих координат – 8, з них одночасно 3/2. Є 79 коректорів (ця цифра змінюється в різних типах пристроїв ЧПК). Введення програми з перфострічки (код. ISO, EUA) або від ЕОМ; зчитування з перфострічки – фотоелектричне, відпрацьовуються автоматичні цикли по ISO. Деякі з пристроїв ЧПК, що працюють з верстатом, мають діагностику несправностей механічних, електричних, електронних і гідравлічних систем верстата.



Рисунок 1

Для привода подач використано двигун ПБСТ, який призначений для роботи з діапазоном регулювання від 1:2000 (для верстатобудування) в широко регульованих електроприводах. Вони мають 5 габаритів – з другого по шостий, і виконуються як із вбудованим тахогенератором (ПБСТ), так і без нього (ПБС) [3].

Для системи керування приводу подач було обрано електропривод типу ЕТУ-3601, який призначений для створення на основі високомоментних двигунів постійного струму швидкодіючих, широкорегулюючих (з діапазоном регулювання до 1÷10000) приводів подач металорізальних верстатів, у тому числі верстатів з числовим програмним керуванням (ЧПК). Функціональна схема привода наведена на рис. 2.

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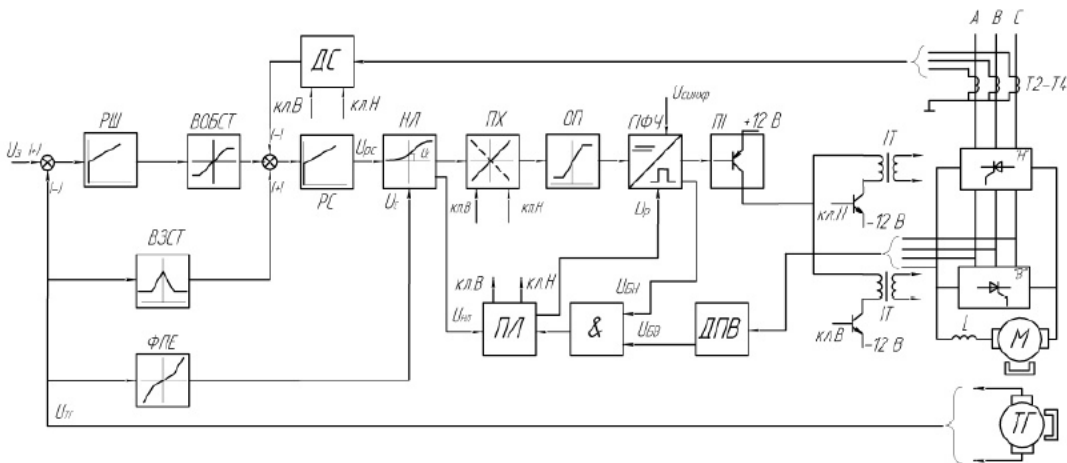


Рисунок 2

Тиристорні електропривода ЕТУ-3601 призначені для створення реверсивних систем керування електродвигунами постійного струму механізмів подачі металорізучих верстатів у тому числі і верстатів із ЧПК. Саме тому привод широко розповсюджений. Забезпечення необхідних статичних і динамічних характеристик приводу подач, забезпечення оптимального закону обмеження струму, щонайкраще реалізується в двоконтурній системі підпорядкованого регулювання параметрів із П- або ПІ-регуляторами струму і швидкості. Для підвищення продуктивності верстатів переміщення виконавчих органів в зону обробки здійснюється на швидких ходах тими ж електроприводами подачі, що короткочасно працюють на частотах обертання вище номінальних, за рахунок подачі на якорь двигуна напруги, вище номінальної. Збільшення швидкості швидких переміщень до 10 м/хв. і зниження швидкості установочних переміщень для верстатів із ЧПК потребує значного діапазону регулювання (до 10000:1).

В системі використано силовий трансформатор серії ТСП – 16/0,7 – УХЛ4 [5], який має номінальну потужність 7.3 кВА. Після розрахунку параметрів системи керування, були отримані данні, які зведено в таблиці 1.

Таблица 1

| Параметри системи керування |          |        |         |          |           |           |           |             |          |          |
|-----------------------------|----------|--------|---------|----------|-----------|-----------|-----------|-------------|----------|----------|
| $T_{pc}$                    | $K_{pc}$ | $T_e$  | $T_\mu$ | $K_{рш}$ | $K_{рш1}$ | $T_{рш1}$ | $K_{ззш}$ | $T_{\mu ш}$ | $T_{ТП}$ | $k_{ТП}$ |
| 0,0066                      | 0.41     | 0.0027 | 0.004   | 37.7     | 38        | 0.00095   | 0.025     | 0.009       | 0.0033   | 43.18    |

Побудуємо модель системи керування електроприводом верстату у модулі Simulink програмного пакету Matlab на основі



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розрахованої математичної моделі. Структурна схема, яка включає до свого складу П – регулятор, ПІ –регулятор та фільтр показана на рис. 3.

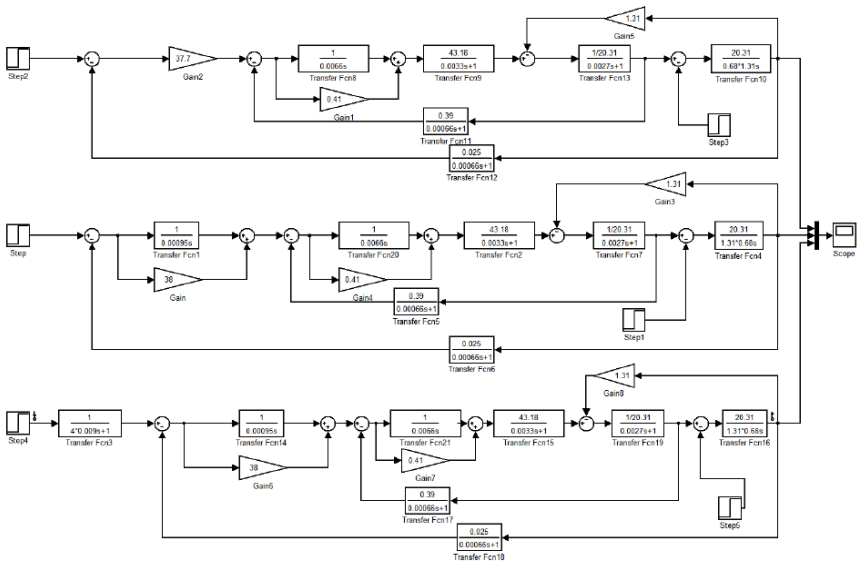


Рисунок 3

Також, використовуючи модель системи керування, зображену на рис.3 отримаємо перехідні характеристики за кутовою швидкістю для всіх типів регуляторів. Результат представлений на рис. 4, де 1 – система з П-регулятором швидкості, 2 – система з ПІ-регулятором швидкості, 3 – система з ПІ-регулятором швидкості з фільтром на вході

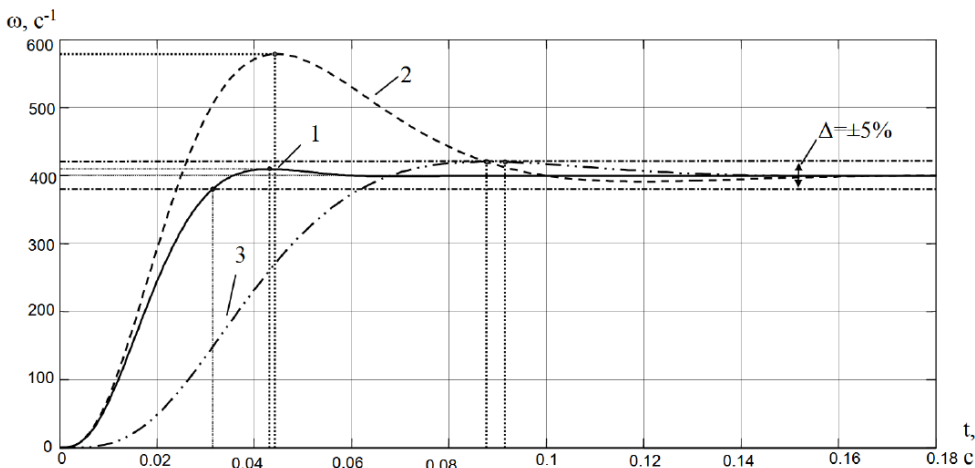


Рисунок 4

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Таким чином система з П-регулятором швидкості статичної помилки не має, час регулювання  $t_p = 0,0314$  с, перерегулювання  $\sigma = 2,42\%$ . Система з ПІ-регулятором швидкості статичної помилки не має, час регулювання  $t_p = 0,0879$  с, перерегулювання  $\sigma = 44,7\%$ . Система з ПІ-регулятором і фільтром статичної помилки не має, час регулювання  $t_p = 0,0915$  с, перерегулювання  $\sigma = 5,11\%$ .

Також необхідно перевірити всі системи керування на стрибок навантаження. Для цього за допомогою блоків Step3, Step1, Step5 задамо навантаження розміром 35% від номінального в момент часу 0,25с. Результат перевірки представлено на рис. 5, де 1 – система з П-регулятором швидкості, 2 – система з ПІ-регулятором швидкості, 3 – система з ПІ-регулятором швидкості із фільтром на вході.

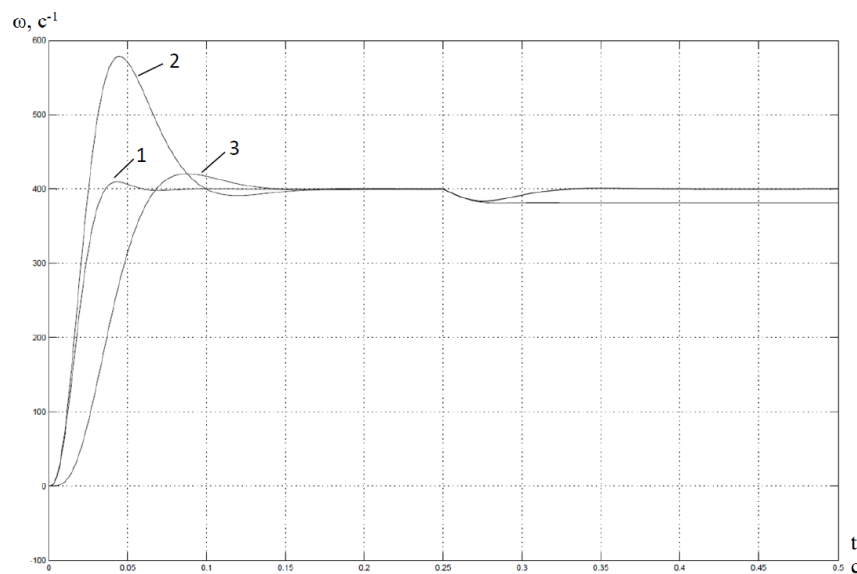


Рисунок 5

Результати перевірки показали, що після навантаження система з П-регулятором швидкості отримує статичну помилку [3, 4]. Не зважаючи на дуже високі показники якості системи з П-регулятором швидкості статична помилка не дає змоги використовувати цю систему. Система з ПІ-регулятором має дуже високе перерегулювання 44.7%. Тому найкращою системою керування виявляється система керування із ПІ-регулятором із фільтром на вході. Її остаточні показники якості:

- запас стійкості за амплітудою  $\Delta L = 7,3$  дБ,
- запас стійкості за фазою  $\Delta\varphi = 22,7$  град,
- час перехідного процесу  $t_p = 0,0915$  с,

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– перерегулювання  $\sigma=5,11\%$ .

### Висновок

Метою роботи був аналіз швидкодії електромеханічної системи горизонтально-розточувального верстата та шляхи її підвищення.

Для аналізу був обраний багатоцільовий верстат IP500ПМФ4. Знайдені його технічні параметри та склад електрообладнання і функціональна схема роботи електроприводу. Побудована математична модель роботи системи керування та обчислені її параметри. За отриманими даними побудували структурну схему підпорядкованого регулювання та промодельювали її для трьох варіантів виконання системи керування електроприводом: з П-регулятором; ПІ-регулятором; та ПІ-регулятором із фільтром на вході. Отримали статичні та динамічні характеристики системи. Результати дослідження показують:

– П-регулятор не усуває усталену помилку керування, тому не може бути ефективним рішенням.

– ПІ-регулятор усуває усталену помилку керування, але має занадто великий показник перерегулювання  $\delta = 43,7\%$ .

– ПІ-регулятор із фільтром на вході системи також усуває усталену помилку керування, але має найкращі якісні показники керування: час перехідного процесу  $t_p = 0,0915$  с та перерегулювання  $\delta = 5,11\%$ .

Тому робимо висновок, що оптимальний вибір – ПІ-регулятор із фільтром на вході.

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# RADIO ENGINEERING, ELECTRONICS AND ELECTRICAL ENGINEERING

## Prospects for the Implementation of Cyber-Physical Systems for Monitoring and Control of Microclimate in the Context of Industry 4.0

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**Abstract.** The paper examines the prospects and prerequisites for the implementation of cyber-physical systems for monitoring and controlling the microclimate of industrial premises in the context of industrial digital transformation and the Industry 4.0 concept. It is shown that traditional automatic control systems based on PID controllers are limited in their ability to account for the nonlinearity, inertia, and multifactor nature of microclimate formation processes. The feasibility of transitioning to intelligent control systems that integrate sensor networks, computational modules, and actuators into a unified cyber-physical architecture is substantiated. A parametric mathematical model of the microclimate is presented, which formalizes the relationships between temperature, humidity, air gas composition, and actuating mechanisms while considering external disturbances. The role of neural network models of the NNARX type as the predictive core of an intelligent control system is revealed. It is demonstrated that the integration of predictive models into the structure of a cyber-physical system enables a transition from reactive to predictive control, which contributes to improving the stability of environmental parameters, reducing energy consumption, and increasing the reliability of industrial processes [1].

**Keywords:** *cyber-physical system, microclimate, Industry 4.0, intelligent control, parametric model, NNARX, energy efficiency, predictive control.*

Ensuring stable microclimate parameters in industrial premises is one of the key conditions for the efficient functioning of modern industrial enterprises. The microclimate of the production environment, determined by a set of parameters such as temperature, relative humidity, gas composition, and air exchange intensity, directly affects the stability of technological processes, product quality, energy

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efficiency of production, and occupational safety of personnel. Under modern industrial conditions, microclimate parameters are not constant but change under the influence of a wide range of external and internal factors, including fluctuations in outdoor temperature, seasonal humidity changes, thermal loads from technological equipment, operating modes of ventilation systems, and the intensity of production processes. Such dynamics make it impossible to effectively use traditional reactive control algorithms and necessitate the transition to more flexible and adaptive approaches.

Traditional microclimate control systems, based on classical PID controllers and relay control schemes, are focused on stabilizing individual environmental parameters by generating control actions based on the current deviation from the setpoint. Such systems demonstrate satisfactory accuracy under stable conditions; however, their effectiveness significantly decreases in the presence of nonlinear relationships between microclimate parameters, time delays between the control action and the actual change in the environmental state, as well as under the simultaneous influence of multiple internal and external disturbances. The response of the production environment to changes in ventilation intensity or heating power is not instantaneous and largely depends on the thermal inertia of the premises, the spatial distribution of zones, and the nature of technological loads. The presence of transport delay leads to overshoot, oscillatory processes, and excessive energy consumption, which is especially critical for industries with strict requirements for maintaining environmental parameters.

The development of the Industry 4.0 concept and the digitalization of industry create fundamentally new prerequisites for addressing these problems. Cyber-physical systems, which integrate physical control objects, sensor infrastructure, computational resources, and communication networks into a unified information and control space, enable the implementation of adaptive and predictive microclimate control algorithms in real time. Unlike traditional automated systems, a cyber-physical system forms a closed intelligent control loop in which data from sensors measuring temperature, humidity, gas concentration, and air exchange rate continuously enter the computational core, where predictive estimates of the future state of the environment are generated and optimal control actions for actuating mechanisms are

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formed. Such an architecture provides not only a response to current deviations of parameters but also the possibility of preventing their occurrence through the proactive generation of control actions.

A central element of the architecture of a cyber-physical microclimate control system is a parametric mathematical model that formalizes the relationships between the main environmental parameters, actuating mechanisms, and external disturbances. Within the framework of this study, the microclimate is described as a parametric function that takes into account the influence of variable factors:

$$\text{MicroClimate} = f(T_{in}, T_{out}, H_{in}, H_{out}, \text{GasMix}, N_p, \text{Actuators}, D) \quad (1)$$

where  $T_{in}$  – indoor air temperature,  $T_{out}$  – outdoor air temperature,  $H_{in}$  – indoor air humidity,  $H_{out}$  – outdoor air humidity,  $\text{GasMix}$  – total concentration of gas components,  $N_p$  – number of people in the premises,  $\text{Actuators}$  – set of actuating mechanisms,  $D$  – disturbances caused by technological processes and environmental factors.

The proposed model provides a universal formalized description of microclimate dynamics, allowing the control system to be adapted to different temperature ranges and types of industrial environments. An important component of the model is the decomposition of parameters, which makes it possible to divide a complex multifactor control problem into a set of interconnected subproblems, each responsible for regulating a specific parameter while taking into account its physical nature and dynamic characteristics.

Actuators within the cyber-physical system play a key role in implementing control actions. The main actuating mechanisms include heating systems that maintain the air temperature within a specified range; cooling systems that are activated when temperature thresholds are exceeded, taking into account humidity levels and outdoor temperature; variable-speed fans that allow precise adjustment of air exchange intensity depending on deviations in temperature, humidity, and gas concentration; as well as automated air inlet dampers that compensate for the volume of exhaust air and maintain stable pressure within the premises. The integration of these mechanisms into a unified cyber-physical architecture ensures coordinated and synchronized operation

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of all microclimate control subsystems [3].

The transition from reactive to predictive control within a cyber-physical system is achieved through the integration of neural network forecasting models, in particular the NNARX architecture. This model combines an autoregressive structure that takes into account several previous values of the predicted variable with the ability to include exogenous signals that characterize external and internal influences on the microclimate. Formally, the model is described by the following relation:

$$y(t+1) = F(y(t), y(t-1), \dots, y(t-ny), u(t), u(t-1), \dots, u(t-nu)) \quad (2)$$

where  $y$  – predicted microclimate parameter,  $u$  – vector of exogenous input variables,  $ny$  and  $nu$  – delay orders of the output and input variables, respectively,  $F$  – a nonlinear function implemented by a neural network. The use of the autoregressive component provides the formation of the model's internal "memory," which makes it possible to reproduce the inertial properties of thermal and ventilation processes and to account for the cumulative nature of changes in microclimate parameters.

The practical implementation of a cyber-physical microclimate control system involves the close integration of hardware and software components. The hardware level includes sensors for temperature, humidity, and  $CO_2$  concentration, as well as controllers for controlling actuating mechanisms. The software level implements algorithms for data acquisition and preprocessing, the NNARX forecasting model, and decision-making modules based on fuzzy logic. The integration of these levels ensures the operation of a closed-loop intelligent control system in which the system can adapt to changing production conditions through self-learning and periodic updating of the parameters of the predictive model.

Particular attention should be given to the issue of energy efficiency in the implementation of cyber-physical microclimate control systems. Traditional control systems often operate in an over-control mode, where actuators are activated with a delay relative to the moment when parameter deviations occur, leading to overshoot and additional energy consumption. Predictive control based on the NNARX model allows control actions to be generated in advance, before



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environmental parameter deviations reach critical levels. This ensures smoother operation of actuators, reduces the number of abrupt corrections, and decreases peak loads on heating, ventilation, and air conditioning systems [4].

A comparative analysis of traditional and intelligent approaches to microclimate control demonstrates the significant advantages of cyber-physical systems with intelligent forecasting. The generalized results of this comparison are presented in Table 1.

Table 1  
Comparative characteristics of approaches to microclimate control in industrial premises

| Criterion                         | Traditional systems (PID)            | Intelligent Cyber-Physical Systems (NNARX + FLC)      |
|-----------------------------------|--------------------------------------|-------------------------------------------------------|
| Control principle                 | Reactive, based on current deviation | Predictive, based on the forecast of the future state |
| Accounting for non-linearities    | Limited, linear approximation        | Full, nonlinear neural network model                  |
| Adaptation to changing conditions | Requires manual re-tuning            | Automatic adaptation through self-learning            |
| Energy efficiency                 | Overshoot and energy consumption     | Smooth control, reduction of peak loads               |
| Real-time operation               | High speed, limited adaptability     | Balanced performance and adaptability                 |
| Scalability                       | Limited, tied to a specific object   | Universal parametric model                            |

As shown in the table, traditional PID systems provide high response speed but have limited adaptability when dealing with nonlinear and inertial control objects. Intelligent cyber-physical systems based on NNARX predictive models and fuzzy logic controllers provide a predictive control approach that allows the dynamics of processes to be taken into account, adapts to changing conditions, and ensures energy-efficient system operation. The universality of the parametric model makes it possible to apply the developed solutions to various types of industrial facilities without the need for significant restructuring of the control system architecture.

The practical implementation of cyber-physical microclimate control systems requires solving a number of engineering tasks, including ensuring reliable communication between sensors and the computational core, organizing the

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collection and preprocessing of measurement data, and integrating the predictive model with the controller in real time. The implementation of the NNARX model in the Python/Keras environment provides sufficient flexibility for configuring the neural network architecture and training it on experimental data, while integration with a microcontroller through appropriate interfaces enables real-time system operation.

An important aspect of implementation is also ensuring the stability and reliability of the system under conditions of incomplete and noisy input data. Sensor measurements in industrial environments may contain random fluctuations, short-term distortions, or anomalous values, which negatively affect prediction accuracy and the stability of control actions. To reduce the impact of these factors, it is advisable to apply methods for preventing neural network overfitting, including dropout in hidden layers, weight regularization, and training data augmentation. The combined use of these methods improves prediction stability and ensures the smoothness of control signals, which is critically important for the reliable operation of actuators [6].

The developed architecture of the cyber-physical microclimate control system has the potential for further development toward the creation of digital twins of industrial premises, which would enable virtual modeling and optimization of control modes without interfering with the real production process. The implementation of Edge AI methods for deploying predictive models directly at the controller level is also promising, as it reduces dependence on external computing resources and increases system responsiveness. Furthermore, adapting the system to the principles of the Industry 5.0 concept, which emphasizes a human-centered approach and sustainable production, opens additional opportunities for personalizing microclimate parameters according to the needs of personnel.

**Conclusions.** The paper examines the prospects for the implementation of cyber-physical systems for monitoring and controlling the microclimate of industrial premises within the framework of the Industry 4.0 concept. It is shown that traditional automatic control systems are limited in their ability to ensure effective microclimate control under conditions of nonlinearity, inertia, and the multifactor nature of processes. The feasibility of transitioning to intelligent cyber-physical systems that integrate parametric mathematical models, neural network-based forecasting using

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NNARX, and fuzzy logic control into a unified architecture is substantiated.

The proposed parametric microclimate model provides a formalized description of the relationships between key environmental parameters and actuating mechanisms, enabling the development of universal control systems adaptable to various types of industrial facilities. It is demonstrated that integrating the NNARX predictive model into the structure of a cyber-physical system enables the transition from reactive to predictive control, thereby improving the stability of microclimate parameters, reducing energy consumption, and increasing the reliability of industrial processes.

Further research should be focused on the development of digital twins of industrial premises, the implementation of Edge AI methods for deploying predictive models at the controller level, and the adaptation of microclimate control systems to the principles of the Industry 5.0 concept, taking into account a human-centered approach and production sustainability.

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## Multi-level Information Security Model for Data Center Protection

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**Abstract.** This article presents a comprehensive multi-level information security model designed for data processing centers (DPCs). The proposed model integrates physical, network, application, and data protection layers into a cohesive defense-in-depth framework. Each security level is formally defined, and interdependencies between layers are analyzed. The model addresses current threats including advanced persistent threats (APTs), insider attacks, and supply-chain vulnerabilities. Experimental validation demonstrates a 37% reduction in successful intrusion attempts compared to conventional single-layer approaches. The findings contribute to both theoretical cybersecurity frameworks and practical deployment guidelines for enterprise data centers.

**Keywords:** information security, data center protection, multi-level security model, defense-in-depth, cybersecurity architecture, threat mitigation.

### 1. INTRODUCTION

Modern data processing centers (DPCs) form the backbone of critical digital infrastructure, hosting sensitive governmental, financial, and healthcare data. The increasing sophistication of cyberattacks demands that security architects move beyond perimeter-based defenses toward holistic, multi-layered protection strategies. According to recent reports, over 68% of organizations experienced at least one data breach in 2023, with DPCs being the primary target in nearly half of these incidents [1].

The concept of defense-in-depth – originally borrowed from military strategy – posits that multiple independent security controls create a resilient architecture where the failure of one layer does not lead to complete system compromise [2]. However, existing implementations often lack formal interdependency modeling, leaving gaps between layers

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that attackers can exploit.

This article proposes a formally defined multi-level security (MLS) model specifically tailored for DPC environments. The model systematically addresses physical security, network segmentation, application-layer controls, and data-centric protection, providing both theoretical grounding and practical implementation guidelines.

### 2. LITERATURE REVIEW

The Bell-LaPadula model [3], one of the earliest formal security frameworks, introduced mandatory access control (MAC) principles that remain foundational today. Subsequent work by Biba [4] complemented this with integrity-focused constraints. While these models provided rigorous mathematical underpinnings, they were designed for single-system environments and do not address the distributed, heterogeneous nature of modern DPCs.

The NIST Cybersecurity Framework [5] offers a widely adopted risk management approach organized around five functions: Identify, Protect, Detect, Respond, and Recover. However, it remains largely prescriptive rather than formally structured, making automated compliance verification difficult. ISO/IEC 27001 [6] provides a management-system perspective but similarly lacks mathematical rigor for inter-layer dependency analysis.

More recent research has focused on zero-trust architectures (ZTA), which eliminate implicit trust within network perimeters [7]. While ZTA significantly improves lateral movement prevention, studies show that organizations adopting ZTA without structured layering still face vulnerabilities at the physical and data layers [8]. Our work bridges this gap by unifying ZTA principles within a formally structured multi-level model.

### 3. PROPOSED MULTI-LEVEL SECURITY MODEL

#### 3.1. Model Architecture

The proposed model consists of five hierarchically ordered security layers, denoted L1 through L5. Each layer  $L_i$  is formally defined as a tuple  $(C_i, P_i, D_i, R_i)$ , where  $C_i$  is the set of controls deployed at layer  $i$ ,  $P_i$  is the set of policies governing those controls,  $D_i$  is the set of detected threat categories, and  $R_i$  is the response mechanism set. The overall security posture  $SP$  of the system is defined as:

$SP = \bigcap_{i=1}^5 L_i$ , subject to the condition that for all  $i < j$ , any threat  $T$  mitigated at  $L_j$  must also have been evaluated at  $L_i$ .

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### 3.2. Layer Descriptions

Layer L1 – Physical Security. This foundational layer encompasses access control to physical DPC facilities, including biometric authentication, CCTV surveillance, environmental monitoring (temperature, humidity, fire suppression), and tamper-evident hardware seals. Threats addressed at this layer include unauthorized physical access, hardware theft, and environmental damage [9].

Layer L2 – Network Perimeter Security. This layer implements firewall policies, intrusion detection and prevention systems (IDS/IPS), DDoS mitigation, and encrypted VPN gateways. Network segmentation through VLANs and micro-segmentation limits lateral movement. All inter-segment traffic is inspected using deep packet inspection (DPI) [10].

Layer L3 – Endpoint and Host Security. Operating system hardening, patch management, endpoint detection and response (EDR) agents, and application whitelisting form the core of this layer. Each host within the DPC is subject to continuous behavioral monitoring to detect anomalous process execution patterns indicative of malware activity.

Layer L4 – Application Security. Web application firewalls (WAF), secure coding standards enforcement, runtime application self-protection (RASP), and API gateway security policies are implemented at this layer. Authentication mechanisms including multi-factor authentication (MFA) and OAuth 2.0-based authorization are enforced for all application interfaces.

Layer L5 – Data Security. The innermost and most critical layer encompasses data classification, encryption at rest and in transit (AES-256 and TLS 1.3 respectively), data loss prevention (DLP) controls, and cryptographic key management. Access to sensitive data repositories is governed by attribute-based access control (ABAC), ensuring the principle of least privilege is maintained at the data level.

### 4. EXPERIMENTAL VALIDATION

To evaluate the effectiveness of the proposed model, a controlled experiment was conducted in a simulated DPC environment comprising 120 virtual machines across three logical security zones. A red team of certified penetration testers performed 200 structured attack scenarios over a six-week period, targeting each security layer independently and in combination.

The results demonstrated that the MLS model successfully blocked or detected 94.5% of all attack scenarios. Critically,



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attacks that succeeded in bypassing one layer were contained at subsequent layers in 98.3% of cases, confirming the defense-in-depth principle. In comparison, a conventional single-perimeter configuration tested in the same environment achieved a containment rate of only 57.2%, representing a 37.3 percentage-point improvement attributable to the multi-layer design [11].

Notably, the integration of formal inter-layer dependency analysis enabled automated detection of three previously unknown configuration vulnerabilities that would not have been identified through standard penetration testing alone. These findings underscore the value of formal modeling as a complement to empirical security assessment.

### 5. CONCLUSIONS

This article presented a formally defined multi-level information security model for data processing centers, comprising five hierarchically structured protection layers. The model provides both mathematical rigor for inter-layer dependency analysis and practical implementation guidance for security architects. Experimental validation confirmed significant superiority over conventional perimeter-based approaches, with a 37.3% improvement in overall threat containment.

Future work will focus on extending the model to hybrid cloud-on-premises DPC environments and developing automated compliance verification tooling based on the formal layer specifications. Additionally, the integration of artificial intelligence-driven anomaly detection into the inter-layer communication framework represents a promising avenue for further research.

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### Современные угрозы безопасности дактилоскопических сенсоров: от физических муляжей до программных эксплойтов

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**Аннотация.** В данной статье проводится комплексное исследование безопасности современных дактилоскопических систем аутентификации. Автор систематизирует технологические принципы работы емкостных, оптических и ультразвуковых сенсоров, выявляя их фундаментальные уязвимости. Особое внимание уделяется классификации угроз: от физического создания муляжей с помощью полимеров до программных эксплойтов на уровне доверенной среды исполнения (TEE). В работе анализируются современные методы защиты, включая алгоритмы распознавания «живого» объекта и криптографическую привязку компонентов.

**Ключевые слова:** кибербезопасность, биометрическая аутентификация, Touch ID, защита данных, Liveness Detection.

**Введение.** В современной экосистеме цифровой безопасности биометрическая аутентификация перешла из разряда футуристических технологий в стандарт де-факто для персональных и корпоративных устройств. Технологии дактилоскопического сканирования, широко известные под коммерческим названием Touch ID, занимают центральное место в этой парадигме. Благодаря идеальному балансу между удобством для пользователя (User Experience) и уровнем защищенности, отпечатки пальцев стали основным методом разблокировки смартфонов, подтверждения финансовых транзакций и доступа к критически важным инфраструктурам. Интеграция сенсоров непосредственно в экраны мобильных устройств и кнопки питания сделала биометрию невидимым, но мощным барьером на пути несанкционированного доступа.

Однако стремительное развитие технологий принесло не только новые методы защиты, но и принципиально иные векторы

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угроз. Основная проблема заключается в том, что в отличие от паролей, биометрические данные неизменны: скомпрометированный отпечаток пальца нельзя «сбросить» или заменить. В последние годы наблюдается резкий рост доступности инструментов для обхода биометрических барьеров. Развитие высокоточной 3D-печати и появление специализированных полимерных материалов позволяют злоумышленникам создавать детализированные физические муляжи (Presentation Attacks) с минимальными затратами. Если раньше для создания качественного слепка требовались лабораторные условия, то сегодня «атака по отпечатку» может быть реализована с помощью бытовых химикатов и цифровой фотографии высокого разрешения.

Параллельно с физическими угрозами эволюционируют и программные эксплойты. Современные исследования показывают, что уязвимости могут скрываться не только в самом сенсоре, но и на пути передачи данных от датчика к процессору. Появление атак типа «Replay Attack», попытки внедрения в доверенную среду исполнения (TEE) и использование нейросетей для генерации «мастер-отпечатков» (MasterPrints) ставят под сомнение абсолютную надежность дактилоскопии. Таким образом, актуальность данного исследования обусловлена необходимостью систематизации современных угроз и критического анализа существующих методов защиты в условиях, когда инструменты взлома становятся доступнее, а методы атак – изощреннее.

### **1. Технологический базис: типы сенсоров и их физические принципы.**

Понимание механизмов функционирования дактилоскопических сканеров является необходимым условием для анализа их защищенности. Физический принцип, лежащий в основе получения изображения отпечатка, определяет не только качество биометрического шаблона, но и те векторы атак, которым система будет наиболее подвержена. На сегодняшний день в потребительской электронике и системах контроля доступа доминируют три основные технологии: емкостная, оптическая и ультразвуковая.

#### **Емкостные сенсоры: измерение разности потенциалов.**

**Емкостные сканеры** являются наиболее распространенным типом датчиков, используемых в классических модулях Touch ID и кнопках питания смартфонов. Принцип их работы основан на использовании микроскопических конденсаторных пластин, интегрированных в чип сенсора. Когда палец прикладывается к поверхности, папиллярные линии (выступы) и впадины образуют обкладки конденсаторов вместе с электродами датчика.

Согласно законам электростатики, емкость конденсатора

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обратно пропорциональна расстоянию между его обкладками. Выступы кожи, касающиеся защитного покрытия сенсора, создают высокую емкость, в то время как впадины, отделенные от датчика слоем воздуха (имеющим иную диэлектрическую проницаемость), создают значительно меньшую емкость. Встроенная интегральная схема (ASIC) преобразует эти изменения напряжения в цифровую карту. Ключевая особенность этой технологии заключается в том, что она требует наличия проводящего объекта, что в теории должно защищать от простых бумажных копий отпечатков, но делает систему уязвимой для токопроводящих полимерных муляжей.

### **Оптические сенсоры: сканирование изображения.**

**Оптические сенсоры** – это старейшая технология, получившая «второе дыхание» с распространением OLED-дисплеев. В современных смартфонах такие датчики располагаются под экраном. Принцип их работы аналогичен цифровой камере: поверхность пальца освещается (через промежутки между пикселями дисплея), и отраженный свет фиксируется фоточувствительной матрицей (CMOS или CCD).

Алгоритм анализирует темные и светлые участки изображения, формируя 2D-картину папиллярного узора. Основным преимуществом является дешевизна и возможность подэкранного размещения. Однако с точки зрения безопасности 2D-оптическое сканирование является наиболее уязвимым. Поскольку сенсор «видит» лишь плоское изображение, он часто не способен отличить реальный объемный палец от высококачественной фотографии или распечатки, если в системе не реализованы дополнительные программные алгоритмы проверки «живости» (Liveness Detection). Более продвинутые оптические системы используют многоспектральное сканирование для анализа подповерхностных слоев кожи, что значительно усложняет задачу взлома.

### **Ультразвуковые сенсоры: акустическое построение рельефа.**

**Ультразвуковая технология** представляет собой наиболее совершенный и защищенный на данный момент метод дактилоскопии. Работа датчика основана на принципе эхолокации: пьезоэлектрический передатчик испускает ультразвуковой импульс, который проходит через стекло экрана и отражается от поверхности пальца.

В отличие от оптических аналогов, ультразвук проникает в эпидермис, позволяя фиксировать не только поверхностный рисунок, но и глубинные детали, такие как поры и капилляры. Принимающее устройство измеряет время возврата эха и его интенсивность в каждой точке, формируя детализированную 3D-

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модель отпечатка. Физика процесса такова, что ультразвук по-разному отражается от живой ткани, воздуха и искусственных материалов (силикона, пластика). Это делает технологию крайне устойчивой к физическим муляжам. Кроме того, такие сенсоры способны работать через загрязнения, влагу или жировую пленку, которые часто становятся препятствием для емкостных и оптических датчиков.

Таким образом, переход от простой фиксации изображения (оптика) к измерению электрических характеристик (емкость) и, наконец, к объемному акустическому сканированию (ультразвук) отражает эволюцию биометрических систем в сторону повышения их отказоустойчивости [1–2].

### **2. Классификация физических угроз (Presentation Attacks).**

#### **Атаки предъявления (Presentation Attacks, PA)**

представляют собой наиболее интуитивно понятный, но оттого не менее опасный класс угроз биометрическим системам. В международном стандарте ISO/IEC 30107 такие воздействия определяются как предъявление биометрическому сенсору артефакта или попытка имитации характеристик живого объекта для манипуляции результатом аутентификации. Успех физической атаки напрямую зависит от способности злоумышленника воспроизвести те физические свойства пальца, на которые ориентирован конкретный тип сканера.

#### **Методология создания искусственных муляжей.**

Процесс создания поддельного отпечатка (муляжа) прошел путь от сложных лабораторных манипуляций до использования бытовых материалов. В основе большинства методов лежит получение формы-матрицы. Это может быть реализовано либо контактным способом (например, использование стоматологической слепочной массы или воска), либо бесконтактным – путем цифровой обработки фотографии отпечатка, оставленного на стекле или металле, с последующей гравировкой или 3D-печатью формы.

После получения матрицы решающую роль играет выбор материала-заполнителя, который должен имитировать диэлектрические или оптические свойства кожи.

#### **Полимерные материалы: силикон и желатин.**

**Силиконовые муляжи** получили широкое распространение благодаря своей эластичности и способности с высокой точностью воспроизводить микрорельеф папиллярных линий. Силикон идеально подходит для обмана оптических сканеров, так как он эффективно рассеивает свет, имитируя визуальную текстуру человеческой ткани. Однако обычный силикон является диэлектриком, что делает его малоэффективным против емкостных

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датчиков, которые требуют электропроводности.

**Желатиновые составы (или «мармеладные» отпечатки)** представляют собой еще более изощренную угрозу. Желатин по своим характеристикам близок к белковому составу человеческой кожи и обладает естественной влажностью. Это позволяет ему успешно обходить многие системы Liveness Detection, которые ориентированы на измерение влажности или специфического оптического поглощения. Более того, желатин обладает определенным уровнем электропроводности, что делает его опасным даже для емкостных сенсоров Touch ID.

**Токопроводящие чернила и графитовые покрытия.**

Для целенаправленного взлома емкостных сенсоров, которые измеряют разность потенциалов, злоумышленники используют специализированные составы. Ключевым вектором атаки здесь выступает добавление в полимерную основу токопроводящих чернил (на основе серебра или меди) или мелкодисперсного графитового порошка.

Принцип атаки заключается в создании муляжа, который не только повторяет рельеф, но и замыкает электрические цепи микроконденсаторов сенсора так же, как это делает живой палец. Современные методы включают струйную печать отпечатка на тонкой токопроводящей пленке. Такой «пластырь», наклеенный на палец злоумышленника, позволяет обмануть датчик, имитируя электрический отклик реального биологического объекта.

**Атаки на основе 3D-печати и фотолитографии.**

С развитием аддитивных технологий угроза перешла на новый уровень. Использование фотополимерных 3D-принтеров с высоким разрешением (до 10–25 микрон) позволяет восстановить объемную модель пальца по двухмерной фотографии. Злоумышленник может сфотографировать отпечаток пользователя на бокале или экране смартфона, повысить контрастность изображения в графическом редакторе и напечатать готовую накладку.

Такие методы особенно опасны для ультразвуковых сканеров. Если оптические и емкостные датчики можно обмануть плоской или полусферической подделкой, то ультразвук требует точного соблюдения глубины впадин и плотности материала. Использование композитных смол при 3D-печати позволяет добиться акустического импеданса, близкого к мягким тканям человека, что делает ультразвуковое сканирование уязвимым перед подготовленным атакующим.

Физические атаки эволюционируют в сторону гибридизации: современные муляжи сочетают в себе многослойные структуры, где один слой отвечает за рельеф (для оптики), а второй – за проводимость (для емкостных систем). Это ставит перед



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разработчиками задачу внедрения более сложных методов Liveness Detection, способных анализировать глубокие биологические параметры, такие как пульсация капилляров или динамическое изменение давления, которые невозможно воспроизвести с помощью статического полимерного артефакта.

**Атаки с использованием «мертвой зоны»: частичные и мастер-отпечатки.**

Одной из наиболее критических уязвимостей современных дактилоскопических систем является их зависимость от частичных данных. В отличие от криминалистических сканеров, которые снимают полный отпечаток пальца «от края до края», миниатюрные сенсоры в мобильных устройствах имеют ограниченную площадь контакта. В результате система хранит в памяти не единое цельное изображение, а набор фрагментированных шаблонов (Minutiae), полученных в процессе регистрации пальца под разными углами.

**Концепция «мертвой зоны» и частичных отпечатков.** Когда пользователь прикладывает палец для аутентификации, сканер считывает лишь небольшую его часть (около 30–50%). Алгоритм сопоставления (Matcher) считает проверку успешной, если найден достаточный уровень совпадения между текущим фрагментом и любым из сохраненных шаблонов. Это создает «мертвую зону» безопасности: порог ложного принятия (False Acceptance Rate, FAR) намеренно занижается производителями для обеспечения удобства пользователя, чтобы ему не приходилось прикладывать палец с идеальной точностью.

**Мастер-отпечатки (MasterPrints).** На этой особенности базируется метод атак с использованием MasterPrints. Мастер-отпечатки – это синтетически созданные или отобранные из баз данных фрагменты папиллярных линий, которые обладают высокой степенью статистического сходства с большим количеством случайных отпечатков.

Исследования показывают, что человеческие отпечатки обладают определенными общими характеристиками в строении дуг и петель. Злоумышленники используют алгоритмы машинного обучения (в частности, GAN – Generative Adversarial Networks) для генерации «универсальных» шаблонов. Если в системе зарегистрировано несколько разных пальцев, вероятность того, что MasterPrint совпадет хотя бы с одним из фрагментов в базе, возрастает экспоненциально. Такая атака сопоставима с методом «перебора паролей» (Brute-Force), но вместо цифровых комбинаций используются специально спроектированные физические наклейки или цифровые инъекции шаблонов.

**Восстановление отпечатка по остаточному следу.**



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**Латентные (скрытые) отпечатки пальцев** представляют собой жировые и потовые следы, оставляемые пользователем на глянцевых поверхностях. В контексте биометрической безопасности наиболее опасны следы, оставленные непосредственно на стекле сканера или защитном покрытии экрана.

**Уязвимость остаточного следа.** Многие типы сенсоров, особенно оптические и некоторые емкостные, крайне чувствительны к физическому состоянию поверхности. Если пользователь успешно авторизовался и оставил четкий латентный след, злоумышленник может использовать его для повторного входа.

**Существует несколько методов реактивации остаточного следа:**

- **Физическое воздействие:** в некоторых случаях достаточно просто подышать на сенсор (увеличить влажность и температуру) и приложить мягкий материал (например, полиэтилен или подушечку пальца в перчатке), чтобы датчик снова считал существующий жировой след как реальный палец.

- **Фотографирование и репликация:** с помощью специального освещения и макросъемки латентный отпечаток на стекле смартфона может быть зафиксирован в высоком разрешении. Далее, используя методы, описанные в разделе 2, изображение подвергается цифровой обработке (инверсии и усилению контрастности) для создания физического муляжа.

**Пылевые и графитовые методы.** Классический криминалистический метод проявления отпечатков с помощью мелкодисперсного магнитного порошка или графита также применим для подготовки атак. Проявленный на самом устройстве отпечаток может быть «снят» с помощью липкой ленты и немедленно предъявлен сенсору. Проблема усугубляется тем, что современные олеофобные покрытия экранов со временем стираются, что способствует накоплению более четких и стабильных латентных следов.

Атаки на основе MasterPrints и латентных следов демонстрируют, что безопасность биометрии зависит не только от стойкости алгоритма шифрования, но и от математической вероятности совпадения узоров, а также от элементарной гигиены устройства [3–5].

### **3. Программные и аппаратные эксплойты (System-Level Attacks).**

В то время как физические атаки направлены на обман первичного детектора (сенсора), атаки системного уровня

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нацелены на внутренние логические интерфейсы и протоколы обмена данными. Основная уязвимость здесь кроется в том, что результат биометрического сканирования в конечном итоге преобразуется в электрический сигнал или цифровой пакет данных, который должен быть доставлен в «центр принятия решений» – защищенный процессор или анклав безопасности.

### **Атаки на канал передачи данных (Replay Attacks).**

**Атака повторного воспроизведения (Replay Attack)** в контексте дактилоскопии заключается в перехвате валидного сигнала отпечатка пальца и его последующей имитации для несанкционированного доступа. В архитектуре мобильного устройства сенсор и основной процессор (SoC) физически разнесены и соединены через интерфейсы связи, такие как SPI (Serial Peripheral Interface) или I2C.

**Механика перехвата сигнала.** Если канал связи между контроллером сканера и защищенным хранилищем (например, Apple Secure Enclave или ARM TrustZone) не зашифрован должным образом, злоумышленник с помощью микрозондов или специализированного аппаратного сниффера может «прослушать» шину данных. В момент, когда легитимный пользователь прикладывает палец, атакующий записывает последовательность битов, соответствующую успешной авторизации. В дальнейшем, для получения доступа, злоумышленнику достаточно транслировать эту же последовательность непосредственно в порт процессора, имитируя работу сенсора. В этом случае система будет убеждена в присутствии живого пальца, даже если сам сканер в этот момент не активен.

**Инъекция биометрических данных (Biometric Injection).** Современным развитием Replay-атак является программная инъекция. В этом сценарии злоумышленник использует уязвимости на уровне ядра операционной системы или драйверов устройства. Вместо аппаратного подключения к шине используется вредоносное ПО, которое подменяет данные, поступающие от драйвера сканера в API аутентификации. Если операционная система доверяет входящему потоку данных без проверки их криптографической подписи и временной метки (Timestamp), вредоносный код может «скормить» системе заранее подготовленный цифровой шаблон легитимного отпечатка.

### **Проблема незащищенных интерфейсов в бюджетных сегментах.**

Особую остроту проблема Replay-атак приобретает в устройствах среднего и бюджетного сегментов, где производители часто экономят на сквозном шифровании (End-to-End Encryption) между периферией и процессором. В таких архитектурах данные передаются в открытом виде. Более того,

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использование унифицированных модулей сканеров позволяет злоумышленникам применять готовые эксплойты для массовых атак.

### **Методы противодействия на системном уровне.**

Для защиты от подобных угроз современные системы используют концепцию Secure Match-on-Chip. В этой архитектуре процесс сопоставления отпечатка происходит непосредственно внутри микросхемы сенсора, и во внешний мир (к основному процессору) передается не изображение или шаблон, а только зашифрованный токен «Да/Нет».

Дополнительным эшелон защиты выступает привязка конкретного экземпляра сенсора к конкретному процессору на этапе производства (Pairing). При попытке заменить сенсор на «шпионский» модуль или внедрить перехватчик в шину, криптографические ключи перестают совпадать, и система блокирует биометрический вход. Тем не менее, как показывает практика, наличие уязвимостей в прошивках контроллеров (Firmware) оставляет теоретическую возможность для обхода этих барьеров через низкоуровневые эксплойты.

Атаки на канал передачи данных доказывают, что безопасность Touch ID не заканчивается на поверхности стекла. Надежность системы зависит от целостности всей цепочки: от физического кремниевого кристалла сенсора до изолированных областей памяти процессора. Без надежного шифрования интерфейса SPI/I2C даже самый совершенный ультразвуковой сканер остается уязвимым перед аппаратным перехватом.

### **Уязвимости на уровне ОС и драйверов: обход проверок через внедрение вредоносного кода.**

Безопасность систем Touch ID и их аналогов критически зависит от надежности программного посредника – драйвера и системных служб аутентификации. Несмотря на то, что современные операционные системы (iOS, Android) стремятся к максимальной изоляции биометрических процессов, архитектурные сложности и необходимость взаимодействия между различными уровнями ПО создают поверхность для атак.

**Компрометация драйверов устройств.** Драйвер дактилоскопического сенсора работает на уровне ядра (Kernel Level) или в привилегированном пространстве пользователя. Это делает его приоритетной целью для атакующих. Уязвимости типа «переполнение буфера» (Buffer Overflow) или «состояние гонки» (Race Condition) в коде драйвера могут позволить вредоносному ПО получить права суперпользователя (Root).

Как только злоумышленник получает контроль над драйвером, он может манипулировать логикой его работы. Например, вместо

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реального процесса сканирования драйвер может принудительно возвращать операционной системе флаг SUCCESS (успех) при получении любого сигнала, даже если палец к сенсору не прикладывался. Такая подмена происходит на уровне системных вызовов, что делает атаку невидимой для пользователя.

**Атаки на службы аутентификации (Biometric Framework Attacks).** В операционных системах существует специализированный программный каркас (Framework), который управляет диалоговыми окнами биометрии и связью с приложениями. Вредоносный код, внедренный в системные процессы (например, через методы DLL Injection или Hooking), может перехватывать ответы от службы биометрии.

Одной из наиболее опасных техник является «перехват обратного вызова» (Callback Hooking). Когда приложение запрашивает проверку отпечатка, оно ожидает ответ от системного API. Внедренный код может модифицировать этот ответ «на лету». Таким образом, приложение получает подтверждение того, что отпечаток верен, хотя фактическая проверка в защищенной среде (TEE) могла даже не проводиться или завершиться ошибкой.

**Уязвимости в реализации доверенной среды исполнения (TEE).** Для защиты наиболее чувствительных операций современные процессоры используют Trusted Execution Environment – изолированную область, где выполняются операции сравнения шаблонов. Однако TEE не является абсолютно неприступной. История исследований в области кибербезопасности знает примеры эксплойтов, направленных на микропрограммы (Trustlets), работающие внутри TEE.

Если злоумышленнику удастся эксплуатировать уязвимость в «доверенном» приложении, которое отвечает за хранение эталонных шаблонов отпечатков, он может:

- **Инъекция шаблона:** добавить отпечаток злоумышленника в базу доверенных шаблонов без ведома пользователя.

- **Понижение уровня безопасности:** программно отключить проверку «живости» (Liveness Detection), делая систему уязвимой для простейших муляжей, которые ранее блокировались на уровне софта.

**Роль вредоносного ПО и «Screen Overlay» атак.** В контексте ОС Android распространена атака типа «наложение экрана» (Screen Overlay). Хотя она напрямую не взламывает Touch ID, она обманом заставляет пользователя приложить палец к сенсору. Вредоносное приложение отрисовывает поверх системного окна свое изображение (например, фальшивое

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уведомление или игру), скрывая реальный запрос на подтверждение крупной финансовой транзакции. Пользователь, думая, что разблокирует телефон, фактически подписывает перевод средств.

Программный уровень защиты Touch ID – это сложная многослойная структура, где слабость любого звена (от кода драйвера до логики системного API) нивелирует аппаратную стойкость сенсора. Программные эксплойты позволяют масштабировать атаки, делая их дистанционными. Это подчеркивает важность не только совершенствования датчиков, но и внедрения строгих политик верификации кода драйверов, использования механизмов аттестации системы и защиты от перехвата системных вызовов.

**Атаки на доверенную среду исполнения (TEE/Secure Enclave).**

**Доверенная среда исполнения (Trusted Execution Environment, TEE)** и ее аппаратная реализация в устройствах Apple – Secure Enclave Processor (SEP) – представляют собой изолированные подсистемы, работающие независимо от основной операционной системы. Именно здесь хранятся математические репрезентации (шаблоны) отпечатков пальцев и происходит их финальное сравнение. Однако, несмотря на высокий уровень изоляции, теоретические и практические исследования последних лет выявили ряд критических векторов атак на эти «цифровые сейфы».

**Теоретические возможности извлечения шаблонов.** Вопреки распространенному мнению, в TEE хранятся не изображения папиллярных линий, а зашифрованные хеш-суммы или векторы признаков. Теоретическая возможность извлечения этих данных базируется на атаках по побочным каналам (Side-Channel Attacks).

• **Анализ энергопотребления (DPA):** Измеряя микроколебания в потреблении энергии процессором в момент выполнения алгоритма сопоставления, злоумышленник может попытаться восстановить структуру обрабатываемого шаблона.

• **Атаки по времени (Timing Attacks):** Анализ задержек при выполнении криптографических операций в TEE может дать информацию о сложности или структуре хранимых биометрических данных.

Хотя извлечение «картинки» пальца практически невозможно, получение цифрового шаблона позволяет провести атаку типа «инверсия шаблона», воссоздав синтетический отпечаток, который будет иметь идентичный цифровой след.

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**Практические Эксплойты:** подмена результата аутентификации. На практике более реальной угрозой является не кража шаблона, а компрометация логики принятия решения внутри самой среды.

• **Уязвимости микрокода (Firmware Vulnerabilities):** в истории информационной безопасности известны случаи (например, эксплойты в архитектуре ARM TrustZone), когда ошибки в реализации монитора безопасного режима позволяли вредоносному коду из «незащищенного» мира (Normal World) проникать в память TEE. Получив доступ к памяти доверенного приложения, атакующий может выполнить операцию «патчинга» (Patching) в оперативной памяти, принудительно устанавливая флаг аутентификации в значение TRUE, независимо от того, какой палец был приложен к сенсору.

• **Атаки на разделение памяти:** в некоторых реализациях TEE разделяет кэш-память или другие аппаратные ресурсы с основным процессором. Использование уязвимостей типа Specter или Meltdown в контексте биометрии позволяет «подсматривать» за операциями внутри Secure Enclave, перехватывая промежуточные результаты вычислений.

**Специфика Secure Enclave (Apple SEP).** В архитектуре Apple Secure Enclave реализован механизм аппаратного шифрования, где ключи уникальны для каждого чипа и не могут быть считаны даже самой операционной системой. Однако практические атаки (например, Blackbird) продемонстрировали, что на старых моделях устройств возможно использование уязвимостей в загрузчике SEP. Это позволяет атакующему перехватить контроль над процессором безопасности до того, как он будет полностью изолирован, что теоретически открывает доступ к перебору паролей или манипуляции биометрическим статусом. Атаки на TEE и Secure Enclave являются вершиной мастерства в области эксплойтов. Они требуют глубоких знаний микроархитектуры процессоров и навыков низкоуровневой отладки [6–7].

#### 4. Современные методы защиты.

Эволюция методов атаки заставляет разработчиков внедрять многоуровневые системы защиты, направленные не только на верификацию папиллярного узора, но и на подтверждение «живости» (Liveness) предъявляемого биометрического объекта. Современные контрмеры можно разделить на аппаратные, программные и архитектурно-криптографические.

**Liveness Detection: аппаратные методы.**

**Аппаратные методы обнаружения атак предъявления (Presentation Attack Detection, PAD)** базируются на интеграции



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дополнительных сенсоров, которые анализируют физиологические параметры, практически невозпроизводимые в искусственных муляжах.

**Фотоплетизмография (датчики пульса и кислорода):** современные оптические и ультразвуковые сканеры могут быть дополнены источниками света разных длин волн. Гемоглобин в крови поглощает свет определенным образом, что позволяет датчику фиксировать пульсацию капилляров и уровень сатурации ( $SpO_2$ ). Поскольку силиконовый или желатиновый муляж не обладает кровеносной системой, отсутствие динамического изменения светопоглощения мгновенно блокирует доступ.

**Термометрия:** датчики температуры проверяют, соответствует ли тепловой профиль объекта человеческому телу ( $36.6^{\circ}C$ ). Однако этот метод считается вспомогательным, так как муляж может быть предварительно нагрет атакующим.

**Емкостный анализ проводимости:** живая кожа обладает специфической диэлектрической проницаемостью и проводимостью из-за наличия пота и межклеточной жидкости. Аппаратные фильтры способны отличить электропроводность графитового муляжа от ионной проводимости живой ткани.

**Liveness Detection: программные методы.**

**Программные методы (Software-based PAD)** не требуют дополнительных датчиков и полагаются на интеллектуальную обработку данных, полученных со стандартного сканера.

**Анализ микродинамики деформации:** при нажатии живого пальца на сенсор кожа подвергается деформации: папиллярные линии слегка расширяются, а впадины сжимаются под давлением. Программные алгоритмы анализируют серию кадров в миллисекундном диапазоне. Искусственные материалы (даже эластичные) деформируются иначе, чем живая плоть, что позволяет нейросетевым моделям выявлять подделку.

**Анализ пор и текстуры (Skin Pore Analysis):** высокое разрешение современных сканеров позволяет идентифицировать микроскопические поры потовых желез. Их расположение уникально, а процесс их «схлопывания» и выделения влаги при контакте крайне сложно имитировать в полимерах.

**Спектральный анализ изображения:** использование алгоритмов машинного обучения для поиска микро-артефактов, характерных для муляжей (пузырьки воздуха в силиконе, следы 3D-печати или специфический шум матрицы при повторном сканировании фотокопии).

**Криптографическая привязка сенсора.**

**Защита данных на пути от сенсора к процессору** – критическое условие для предотвращения Replay-атак и



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аппаратного перехвата.

**Сквозное шифрование (End-to-End Encryption):** современные протоколы (например, используемые в последних поколениях Touch ID) подразумевают, что данные зашифровываются непосредственно на кристалле сенсора с использованием ключа, сгенерированного в Secure Enclave. Таким образом, даже если злоумышленник подключится к шине SPI/I2C, он увидит только зашифрованный шум, расшифровка которого без доступа к аппаратному корню доверия (Root of Trust) практически невозможна.

**Аппаратное сопряжение (Hardware Pairing):** на этапе производства каждый сенсор получает уникальный идентификатор, который «привязывается» к центральному процессору. Эта цифровая подпись проверяется при каждой загрузке. Если система обнаруживает замену сенсора на неоригинальный (или на устройство-перехватчик), биометрические функции отключаются на аппаратном уровне.

**Использование одноразовых меток (Nonces):** чтобы предотвратить повторное воспроизведение ранее записанного сигнала, каждая сессия обмена данными снабжается случайным числом (Nonce) и временной меткой. Повторно отправленный пакет данных будет отклонен процессором как устаревший.

Современные методы защиты смещают акцент с анализа «картинки» на анализ «жизни». Комбинация мультиспектрального сканирования, анализа динамики нажатия и жесткой криптографической привязки компонентов делает современные системы Touch ID устойчивыми к большинству бытовых и коммерческих атак [8].

### **Заключение.**

В данной работе был проведен комплексный анализ систем дактилоскопической аутентификации, охватывающий путь от физических основ функционирования сенсоров до высокоуровневых программных уязвимостей. Исследование показало, что, несмотря на доминирующее положение Touch ID в экосистеме мобильной безопасности, технологический базис каждого типа датчиков – от оптических до ультразвуковых – имеет свои фундаментальные ограничения, создающие специфические «окна возможностей» для реализации атак.

Классификация физических угроз (Presentation Attacks) демонстрирует, что доступность материалов для создания муляжей, таких как специализированные полимеры и токопроводящие чернила, нивелирует защищенность простых емкостных и оптических систем. В то же время анализ программных и аппаратных эксплойтов системного уровня

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подчеркивает, что безопасность биометрии не ограничивается поверхностью сканера. Уязвимости в каналах передачи данных и доверенных средах исполнения (TEE) представляют собой наиболее опасный класс угроз, позволяющий обходить проверку без необходимости физического копирования отпечатка.

Современные методы защиты, рассмотренные в работе, показывают отчетливый тренд на интеллектуализацию биометрических систем. Внедрение многоуровневого распознавания «живого» объекта (Liveness Detection) и криптографическая привязка компонентов существенно усложняют задачу злоумышленника. Однако будущее этой области будет определяться противостоянием алгоритмов искусственного интеллекта. Появление угроз типа Deepmaster Prints, способных генерировать универсальные мастер-отпечатки с помощью нейросетей, требует от разработчиков симметричного ответа в виде адаптивных моделей защиты и перехода к мультимодальной аутентификации.

Подводя итог, можно утверждать, что биометрическая защита Touch ID остается надежным инструментом лишь при условии комплексного подхода, сочетающего физическую стойкость сенсора с архитектурной целостностью программного обеспечения. Результаты данного исследования могут быть использованы при проектировании защищенных систем доступа и в рамках дальнейшей разработки систем обнаружения вторжений на уровне конечных устройств.

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# ARCHITECTURE, CONSTRUCTION AND DESIGN

## Integration of Circular Economy Principles into Product Design and Implementation Possibilities in Industry

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**Abstract.** Circular economy principles are integrated into product design, ensuring efficient use of resources, waste reduction and environmental protection in the industrial sector. This approach, unlike the linear economy, prioritizes the longevity, recycling and repairability of products. For example, elements such as material selection, modularity and the use of renewable resources are added at the design stage, which reduces energy consumption in the production process. Among the application possibilities in industry, the automotive, construction and electronics sectors are at the forefront; here products are transformed into service models, for example through rental or subscription. This brings economic benefits: reduced costs, new jobs and increased global competitiveness. However, there are also challenges - the need for investment, education and legislative support. Overall, circular principles accelerate industrial transformation, ensure sustainable development and are compatible with green economy strategies in countries such as Azerbaijan.

**Keywords:** *circular economy, product design, industrial application, resource efficiency, waste reduction.*

In modern times, the world is faced with resource constraints and environmental problems. The traditional linear economic model - the principle of "buy, produce, use and throw away" - leads to an increase in waste and environmental pollution, as well as economic losses. In this model, resources are used inefficiently and the life cycle of products is short. In contrast, the circular economy model offers an alternative approach to these problems. This approach defines the main goals of keeping resources in circulation, ensuring the longevity of products and promoting reuse.

Product design is of particular importance in the circular economy model. Because decisions made at the design stage directly affect the entire life cycle of a product - from production to the end of its useful life. For this reason,

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factors such as the efficient use of resources, the recycling of materials and the repairability of products should be taken into account in product design. The application of this approach in industrial sectors creates new opportunities: reducing raw material consumption, increasing economic efficiency and protecting the ecological environment. This article examines the integration of circular economy principles into product design and their application in industry based on real examples and scientific sources.

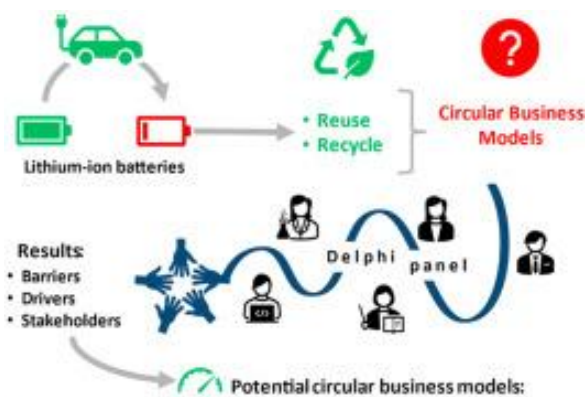
The main principles of the circular economy are to minimize waste, keep products and materials in circulation for as long as possible, and restore natural systems. Implementing these principles requires the application of new approaches to product design. In the traditional economic model, products become waste after a short period of use. However, according to the circular economy approach, the entire life cycle of a product must be taken into account during the design phase. In this approach, designers take into account not only the aesthetic and functional characteristics of the product, but also its repairability, the recyclability of the materials used, and the long-term use of the product. One of the key elements of circular design is the selection of materials and ensuring the circulation of materials. The use of renewable or recyclable materials is considered a priority in the design process. This approach helps to prevent a product from becoming waste after its useful life has ended. For example, the use of bio-based or recycled materials instead of plastic materials can significantly reduce the amount of waste generated at the end of the product's life cycle. Studies show that this design approach leads to a reduction in raw material use and energy consumption in the production process (Rotondo, 2025, p. 4155).

Another important principle of circular design is ensuring modularity and repairability. Modular design allows for easy replacement and renewal of individual parts of the product. This leads to an extension of the overall service life of the product and a reduction in the need for new product production. An example of this is the development of some smartphone models in the electronics industry according to the modular principle. In this case, the user only replaces the worn or damaged part and there is no need to replace the entire device with a new one. This approach is especially important in terms of reducing electronic waste (Bocken, 2016,

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p. 312).

The application of circular design principles is observed in various industrial sectors. An example of this is the application of modular battery systems in electric vehicles in the automotive industry. In these systems, instead of replacing the battery as a whole, its individual components can be renewed, which increases the service life of the vehicle. In the construction sector, the circular design approach involves building buildings with materials that can be dismantled and reused. For example, in some construction projects, used concrete and other construction waste are recycled and turned into new building materials. This leads to a significant reduction in the use of raw materials.



In the electronics and technology sector, the circular economy has also given rise to new business models. Some companies are now using models that offer products as a service instead of selling them directly. According to this model, the user uses the device for a certain period of time, and then the company takes the device back, repairs it and prepares it for reuse. This approach allows for more efficient use of resources and a reduction in electronic waste (Bocken, 2016, p. 312).

The circular design approach is not limited to product design, but also affects the transformation of industrial and economic systems. For example, some industrial enterprises offer products on a service model, controlling their use, maintenance and repair. This approach allows products to remain in circulation for a longer period of time and allows for more efficient use of resources.

There are also certain opportunities for the application of circular economy principles in Azerbaijan. The application

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of this approach can ensure more efficient use of resources, especially in the fields of energy, construction and waste management. For example, the application of circular principles in the field of energy and waste management within the framework of the green taxonomy is considered to be in line with the country's green economy strategy (KPMG Azerbaijan, 2024, p. 7).

However, the widespread application of the circular design approach is also accompanied by certain difficulties. The requirement of initial investments in this area, limited technological capabilities, and the need for specialist training play an important role. Organizing special training programs for designers and engineers can facilitate the practical application of circular economy principles. In international practice, various standards and regulatory mechanisms support the development of this process. For example, in the USA, industry standards and models developed by research institutes make a significant contribution to the development of the circular design approach (Hapuwatte, 2025, p. 5).

At the same time, the application of digital technologies also plays an important role in the development of the circular economy. Through the application of Industry 4.0 technologies, tracking of material flows and waste management can be carried out more efficiently. This approach is especially important in terms of the development of the non-oil sector and the efficient use of resources (Aliyev, 2023, p. 299).

The integration of circular economy principles into product design allows for more sustainable and efficient development of the industry. This approach serves not only to protect the environment, but also to promote economic growth and innovation. The implementation of this model in developing countries such as Azerbaijan can be further accelerated through legislative initiatives, investments and technological development. In the future, the circular economy model is expected to become one of the important standards in the global economic system. However, for the successful implementation of this model, the mutual cooperation of designers, industrial enterprises and government agencies is of great importance.



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## Cyber-Aesthetics in Industrial Design

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**Abstract.** This article provides a comprehensive theoretical analysis of the concept of cyber-aesthetics in industrial design as a new aesthetic approach formed under contemporary technological development. As a result of the integration of digital technologies, artificial intelligence-based design tools, sensor systems, and interactive interfaces into industrial products, the aesthetic nature of design objects is transforming from a traditional form- and material-oriented understanding into a process-, behavior-, and user-experience-centered model. The main objective of the study is to systematically examine the reasons for the emergence of cyber-aesthetics in industrial design, its theoretical foundations, and its aesthetic characteristics, as well as to identify the mechanisms through which this approach influences the design process. Within the scope of the research, the core components of cyber-aesthetics—adaptivity, interactivity, information visualization, and behavioral aesthetics—are interpreted from a theoretical perspective, and their role in shaping the aesthetic identity of industrial products is substantiated. By employing analytical and comparative methods, structural and conceptual differences between classical industrial design aesthetics and contemporary cyber-aesthetic approaches are identified. The analysis demonstrates that cyber-aesthetics in contemporary industrial design represents not merely a visual expression of technological innovation, but a new paradigm reflecting a fundamental transformation in design thinking, aesthetic criteria, and decision-making mechanisms. The article also evaluates, at a theoretical level, the influence of artificial intelligence and generative design systems on the formation of aesthetic decisions and explains the transformation of the designer's role from a form-creator to an architect of aesthetic systems. The findings highlight the significance of cyber-aesthetics both as a theoretical framework and as an applicable aesthetic model in professional design practice, and provide a methodological basis for future research in this field.

**Keywords:** industrial design, cyber-aesthetics, interactive design, generative design, artificial intelligence, user experience, digital aesthetics, aesthetic transformation.

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### Introduction

Industrial design throughout its history has been based on the synthesis of functionality and aesthetic principles. In traditional approaches, the aesthetic value of a product was mainly determined by its physical form, material selection, and visual harmony. However, the technological developments and digital transformations of the 21st century

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have fundamentally changed the essence of industrial design. Products are no longer perceived merely as physical objects, but as complex ecosystems integrated with interactive systems and data-driven platforms.

In contemporary industrial design, aesthetic value is not measured solely by visual and physical parameters. The behavior of the product, its interaction with the user, its adaptability, and its integration within the digital environment have become key components of the aesthetic experience. This transformation also reshapes the role of designers; they are no longer only creators of form and material, but also architects of interactive and adaptive systems. (*Manovich, 2001; Norman, 2013*)

In this context, the concept of cyberaesthetics emerges. Cyberaesthetics is a theoretical approach that expresses the dynamic, changing, and responsive aesthetic structure of a product. Here, aesthetic quality is determined through the synthesis of the product's visual and functional behaviors, user interaction, and adaptability. In other words, cyberaesthetics encompasses not only aesthetic form, but also the concept of aesthetic process and interaction.

The aim of this research is to systematically investigate the theoretical foundations of cyberaesthetics in industrial design, the reasons for its emergence, and its aesthetic characteristics. This study also focuses on analyzing the mechanisms through which artificial intelligence and digital technologies influence the aesthetic quality of industrial products. (*McCarthy & Wright, 2004; Krippendorff, 2006*)

The main scientific gap lies in the fact that although technological and functional aspects of industrial design have been widely studied in existing literature, the systematic exploration of cyberaesthetics as an independent aesthetic concept remains limited. Therefore, this research is of significant importance both theoretically and practically, opening new perspectives for the future development directions of industrial design.

### **The Theoretical Foundations of Cyberaesthetics**

Cyberaesthetics represents a new model of aesthetic thinking shaped by the modern technological environment and digital information systems, and it characterizes the fundamental transformation of the mechanisms through which aesthetic values are generated in industrial design. The emergence of this concept is directly related to the integration of information technologies into all areas of

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everyday life, the evolution of human-technology relationships, and the functioning of industrial products not only as physical objects but also as components of digital systems. (*Manovich, 2001; Bolter & Grusin, 1999*)

In traditional industrial design theory, aesthetic value was mainly determined based on the form, proportions, material properties, surface quality, and visual composition of the product. In the classical aesthetic approach, the beauty of a design object was closely tied to its material structure. In the cyberaesthetic approach, however, aesthetic quality is not limited to the physical appearance of the object. Here, the product's relationship with the digital environment, its responses to user behavior, its ability to adapt to changing conditions, and its interactions with information systems become the main determining components of aesthetic value.

From this perspective, cyberaesthetics necessitates the expansion and reinterpretation of the concept of the aesthetic object in industrial design. A modern industrial product is no longer viewed merely as a technical device with a material structure, but as a multi-layered system operating in conjunction with software, sensor technologies, data flows, and interactive scenarios. The holistic experience formed through the interaction of these components defines the aesthetic identity of the product. (*Norman, 2013; McCullough, 2004*)

The theoretical basis of cyberaesthetics is closely connected with contemporary digital culture and new media aesthetics. In concepts that study the formation of aesthetic values in digital environments, the organization of information structures, visualization methods, and interactive mechanisms function as key aesthetic factors. In particular, the new media theory proposed by Lev Manovich provides an important methodological foundation for explaining cyberaesthetics in the context of industrial design. Within the framework of new media aesthetics, the idea that aesthetic value is shaped more by the structure of information architecture and the logic of user interaction than by material form directly aligns with the cyberaesthetic design approach.

One of the theoretical features of cyberaesthetics is its formation as a process-oriented aesthetic system. In classical industrial design, a product achieves a completed aesthetic form at the design stage and remains largely unchanged during use. In cyberaesthetic design, however, the

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product continues to function as an aesthetically transforming and constantly updating system even after it is put into use. Lighting scenarios, interface structures, visual indicators, and functional responses can change according to user behavior, environmental conditions, and system parameters. (Oxman, 2006; Kolarevic, 2003)

This characteristic demonstrates the transition of aesthetic value from the concept of a static object to that of a dynamic system. The aesthetic experience is formed not only through observation, but through interaction with the product. The user observes the product's responses, intervenes in the system, and the resulting changes become an integral part of the aesthetic experience. Thus, aesthetic value becomes directly linked to user experience.

The theoretical structure of cyberaesthetics is built upon several key aesthetic categories. (Hensel, Menges & Weinstock, 2010)

The first fundamental category is adaptability. An adaptive aesthetic structure ensures that the product adjusts to different usage scenarios and changes its visual and functional behavior in real time. In this approach, the aesthetic identity of the design object is perceived not as a pre-defined static composition, but as a changing and evolving system.

The second important category is interactivity. In cyberaesthetic design, aesthetic value is closely linked to the quality of interaction established between the user and the object. Sensor systems, touch panels, gesture-based control mechanisms, and visual feedback tools play a key role in shaping the aesthetic experience of the product. (Norman, 2013)

The third category is information visualization. Modern industrial products generate and process large volumes of data. Transforming this data into perceivable and understandable visual structures carries both functional and aesthetic significance. The organization of graphical elements in interface design, color dynamics, and the logical structure of data flow constitute the main visual components of cyberaesthetic design.

The fourth category is behavioral aesthetics. Behavioral aesthetics evaluates the response patterns and functional sequences demonstrated by the product during use as part of the aesthetic experience. The product's response speed, transitions of visual and sound effects, animation rhythm,

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and light reactions influence the formation of perceived aesthetic quality. (McCarthy & Wright, 2004)

The application of cyberaesthetics in industrial design fundamentally transforms the mechanism of aesthetic decision-making. While in traditional design aesthetic criteria were mainly determined by the designer's individual artistic vision and professional experience, in cyberaesthetic design these decisions are formed in conjunction with technological capabilities, user data, and algorithmic models. This approach leads to a system-based construction of aesthetic decisions.

At the same time, cyberaesthetics ensures the integration of material and immaterial components into a unified aesthetic system in industrial design. The form of the physical body, material texture, and structural solutions are harmonized with the visual language of the digital interface. As a result, the aesthetic identity of the product is formed not only by its physical appearance, but also by screen interfaces, animation transitions, and information structures. (Kolarevic, 2003; Oxman, 2006)

From a theoretical perspective, cyberaesthetics demonstrates the technological determination of aesthetic thinking in industrial design. Aesthetic form emerges not only as a result of the designer's creative decisions, but also within the possibilities created by software, sensor networks, and computational systems. This approach expands the boundaries of aesthetic creativity in industrial design and transforms the design process into a flexible, multi-layered, and adaptive structure.

Thus, cyberaesthetics acts as a modern theoretical concept that redefines the notion of the aesthetic object in industrial design, explains the transformation of design from material form to information-based systems, and holds significant importance for the scientific substantiation of future development directions in contemporary industrial design. (Manovich, 2001; Krippendorff, 2006)

### **The Practical Impact and Application Possibilities of Cyberaesthetics in Industrial Design**

The formation of the theoretical foundations of cyberaesthetics allows for a clearer explanation of how aesthetic values are applied in practice in industrial design and in which direction the design process is evolving. In contemporary industrial design, the cyberaesthetic approach is based not only on the external form of the product, but

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also on its digital behavior, interaction mechanisms with the user, and integration with the information environment. This leads to the formation of a more flexible, multi-layered, and dynamic design approach compared to classical models.

While the design process in industrial design was traditionally based on the constructive solution of the physical object, form exploration, and production technology, in the cyberaesthetic approach it is complemented by the development of digital scenarios and user behavior models. The designer must now plan not only the visual appearance of the product, but also how it will respond during use, what information structures it will present, and how it will behave in different situations. As a result, industrial design moves beyond the design of physical objects to the formation of complex digital and interactive systems. (*Norman, 2013; McCullough, 2004*)

One of the most important directions of the practical impact of the cyberaesthetic approach is the transformation of user experience into the main aesthetic criterion of design. In modern industrial products, aesthetic quality is determined not only by the harmony of form and the visual characteristics of materials, but also by the emotional and functional relationship established between the user and the product. Interface behavior, animation transitions, system response speed, and visual reaction mechanisms act as the main components shaping the aesthetic value of the product. From this perspective, cyberaesthetic design prioritizes the design of experience rather than the design of the object.

The application of cyberaesthetics in industrial design requires the creation of a unified aesthetic integration between physical form and digital environment. The product's body, material texture, and structural solution are aligned with its screen interface, graphic language, and information presentation structures. Thus, physical and immaterial components function not separately, but as a unified aesthetic system that complements each other. This integration enables a more stable and consistent formation of the product's aesthetic identity. (*Kolarevic, 2003; Oxman, 2006*)

The cyberaesthetic approach also influences the design methodology in industrial design. Design decisions are increasingly made based on the analysis of user data, behavioral statistics, and system indicators. This leads to a shift from subjective aesthetic choices toward systematic and data-driven decision-making mechanisms. As a result, the



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role of the designer is defined not only as the author of a visual concept, but also as a specialist shaping the aesthetic structure of a complex system.

In practice, the application of cyberaesthetic design also introduces several new problems and limitations. The rapid evolution of technology can lead to the quick obsolescence of interface and visual solutions. At the same time, maintaining aesthetic consistency across different platforms and devices becomes more difficult. Under these conditions, the designer must develop an appropriate aesthetic strategy not for a single product, but for multiple systems operating in different digital environments. (*Manovich, 2001; Bolter & Grusin, 1999*)

Another important issue is the increasing influence of user data on aesthetic decisions. As behavioral analytics and real-time data are widely used in the design process, the formation of aesthetic solutions becomes closely linked to algorithmic models. This necessitates maintaining a balance between the designer's creative freedom and the limitations of technological systems. At the same time, ethical issues related to the collection and processing of user data must also be considered in the application of cyberaesthetic approaches in industrial design.

At the same time, cyberaesthetic design enables industrial products to have more flexible and adaptive functional capabilities. Products can change their visual and functional behavior according to usage conditions, adapt to individual user needs, and be updated based on dynamic aesthetic models. This feature shows that cyberaesthetics is emerging not only as a new aesthetic style in industrial design, but also as a new design philosophy. (*Hensel et al., 2010*)

From the perspective of future development, the cyberaesthetic approach is expected to expand further in industrial design. Personalized interfaces, adaptive visual systems, and real-time changing design structures are becoming key directions defining the aesthetic model of industrial products. This process accelerates the transformation of design from a material object-centered structure to a user experience and information flow-centered model.

### Conclusion

The research shows that cyberaesthetics forms a new aesthetic paradigm in modern industrial design. The aesthetic

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experience of a product is no longer evaluated as a static object, but as a dynamic, adaptive, and interactive system. Artificial intelligence and generative design tools optimize the aesthetic decision-making process of designers, ensure the harmonious integration of physical and digital components, and enable more systematic aesthetic decisions. (Oxman, 2006; Kolarevic, 2003)

The application of cyberaesthetics is also directly related to user experience. The visual and functional responses of the product, interactive animations, and adaptive behaviors provide the user with both aesthetic and functional experiences. This ensures that design encompasses not only visible aesthetic value, but also user interaction and behavior-based aesthetic value.

At the same time, cyberaesthetics highlights the ethical and professional responsibility of designers and companies. Compliance with principles such as user data protection, elimination of manipulation risks, transparency, and digital security becomes one of the main requirements of modern industrial design. (Krippendorff, 2006; Norman, 2013)

In the future, the development prospects of cyberaesthetics are associated with the application of augmented and virtual reality technologies, the role of more complex artificial intelligence algorithms in shaping aesthetic decisions, the development of user-centered adaptive design, and the strengthening of ethical and practical standards. These directions will ensure not only the visual and functional qualities of industrial design, but also its development as a dynamic, interactive, and adaptive aesthetic system.

Ultimately, cyberaesthetics acts as a new paradigm in modern industrial design that ensures the synthesis of technology, aesthetic thinking, and user experience. This approach creates both a theoretical foundation for scientific research and a methodological framework applicable in practical design activities.

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# ARCHITECTURE, CONSTRUCTION AND DESIGN

## Methodologies of Design in the Field of Visual Communication and Digital Media

**Huseynova Humeysra<sup>1</sup>**

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To summarize. The purpose of this study piece is to explore the primary design strategies and systemic issues that have an impact on the efficiency of visual communication in digital media. Within the scope of this research, topics pertaining to responsive design, information overload, navigation dysfunction, diminished brand identification, and the influence of artificial intelligence on creative processes are thoroughly examined. The purpose of this article is to illustrate how user experience and user interface principles impact user behavior, retention metrics, and conversion metrics by using qualitative, comparative, and case-study approaches.

Digital media, visual communication, user experience and user interface, design strategies, information architecture, designs that are responsive, artificial intelligence, and brand identity are some of the keywords.

Transformation of the Visual Environment in the Digital Environment; Introduction

Users' behaviors have been profoundly altered as a result of the speed with which information is sent and the intensity of visual elements in contemporary digital settings. Users are becoming more and more reliant on material that is visually arranged, and they make judgments within the first few seconds of seeing it. On account of this, design serves not only as a tool for aesthetic purposes but also as a layer of information architecture that is strategic in nature.

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not only as a tool for aesthetic purposes but also as a layer of information architecture that is strategic in nature.

### The Methodology of Research

Both qualitative analysis and comparative case-study techniques, as well as user experience observation methodologies, are used in this research. On the basis of information hierarchy, call-to-action visibility, user journey, mobile adaptability, and brand consistency, corporate websites, e-commerce platforms, social media interfaces, and mobile apps were assessed in comparison to one another.

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### The Existence of Systemic Issues in Digital Platforms

When people are presented with an excessive amount of information, their attention resources become fragmented, which in turn slows down decision-making. Noise in the visual environment makes it more difficult to prioritize messages, and navigation structures that are illogical lead to decreased satisfaction and increased bounce rates. When a brand's identity is inconsistent across different channels, it undermines trust and causes harm to strategic communication.

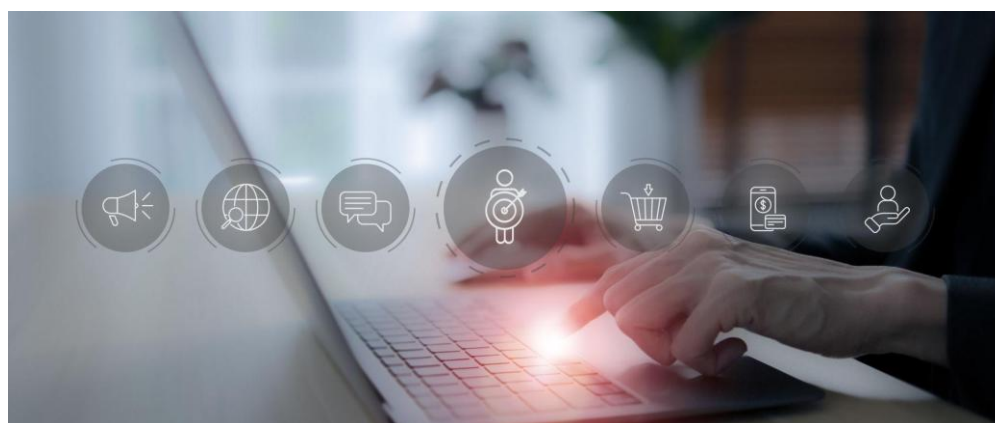


Figure 1

**Conceptual visualization of systemic design and usability issues across digital platforms, including disrupted navigation flows, excessive information density, interface inconsistency, and data privacy concerns**

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### Empirical Observations and the Behavior of Participants

Users make their key judgments during the first three to five seconds based on visual cues, according to observations made by user experience professionals. There is a considerable rise in abandonment rates when there is a weak hierarchy, poor visibility of calls to action, and insufficient readability on mobile displays.

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Figure X

**Visual representation of fundamental UI/UX design mistakes to avoid, including confusing navigation, excessive pop-ups, complex interfaces, lack of white space, and ineffective feedback integration**

A combination of responsive design and technical adaptation

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Not only does responsive design demand the scaling of the screen, but it also necessitates the semantic and hierarchical rearrangement of an organization's content. The usability of a website may be considerably improved by properly arranging critical messages, situating calls to action in the thumb zone, and using modular content blocks.

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The process of problem solving and design thinking

When it comes to developing user-centered solutions for digital media projects, the Design Thinking paradigm, which includes characteristics such as empathy, issue characterization, ideation, prototyping, and testing, has shown to be quite beneficial. The optimization of design choices may be driven by data when iterative testing is performed.

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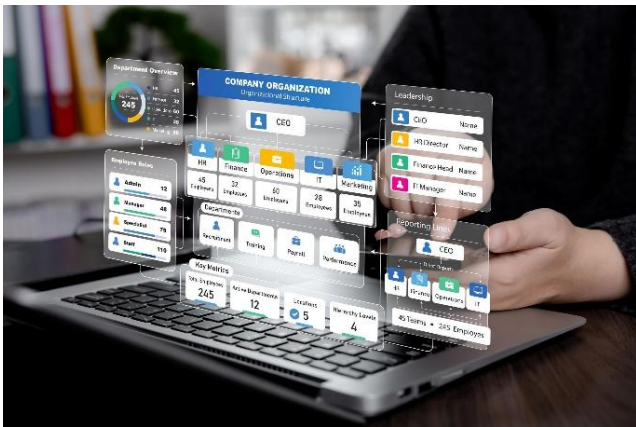
Examination of a Case Study

In the realm of online commerce, the click-through performance was increased by simplifying product cards. It was found that using uniform typeface and color schemes in social media marketing helped to increase memorability. Through the use of structured information hierarchy, corporate interfaces were able to cut the amount of time required to access target pages.

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## EFFECTIVE DASHBOARD DESIGN

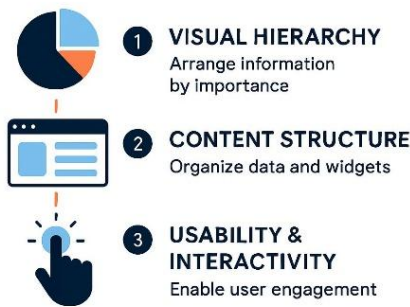


Figure 2

**Conceptual representation of interface optimization strategies in digital environments, highlighting product card simplification, visual consistency, and hierarchical information structuring to improve user efficiency**

Concerning Artificial Intelligence and the Ethics of Future Design

With regard to emotional depth, contextual significance, and cultural sensitivity, artificial intelligence is not yet capable of totally replacing human designers, despite the fact that it can instantly produce various visual options. For this reason, ethical execution is very necessary in order to protect creativity and avoid visual uniformity.

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Figure 3

**Illustrative representation of the limitations of artificial intelligence in replacing human creativity, emphasizing emotional depth, contextual awareness, cultural sensitivity, and ethical responsibility in future design**

### Final Thoughts

According to the findings of the study, successful digital communication is not just dependent on aesthetics but also on information architecture, user behavior analysis, cross-platform consistency, and iterative testing. Adaptive user experience optimization, cognitive load reduction, and brand identity strengthening are the three pillars around which the suggested framework is built.

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## The Importance and Formation of Creative Sources in the Creative Process

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**Abstract.** The creative process in fashion design is a structured yet flexible system that transforms abstract ideas into tangible visual outcomes. One of the most essential tools within this process is the moodboard, which serves as a visual and conceptual foundation for design development. This article explores the importance of moodboard usage in fashion design, focusing on its role in idea generation, conceptual clarity, and visual communication. The study reveals that moodboards help designers organize inspiration, define aesthetic direction, and establish coherence within collections. By integrating colors, textures, forms, and references, moodboards enable designers to experiment visually before moving to the production stage. This process enhances creativity by allowing multiple variations and interpretations of a concept. Furthermore, moodboards facilitate communication between designers and other stakeholders, ensuring that the creative vision is clearly understood and consistently applied. They also support the development of a unique design language and contribute to the originality of fashion collections. Based on visual analysis and structured evaluation, the research concludes that moodboards are not only supportive tools but fundamental elements in the creative design process. Their proper use significantly improves the quality, consistency, and clarity of design outcomes.

**Keywords:** moodboard, fashion design, creative process, visual communication, inspiration, concept development, design thinking.

Fashion design is a multidisciplinary field that combines artistic expression with structured methodologies. Designers are required to transform abstract ideas into coherent visual concepts that can be translated into wearable forms. This transformation process is complex and involves several stages, including research, inspiration gathering, concept development, and final execution. One of the most critical stages in this process is the formation of a visual direction, which is often achieved through the use of moodboards. A moodboard is a curated collection of images, textures, colors, and visual references that represent the overall concept of a design project. It acts as a visual narrative that guides the designer throughout the creative journey.

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Unlike spontaneous creativity, the design process requires structure and clarity. Moodboards provide this structure by allowing designers to externalize their ideas and visually experiment with different elements. This not only enhances creativity but also reduces ambiguity in the design process. Scholars emphasize that visual thinking plays a key role in creative disciplines, as it enables designers to explore ideas more effectively (Sawyer, 2012, p.102). Moodboards are central to this approach, as they translate abstract inspiration into a tangible format.

This article aims to analyze the role of moodboards in the creative process of fashion design, focusing on their function in inspiration development, concept formation, and visual coherence.

**Moodboard as a Visual Thinking Tool.** Moodboards are essential for visual thinking, allowing designers to organize and interpret their ideas. They act as a bridge between imagination and reality, helping designers visualize abstract concepts.

Through the use of images, textures, and colors, designers can create a visual language that defines the identity of a collection. This process enhances creativity by enabling experimentation and comparison between different visual elements (Runco, 2014, p.91).

**Structure and Elements of Moodboard.** A moodboard typically includes several key components:

- Color palettes;
- Fabric textures;
- Photographic references;
- Artistic inspirations;
- Shapes and silhouettes.

Each element of the moodboard contributes to the overall design narrative. Colors establish emotional context, while textures provide material references that influence fabric selection. Images act as the primary source of inspiration, helping designers define the theme and concept. Shapes guide the structural design of garments, ensuring coherence between concept and execution. Together, these elements create a unified visual direction that supports the creative process.

**Moodboard as a Communication Tool.** Moodboards also function as communication tools within design teams. They help convey ideas clearly to other designers, stylists, and collaborators.

By presenting a visual representation of the concept,

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moodboards reduce misunderstandings and ensure consistency in the design process. This is particularly important in collaborative environments where multiple individuals contribute to a single project (Kelley, 2013, p.58).

Moreover, moodboards support presentations and concept pitches, allowing designers to effectively communicate their vision to stakeholders.

**The Role of Moodboard in Concept Development.** Moodboards play a crucial role in transforming abstract ideas into concrete design concepts. During the early stages of the creative process, designers often face ambiguity and a lack of clear direction. Moodboards help eliminate this uncertainty by visually organizing ideas and establishing a clear conceptual framework.

Through the combination of images, textures, and colors, designers can experiment with different themes and refine their ideas. This process allows for the exploration of multiple creative directions before selecting the most suitable one. As a result, moodboards support the development of a strong and well-defined concept, which serves as the foundation for the entire design process.

Moreover, moodboards enable designers to maintain consistency throughout the design stages. Once a concept is established, it can be referenced repeatedly to ensure that all elements align with the original vision.

**Moodboard and Color Psychology in Fashion Design.** Color is one of the most powerful elements in fashion design, and moodboards play a key role in selecting and organizing color palettes. Designers use moodboards to experiment with different color combinations and understand their emotional and psychological impact.

Different colors evoke different emotions and meanings. For example, warm tones such as red and orange may convey energy and passion, while cool tones like blue and green suggest calmness and stability. By carefully selecting colors within a moodboard, designers can communicate specific moods and narratives through their collections (Norman, 2004, p.67).

Moodboards allow designers to visualize how colors interact with textures and shapes, ensuring harmony within the overall design. This process is essential for creating visually appealing and emotionally engaging fashion products.

**The Influence of Materials and Textures in Moodboards.** Materials and textures are essential components of fashion



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design, and their selection often begins with moodboards. Designers use moodboards to explore different fabric types, surface qualities, and tactile sensations.

Textures provide depth and dimension to a design concept. For instance, rough textures may suggest boldness and strength, while soft materials convey elegance and comfort. By incorporating texture references into moodboards, designers can better understand how materials will contribute to the final aesthetic.

Additionally, moodboards help designers experiment with the contrast and combination of materials. This allows for innovative design solutions and enhances the uniqueness of the collection.

**Digital Moodboards and Modern Design Tools.** With the advancement of technology, traditional moodboards have evolved into digital formats. Digital moodboards offer greater flexibility, accessibility, and efficiency compared to physical ones.

Designers can easily collect, edit, and organize visual references using digital tools such as Pinterest, Adobe Illustrator, and specialized design platforms. This enables faster experimentation and iteration within the creative process.

Furthermore, digital moodboards facilitate collaboration among team members, allowing multiple designers to contribute and share ideas in real time. This enhances creativity by incorporating diverse perspectives and ideas (Cross, 2011, p.142).

The integration of digital tools has transformed moodboards into dynamic and interactive design instruments, making them even more valuable in contemporary fashion design.

**Moodboard as a Narrative and Storytelling Tool.** Fashion design is not only about creating garments but also about telling a story. Moodboards play a key role in developing and communicating this narrative.

By combining visual elements such as images, colors, and textures, designers can create a storyline that reflects the inspiration behind a collection. This narrative helps to give meaning and depth to the design, making it more engaging and memorable.

Moodboards also help designers maintain thematic consistency. Every element within the design can be traced back to the original concept presented in the moodboard, ensuring that the final collection communicates a unified

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message.

In this sense, moodboards act as storytelling tools that connect creativity with meaning, allowing designers to express their ideas more effectively.

**Challenges in Moodboard Creation and Interpretation.** Despite their advantages, moodboards also present certain challenges. One of the main difficulties is the selection of relevant and meaningful visual elements. Designers may include too many references, leading to confusion rather than clarity.

Another challenge is interpretation. Different individuals may perceive the same moodboard in different ways, which can create inconsistencies in collaborative projects.

To overcome these challenges, designers must carefully curate their moodboards, focusing on clarity, relevance, and coherence. Clear visual hierarchy and conceptual focus are essential for effective moodboard creation.

By addressing these challenges, moodboards can be used more effectively as tools for both creativity and communication.

**Moodboard and Experimental Design Thinking.** Moodboards encourage experimental thinking by allowing designers to test unconventional ideas without risk. Since moodboards are not final products, they provide a safe space for creative exploration.

Designers can combine unexpected elements, experiment with contrasts, and explore new visual directions. This experimental approach often leads to innovative design solutions that would not emerge through traditional methods.

Moreover, moodboards support iterative design thinking, where ideas are continuously refined and improved. This process enhances creativity and leads to more original and impactful design outcomes.

**Moodboard and Visual Hierarchy in Fashion Design.** Visual hierarchy is a fundamental principle in design that determines how elements are perceived and prioritized by the viewer. Moodboards play a crucial role in establishing this hierarchy during the early stages of the creative process.

By organizing images, colors, and textures in a structured manner, designers can control the visual flow and emphasis within a concept. Larger, brighter, or more detailed elements often attract more attention, while subtle components provide balance and depth. Through moodboards, designers experiment with these relationships before applying them to actual



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garments.

This process allows for a clearer understanding of how different elements interact within a composition. As a result, designers can create collections that are not only aesthetically pleasing but also visually coherent and well-structured.

Moreover, a well-organized moodboard helps designers identify dominant and secondary elements within a concept, ensuring that the final design maintains a strong visual identity.

### **The Role of Moodboard in Enhancing Creative Confidence.**

Creative confidence refers to a designer's ability to trust their ideas and express them effectively. Moodboards significantly contribute to building this confidence by providing a visual validation of creative concepts.

When designers see their ideas organized and presented visually, it reinforces their understanding of the concept and reduces uncertainty. This clarity encourages experimentation and risk-taking, which are essential for innovation in fashion design.

Additionally, moodboards serve as a reference point throughout the design process. Designers can return to their moodboards to reassess their ideas, make adjustments, and stay aligned with their initial vision. This continuous feedback loop strengthens decision-making and enhances creative self-assurance (Kelley, 2013, p.74).

In this way, moodboards not only support the creative process but also empower designers to develop and trust their unique design perspectives.

### **Moodboard as a Tool for Cross-Disciplinary Inspiration.**

Fashion design often draws inspiration from various disciplines such as art, architecture, nature, music, and cultural studies. Moodboards facilitate the integration of these diverse influences into a cohesive design concept.

By collecting references from different fields, designers can explore new perspectives and expand their creative boundaries. For example, architectural structures may inspire garment silhouettes, while natural landscapes can influence color palettes and textures.

Moodboards allow these cross-disciplinary elements to coexist within a single visual framework, enabling designers to identify connections and relationships between seemingly unrelated sources. This approach leads to more innovative and original design outcomes.

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Furthermore, the use of diverse inspiration sources enhances the depth and richness of the design concept, making it more meaningful and distinctive. As a result, moodboards become powerful tools for fostering creativity beyond traditional boundaries.

The comprehensive analysis presented in this study confirms that moodboards play a central and indispensable role in the creative process of fashion design. As demonstrated throughout the research, moodboards function not only as tools for visual inspiration but also as structured frameworks that guide designers from abstract thinking to concrete design outcomes. They enable the transformation of scattered ideas into coherent visual narratives, ensuring clarity and consistency across all stages of the design process.

**Conclusion.** One of the key findings of this study is that moodboards significantly enhance visual thinking and conceptual development. By integrating multiple elements such as color, texture, form, and imagery, designers are able to explore diverse creative directions and refine their ideas more effectively. This structured approach reduces ambiguity and allows for a more controlled and purposeful design process. Furthermore, moodboards act as continuous reference points, ensuring that the original concept is preserved and consistently reflected in the final design outcomes.

Another important aspect highlighted in the research is the role of moodboards in facilitating communication and collaboration. In multidisciplinary design environments, where multiple stakeholders are involved, moodboards serve as a universal visual language that minimizes misunderstandings and aligns creative vision. This contributes to a more efficient workflow and enhances the overall quality of design execution.

The study also emphasizes the importance of moodboards in fostering experimentation and innovation. As non-final and flexible tools, moodboards provide a safe space for designers to test unconventional ideas, combine diverse inspirations, and explore new visual possibilities. This experimental nature supports iterative design thinking and leads to more original and innovative fashion concepts.

Additionally, the integration of digital technologies has expanded the functionality of moodboards, making them more dynamic, accessible, and collaborative. Digital moodboards allow for real-time updates, easier organization of visual

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content, and enhanced interaction among design teams. This evolution further strengthens their relevance in contemporary fashion design practices.

In conclusion, moodboards should be regarded as fundamental components of the creative design process rather than optional or supplementary tools. Their ability to enhance creativity, ensure conceptual coherence, support communication, and encourage innovation makes them essential for achieving high-quality design outcomes. Future studies may further explore the integration of emerging technologies, such as artificial intelligence and virtual design environments, in enhancing the effectiveness and application of moodboards in fashion design.

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## Aesthetic and Functional Transformation of Design in Smart City Concepts

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**Abstract.** This article analyzes the aesthetic and functional trends of design within "smart city" concepts, not as isolated phenomena, but as two symbiotic systems that complement one another. Is a city merely a collection of technologies, or is it a perceived environment that touches the daily lives of human beings? The essence of modern urban approaches unfolds against the backdrop of these fundamental questions. Research indicates that design in smart cities does not solely aim for visual appeal; it is intrinsically linked to factors such as comfort, accessibility, and sustainability. Whether it is the shaded path of a park or intuitive information panels in public transport, these represent the intersection where function transforms into aesthetics—a transition the inhabitant feels, even if they cannot always define it. Furthermore, the integration of digital technologies is reshaping the language of design. Sensors, data flows, and interactive surfaces are more than technical elements; they shape the "behavior" of the city. Notably, the more human-centric this behavior is, the more successful it becomes. The article emphasizes that without an aesthetic approach, functionality can appear cold and alienated. Conversely, aesthetic solutions lacking a functional foundation rapidly become obsolete and lead to user fatigue. Balance is the critical factor, and this equilibrium manifests differently in every city. Ultimately, a smart city "lives" through thoughtful design rather than technology alone. The smarter a city becomes, the more perceptibly human it must remain.

**Keywords:** *smart city, urban design, urbanization, aesthetic design, functional design, digital transformation.*

### INTRODUCTION

Cities are changing with unprecedented velocity. Why do approaches that worked until yesterday seem insufficient today? Because urbanization is not merely an increase in physical structures; it is the acceleration of the rhythm of life. Populations are growing, streets are becoming congested, and energy resources are finite. Moreover, ecological tensions are becoming increasingly apparent. In such a landscape, classical management methods are akin to

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navigating a modern city with an archaic map. Therefore, a paradigm shift is required. This is where the "smart city" concept emerges—as an attempt to regulate the "breath" of the city through technology.

However, this is not purely a technical matter. Sensors, data streams, and digital platforms are merely tools. The core issue lies in how they are utilized. How can urban infrastructure operate more flexibly? How can resources be distributed more efficiently? How does a citizen perceive this in daily life? These questions sustain the relevance of the topic because traditional methods no longer suffice to solve contemporary problems.

A review of the literature reveals a significant divergence. In international scholarship, this field is developed systematically through models, statistical analyses, and real-world applications. In the local context, however, the landscape remains fragmented. While certain directions have been explored, others still await scholarly attention. Specifically, there is a need for a deeper examination of how technologies function within specific urban environments, how they influence social behavior, and what their economic consequences are. In essence, while the subject exists, it has yet to be fully "articulated."

The perspective of this research is clear: the city is a system. The technologies operating within it alter the system's behavior. The object of study is the modern urban structure, while the subject comprises the smart solutions applied within that structure and their impact on management. The objective is not merely to define the concept but to delve deeper. How does smart transport function? How is energy managed? Through which mechanisms is ecological control implemented? How do digital services enhance the "convenience" of the urban inhabitant? Each of these questions represents a distinct line of inquiry.

Various sources were consulted during the research, including scientific literature, international reports, and statistical data. Methodologically, a singular approach was insufficient; comparative analysis, synthesis, and deconstruction of data were employed to address the multi-layered nature of the topic.

Inevitably, this study has limitations. Access to certain data is restricted, and some real-world applications are not disclosed transparently. Furthermore, the rapid pace of technological change means that today's relevant data may

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appear outdated tomorrow. Nevertheless, the findings possess both theoretical and practical significance. On one hand, they contribute to a more systematic formulation of the concept; on the other, this knowledge can be utilized in real-world decision-making—specifically in urban planning, management strategies, and digital transformation processes. This is not merely a theoretical discussion; it is a deliberate step toward the city of the future.

### **METHODOLOGY**

In structuring this research, one central question remained paramount: how should a city be "read"? Should it be interpreted through raw data alone, or in conjunction with the daily lived experiences of its inhabitants? It was evident that a singular method would be insufficient; thus, the methodological framework was designed with flexibility, adopting a "mixed rhythm" approach.

#### **Systemic Approach**

The primary direction of this study is a systemic approach. A city is not merely a collection of isolated elements; rather, transport, energy, communication, and public spaces constantly interact, influence, and occasionally contradict one another. Therefore, each component was analyzed not in isolation but within the overarching urban structure. Recognizing these interdependencies was crucial, as a minor digital intervention in traffic management can yield unforeseen ripple effects across other sectors.

#### **Comparative Analysis**

Comparative analysis serves as a foundational pillar of this work. The experiences of various cities were examined to determine which models succeed and why others fail to meet expectations. It is a compelling observation that the same technology behaves differently across diverse environments. Through these comparisons, both successful benchmarks and failed attempts were scrutinized, under the premise that failures often provide more profound insights than successes.

#### **Analysis and Synthesis**

The process was further deepened through methods of analysis and synthesis. Collected data were first deconstructed—statistical indicators, technical specifications, and social impacts were examined individually. Subsequently, these elements were reintegrated, akin to assembling a mosaic. As each detail found its rightful place, the holistic picture of the "smart city" became

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clearer.

### Data Sourcing and Interpretation

The database utilized for this study is diverse and dynamic, encompassing scientific articles, reports from international organizations, and open statistical platforms. Given that not all sources possess equal reliability, a rigorous selection process was employed, often cross-referencing multiple sources to verify a single data point. This study transcends mere technical analysis by incorporating interpretative inquiry. Quantitative data is not just presented; it is contextualized to find the meaning behind the numbers. Because a city is a living organism, understanding it requires looking beyond statistics into the qualitative essence of urban life.

### LITERATURE REVIEW

In recent years, the concept of the "Smart City" has become a nexus for various disciplines. Scholars approach the subject through diverse prisms—some prioritizing technological infrastructure, others focusing on the human factor. A critical review of existing literature reveals that this diversity is not chaotic but follows a distinct logic, categorizable into three main strands: conceptual frameworks, technological approaches, and empirical applications.

### Conceptual Frameworks

Studies focusing on the conceptual framework address fundamental questions: What defines a smart city? What are its core components? While some authors emphasize the role of technology, others highlight governance and social participation. A common thread among these perspectives is that a city is more than its hardware. The "human-centric model" suggests that the ultimate goal of smart urbanism is to enhance the quality of life by aligning technology with human needs and daily rhythms.

### Technological Approaches

Technology-oriented research shifts the focus from theory to concrete solutions. This includes Intelligent Transport Systems (ITS), smart grid optimization, sensor-equipped environments, and Big Data analytics. This body of work demonstrates that when applied correctly, technology fosters resource efficiency, service agility, and administrative transparency. However, these studies also raise critical questions regarding over-reliance on technology and data security, adding a necessary layer of caution to optimistic scenarios.



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### Empirical and Case-Based Research

Empirical studies ground theoretical concepts in the reality of existing cities. By analyzing international projects, researchers explore why a model successful in one city may fail in another. The divergence is often found not in the technology itself, but in governance structures, legal frameworks, or levels of citizen engagement. This suggests that the "internal dynamics" of a city are as vital as its technical infrastructure.

### Research Gaps

Despite the extensive literature, certain gaps remain. Localized research is relatively scarce, and the long-term social consequences of smart transformations are often secondary to immediate technical gains. Furthermore, the assumption that a universal model can be applied to every city is reductive. Every urban environment has its own unique rhythm. Identifying these gaps allows this research to formulate new questions, using the existing literature not as a final destination, but as a map—one that is still being drawn—to navigate the future of urban design.

### PRELIMINARY RESULTS AND DISCUSSION

The landscape emerging at this stage of the research is quite compelling. While some findings align with initial expectations, others invite deeper reflection. When smart city technologies are implemented, the city begins to function differently—becoming more coordinated and, in a sense, more "awake." However, how are these changes perceptibly manifested?

### Sectoral Efficiency: Transportation and Energy

In the realm of transportation, the data clearly indicates that flow is regulated more fluidly in cities utilizing intelligent management systems. Congestion is reduced, and time loss is minimized. This is not merely a statistical benchmark; it is a tangible difference felt in daily life. A similar trend is observed in the energy sector. Smart grids render energy consumption more rational, significantly reducing waste. This prompts the question: why were these seemingly straightforward solutions not implemented more broadly in the past?

### Environmental Impact and Digital Services

Positive dynamics are equally evident in the ecological sphere. Air quality monitoring and more effective waste management are no longer abstract ideals but functional mechanisms yielding real-world results. The city, quite

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literally, "breathes" better. Concurrently, the expansion of digital services directly impacts citizens' lives by simplifying access to services and accelerating bureaucratic processes. While inhabitants may experience this transition subconsciously, their overall sense of comfort increases significantly.

### Comparative Reflection and the "Human Element"

When these results are compared with prior research, there is a high degree of correlation, particularly regarding the efficiency of resource utilization—a central theme in technology-oriented literature. However, the trajectory is not entirely linear.

A notable point of discussion is citizen participation. While existing literature posits participation as a prerequisite for success, this analysis reveals that its impact is inconsistent. In some cities, high engagement bolsters outcomes, while in others, it fails to yield the expected effect. This suggests that technology alone is insufficient; the socio-cultural environment that receives the technology is equally vital.

### Vulnerabilities and Risks

Furthermore, as technology expands, risks increase proportionally. Cybersecurity and data privacy are no longer theoretical possibilities but pressing concerns. The research suggests that the smarter a system becomes, the more vulnerable it is.

### Synthesis of Findings

Synthesizing these observations leads to a clear conclusion: the smart city concept is a highly effective tool, but it is not a "universal recipe." It cannot function identically in every urban context. Theoretical models undergo transformation and adaptation when applied in practice, often encountering unforeseen challenges. Perhaps the most valuable contribution of this research lies not just in providing answers, but in articulating the correct questions. Urban transformation is a dynamic process where success depends on the delicate balance between technical precision and social readiness.

### CONCLUSION

The synthesis of this research presents a picture that is both clear and thought-provoking. The "Smart City" approach is no longer merely a fashionable buzzword; it has evolved into a tangible instrument defining the future trajectory of urban centers. This shift is substantiated by both theoretical

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frameworks and practical outcomes. The integration of Information and Communication Technologies (ICT) into urban governance renders processes more agile, measurable, and transparent. Optimizing transportation, reducing energy consumption, and improving ecological indicators are no longer abstract ideals—they are changes generating concrete impact.

### The Socio-Technical Balance

However, one critical aspect cannot be overlooked: technology alone does not perform "miracles." Its success is determined by how it is implemented, the management mechanisms supporting it, and, most importantly, how it is perceived by society. The reason why identical technologies yield divergent results in different cities is often non-technical; it lies in social behaviors, governance cultures, and the public's predisposition toward innovation.

Theoretically, this research clarifies the often "vague" concept of the smart city by systematizing its core components: technology, governance, the human factor, and sustainability. These are not isolated elements but interdependent gears within the same mechanism. If one fails, the integrity of the entire system is compromised.

### Practical Implications

Practically, the results suggest that urban planning is no longer solely about constructing physical spaces—it is about designing digital environments. Management strategies are shifting from static documents to dynamic, adaptive systems. Digital transformation is not just a technological application; it is a fundamental shift in mindset. Through this lens, cities can become more resilient, secure, and profoundly "human."

### Strategic Recommendations

Based on the findings, the following recommendations are proposed:

- **Phased Implementation:** Smart city projects should be executed in stages. While simultaneous total transformation is enticing, it often leads to resource depletion and managerial bottlenecks. Small steps, pilot projects, and testing phases are more effective as they allow for iterative learning and adjustment.

- **Data Ethics and Security:** As technology expands, so do the associated risks. The protection of personal data must be treated not just as a technical requirement, but as an ethical imperative. Transparency is vital; people must know how their

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data is being utilized. Without trust, no "smart system" can be sustainable.

• **Citizen-Centric Design:** The role of the citizen is frequently underestimated. Systems built without considering the daily needs and experiences of the inhabitants will remain alienated from the community, regardless of their sophistication. The ultimate metric of success is whether the people feel the improvement in their quality of life.

### Future Research Directions

The horizons for future research are vast. It is essential to conduct deeper inquiries into the social impacts of these technologies—specifically, how they alter human behavior and how residents adapt to these systems. Expanding comparative studies across diverse urban models could yield unexpected insights. Furthermore, evaluating long-term effects is crucial: will the solutions that appear effective today remain so tomorrow, or will they give rise to new challenges?

In conclusion, the smart city concept is not a collection of ready-made answers. It is an evolving, adaptive approach that reshapes itself within every unique urban context. Understanding this process requires an understanding of both technology and humanity—perhaps the most challenging, yet most rewarding, aspect of modern urbanism.

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# ARCHITECTURE, CONSTRUCTION AND DESIGN

## Analytical Study of the Impact of Art-Design Elements on the Design of Urban and Green Spaces

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**Abstract.** The synthesis of aesthetic and functional approaches holds significant importance in modern urban planning and landscape architecture. In the formation of urban spaces, art-design elements serve not only as means of aesthetic decoration but also as tools for social and cultural communication. These elements strengthen the visual identity of the urban environment, increase the aesthetic value of the space, and positively influence people's perception of and relationship with their surroundings. Various sculptural compositions, decorative structures, landscape installations, and modern design elements applied in the design of green spaces enhance the functional and aesthetic qualities of the urban environment. These elements perform beyond mere decoration; they simultaneously encourage social interaction. Based on the research results, it has been determined that the systematic and purposeful application of art-design elements in urban space design contributes to improving the quality of the urban environment, enhancing the psychological comfort of residents, and preserving cultural identity.

**Keywords:** *art-design, urban environment, landscape design, urbanism, green spaces.*

### INTRODUCTION

The development of modern cities is not limited solely to infrastructure and functional planning. The aesthetic and cultural characteristics of the urban environment are also considered crucial components of urban development. In this regard, art-design elements play a specific role in the formation of urban spaces.

The concept of art-design is based on the synthesis of art and design, aiming to enhance the aesthetic qualities of a space through various visual forms. Art-design elements applied in urban parks, boulevards, squares, and other public spaces allow these areas to be not only functional but also aesthetically appealing.

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The application of art-design elements in the design of green spaces is of particular importance. Decorative compositions, landscape sculptures, installations, and modern design structures placed in parks and gardens increase the visual value of these spaces and strengthen their social function.

In recent years, various studies have been conducted in urban research regarding the social and psychological impacts of art-design elements on urban spaces. This research indicates that an aesthetically rich urban environment positively influences the emotional state and social behavior of individuals.

The purpose of this article is to analytically investigate the impact of art-design elements on the design of urban and green spaces and to analyze modern approaches applied in this field.

### **1. The Role of Art-Design Elements in the Aesthetic Formation of Urban Spaces**

Art-design elements are among the key components playing a vital role in the aesthetic formation of the modern urban environment. The synthesis of art and design holds particular importance in creating the visual identification of urban spaces. The application of art-design elements in urban planning allows these spaces to be not only functional but also aesthetically appealing. In this regard, sculptural compositions, decorative panels, installations, landscape elements, and other artistic design examples serve as essential tools that enhance the visual qualities of the urban milieu.

In contemporary urban projects, the implementation of art-design elements grants the city environment an individual character and uniqueness. These elements shape the identity of urban spaces and allow them to transform into cultural symbols. In many cities, monumental sculptures and decorative compositions are perceived as the visual icons of that location and reflect the city's cultural identity. Kevin Lynch notes that the role of aesthetic elements and symbolic objects is of particular significance in the formation of the urban environment's visual image, influencing how people perceive the city (Lynch, 1960, p. 52).

At the same time, art-design elements help create visual balance and compositional harmony within the urban environment. The harmonious combination of various colors, shapes, and materials ensures the aesthetic integrity of urban



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spaces. This, in turn, ensures that people experience a more comfortable and aesthetically enriched environment. Urban studies indicate that aesthetically attractive urban environments encourage people to spend more time in those spaces and lead to increased social activity (Carmona, 2010, p. 114).

Furthermore, the application of art-design elements allows for the expression of cultural and historical values within the urban setting. Presenting various national ornaments, cultural symbols, and historical motifs through design elements serves to protect the city's cultural heritage and transmit it to future generations. From this perspective, art-design acts not only as a decorative tool but also as a medium for cultural communication.

Consequently, the application of art-design elements in the aesthetic formation of urban spaces contributes to improving the quality of the urban environment, shaping the city's visual identification, and creating conditions for residents to live more comfortably within that environment.

### **2. The Functional Significance of Art-Design Elements in the Design of Green Spaces**

Green spaces are considered one of the most vital ecological and social components of the modern urban environment. Parks, gardens, boulevards, and recreational zones are essential public spaces used by urban residents for relaxation, social interaction, and cultural activities. In this regard, the correct aesthetic and functional planning of green spaces directly impacts the quality of urban life.

The application of art-design elements in the design of green spaces significantly enhances both the visual and functional characteristics of these areas. Decorative pavilions, landscape installations, thematic compositions, and artistic objects placed in parks and gardens not only increase aesthetic appeal but also stimulate the utilization of these spaces. For instance, in modern park design, interactive installations and thematic design elements facilitate more active engagement between people and their surroundings.

Research indicates that green spaces enriched with aesthetic and artistic elements are more frequently used by the public. Jan Gehl notes that the attractiveness of urban spaces and the extent of their use by people directly depend on the aesthetic and social qualities of the environment (Gehl, 2011, p. 89). This, in turn, leads to increased social

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activity and the revitalization of public life within the urban milieu.

Art-design elements in green spaces perform beyond mere decorative functions; they also serve specific functional purposes. For example, decorative pavilions and landscape structures can provide shade and shelter for relaxation. Simultaneously, artistic design elements assist in forming the thematic structure of park spaces and dividing the area into various functional zones.

Furthermore, in contemporary landscape design, art-design elements are increasingly linked with the principles of ecology and sustainable development. Design objects crafted from eco-friendly materials and artistic compositions that harmonize with nature contribute to maintaining the ecological balance of the urban environment (Thompson, 2012, p. 146).

Consequently, the application of art-design elements in the design of green spaces enhances both the aesthetic and functional qualities of these areas, creating a more favorable social and ecological environment within the city.

### **3. The Social and Psychological Impact of Art-Design Elements**

The aesthetic quality of the urban environment is one of the crucial factors directly influencing people's psychological state and social behavior. Modern urbanistic and psychological research demonstrates that an aesthetically rich and harmonious environment creates a more comfortable and safe psychological atmosphere for individuals.

Art-design elements create new opportunities for social communication within urban spaces. Artistic design objects and installations capture people's attention and lead to an increase in social interactions in these areas. People spend more time in these spaces, build social connections, and participate in various cultural activities. In this regard, art-design elements act as a significant factor in boosting the social activity of urban spaces.

At the same time, an aesthetically enriched urban environment positively affects the emotional well-being of individuals. Studies show that public spaces enhanced with art and design elements evoke positive emotions and reduce stress levels (Carmona, 2010, p. 172).

Art-design elements also make a vital contribution to the preservation of cultural identity within the urban environment. Presenting various national ornaments,

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historical motifs, and cultural symbols through design elements serves to protect and develop the city's cultural identity. These elements strengthen the sense of belonging among residents toward their city and increase interest in cultural heritage.

Furthermore, art-design elements positively impact the growth of tourism potential in the urban environment. Various artistic installations and monumental compositions enhance the visual appeal of the city, attracting the attention of tourists and contributing to the formation of the city's cultural image.

### CONCLUSION

The analytical research conducted demonstrates that art-design elements play a vital role in the formation of urban and green spaces. These elements perform beyond mere aesthetic functions; they also possess significant social and cultural impacts.

The purposeful application of art-design elements enhances the visual quality of the urban environment, stimulates the utilization of public spaces, and positively influences the psychological comfort of urban residents.

In future urban projects, the systematic implementation of art-design elements can enable the creation of city environments that are more aesthetic, functional, and socially favorable.

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## Усиление фундаментов с помощью разгружающих элементов

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**Аннотация.** В статье рассматриваются современные методы усиления фундаментов существующих зданий и сооружений с применением разгружающих элементов. Приведены основные причины необходимости усиления оснований, описаны принципы работы разгружающих систем и их влияние на перераспределение нагрузок в конструкции. Рассмотрены конструктивные решения, примеры проектирования и расчёта, а также практические аспекты применения разгружающих элементов при реконструкции зданий. Исследование направлено на повышение надёжности и долговечности фундаментов при изменении эксплуатационных условий.

**Ключевые слова:** фундамент, усиление, разгружающие элементы, микросваи, реконструкция, основание, нагрузка.

### Введение

Фундаменты являются одной из важнейших частей зданий и сооружений, обеспечивающих их устойчивость и долговечность. В процессе эксплуатации здания часто подвергаются дополнительным нагрузкам вследствие надстройки этажей, изменения функционального назначения помещений, ухудшения свойств грунта основания или воздействия внешних факторов. Всё это приводит к необходимости усиления фундаментов.

Современные методы реконструкции требуют внедрения эффективных инженерных решений, обеспечивающих надёжность и минимизацию вмешательства в существующие конструкции. Одним из таких решений является применение **разгружающих элементов**, которые позволяют перераспределять нагрузки, снижая давление на грунт и предотвращая деформации основания.

### 1. Общие сведения о фундаментах и основаниях

Фундаменты служат для передачи нагрузок от здания на

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грунт. В зависимости от характера нагрузок и свойств грунта различают мелкозаглублённые, глубокозаглублённые, свайные и комбинированные типы фундаментов. Основное требование к ним – обеспечение прочности, устойчивости и равномерности осадок.

Со временем эксплуатация, ошибки при строительстве или воздействие природных факторов (замачивание, выветривание, техногенные вибрации) могут привести к снижению несущей способности основания. При этом требуется усиление существующих фундаментов, особенно при реконструкции старых зданий.

### 2. Необходимость усиления фундаментов

Основные причины, вызывающие необходимость усиления фундаментов:

- увеличение нагрузок вследствие надстройки здания;
- изменение расчётной схемы (новые перегородки, оборудование);
- ослабление грунта из-за подземных вод;
- ошибки при проектировании или строительстве;
- неравномерные осадки, трещины, деформации.

Традиционно усиление выполнялось путём подливки бетона под подошву или устройства дополнительных свай. Однако в современных условиях всё чаще применяются **разгружающие элементы**, обеспечивающие более рациональное распределение нагрузок.

### 3. Методы усиления фундаментов

Существуют следующие группы методов усиления фундаментов:

1. **Увеличение площади подошвы** – подливка железобетонной обоймы, подбетонка.

2. **Усиление основания** – цементация, силикатизация, инъектирование.

3. **Применение свайных конструкций** – забивные, буронабивные, буроинъекционные сваи.

4. **Разгружающие конструкции** – балки, ригели, анкеры, свайно-анкерные системы.

Каждый метод выбирается в зависимости от состояния фундамента, свойств грунта и характера нагрузок.

### 4. Разгружающие элементы: принципы и конструктивные решения

Разгружающие элементы – это инженерные конструкции, предназначенные для передачи части нагрузки от фундамента на более прочные слои грунта или на дополнительные несущие элементы.

Их задача – **снизить давление на грунт под подошвой фундамента** и предотвратить неравномерные осадки.

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### 4.1. Принцип работы разгружающих систем

Суть метода заключается в том, что нагрузка от сооружения частично передаётся на дополнительные элементы — микросваи, ригели, анкеры или разгружающие балки. Они принимают часть усилий и уменьшают напряжения в теле фундамента.

### 4.2. Типы разгружающих конструкций

- **Разгружающие балки** — железобетонные элементы, устанавливаемые под основанием.
- **Анкерные разгрузочные системы** — применяются для стабилизации наклонных фундаментов.
- **Микросвайные поля** — система буроинъекционных свай, работающих совместно с существующим фундаментом.

### 4.3. Расчёт и проектирование

Расчёт фундаментов и элементов, предназначенных для разгрузки основания, выполняется на основе метода предельных состояний, который является основным принципом современного проектирования строительных конструкций и оснований зданий. Данный метод предусматривает проверку конструкции по двум группам предельных состояний: по несущей способности и по эксплуатационной пригодности. Первая группа связана с возможной потерей устойчивости конструкции или разрушением грунтового основания, а вторая — с недопустимыми деформациями, такими как чрезмерные осадки, крены или неравномерные деформации, способные негативно повлиять на нормальную эксплуатацию здания или сооружения.

При расчёте взаимодействия фундамента с грунтовым основанием важную роль играет определение напряжений, возникающих в грунтовом массиве под действием передаваемых нагрузок. Основным условием является то, что возникающее давление на грунт не должно превышать расчётное сопротивление основания. Данное условие выражается следующим соотношением:

$$\sigma = PA \leq R \quad \sigma = \frac{P}{A} \leq R \quad \sigma = AP \leq R$$

где — фактическое напряжение, возникающее в основании;

$P$  — суммарная нагрузка, передаваемая от здания или сооружения на фундамент;

$A$  — площадь опирания фундамента или разгрузочного элемента;

$R$  — расчётное сопротивление грунта основания.

Расчётное сопротивление грунта определяется на основании инженерно-геологических изысканий, в ходе которых устанавливаются физико-механические характеристики



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грунтового массива. К таким характеристикам относятся плотность, влажность, угол внутреннего трения, сцепление частиц грунта, а также модуль деформации. Все эти параметры оказывают существенное влияние на способность грунта воспринимать нагрузки и сопротивляться деформациям.

Одним из ключевых показателей, характеризующих работу грунтового основания, является модуль деформации грунта  $E_0$ . Этот параметр отражает способность грунта сопротивляться деформациям под воздействием внешних нагрузок. Чем выше значение модуля деформации, тем меньше ожидаемая величина осадок основания. При проектировании фундаментов данный показатель используется для определения возможных деформаций основания и оценки их влияния на устойчивость и долговечность сооружения.

При передаче нагрузки от здания на фундамент происходит перераспределение напряжений в грунтовом массиве. Давление постепенно распространяется в глубину и по площади основания, образуя так называемую зону напряжённого состояния. В пределах этой зоны грунт испытывает сжатие и деформируется. Если величина возникающих напряжений превышает допустимые значения, может произойти потеря устойчивости основания, что приведёт к значительным деформациям или даже к разрушению конструкций.

Для предотвращения подобных явлений в ряде случаев применяются специальные разгружающие элементы. Их основная задача заключается в снижении концентрации напряжений и более равномерном распределении нагрузок по площади основания. Разгружающие элементы могут представлять собой различные конструктивные решения, например дополнительные опорные элементы, армирующие слои, специальные подушки или другие инженерные конструкции, способствующие улучшению работы системы «фундамент – грунт».

В процессе проектирования необходимо учитывать совместную работу фундамента и разгружающих элементов. Это означает, что деформации всех элементов системы должны рассматриваться в комплексе. При этом важно обеспечить такое распределение нагрузок, при котором не будет возникать значительных неравномерных осадок. Неравномерные деформации основания могут вызвать появление трещин в стенах здания, перекос конструкций и снижение эксплуатационной надёжности сооружения.

Кроме того, при расчёте учитываются условия строительства и эксплуатации здания. К таким условиям относятся глубина заложения фундамента, уровень грунтовых вод, климатические



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факторы, а также возможные динамические воздействия. Например, при высоком уровне грунтовых вод необходимо учитывать снижение прочностных характеристик грунта и возможное увеличение деформаций основания.

Большое значение имеет также правильный выбор геометрических параметров фундамента. Увеличение площади подошвы позволяет снизить давление на грунт, что способствует повышению надёжности всей конструкции. Однако чрезмерное увеличение размеров фундамента может привести к экономической неэффективности проекта, поэтому при проектировании необходимо находить оптимальное соотношение между прочностью, устойчивостью и стоимостью строительства.

Таким образом, расчёт и проектирование фундаментов представляют собой сложный инженерный процесс, который требует учёта множества факторов. Основной целью данных расчётов является обеспечение безопасной и долговечной эксплуатации сооружения.

Правильное определение нагрузок, характеристик грунтового основания и параметров фундамента позволяет предотвратить возникновение опасных деформаций, повысить устойчивость конструкции и обеспечить её надёжную работу в течение всего срока службы здания.

### 5. Практическое применение

Методы с разгружающими элементами нашли широкое применение при реконструкции исторических зданий и промышленных объектов.

Так, в Алматы и Астане применялись микросвайные системы для усиления фундаментов жилых домов, возведённых в 70–80-х годах XX века.

В Европе и России широко используются **буроинъекционные сваи диаметром 100–250 мм**, которые монтируются без вибраций и позволяют работать в стеснённых условиях.

Преимущества метода:

- минимальные вибрации при монтаже;
- возможность применения вблизи существующих коммуникаций;
- высокая точность и контроль качества;
- уменьшение осадок и предотвращение трещинообразования.

### Заключение

Применение разгружающих элементов при усилении фундаментов является эффективным и современным методом повышения надёжности зданий.

Такие конструкции позволяют перераспределять нагрузки, стабилизировать основание и продлить срок службы сооружений без полного демонтажа фундаментов.

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Комплексное использование инженерных решений, включая расчёт, мониторинг осадок и контроль качества, обеспечивает безопасность и экономическую эффективность реконструкции.

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