ISSN NO: 2770-4491
April 2026

Correlation and regression model of medical clinic quality indicators through ISO 9001:2015 and ISO 7101:2023 standards

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Annotation. In this article, quality indicators were studied based on international standards ISO 9001:2015 and ISO 7101:2023, and an empirical-statistical analysis was conducted based on the identified quality indicators. The identified model was tested for adequacy based on Student's and Fisher's criteria. The identified regression equation was confirmed by statistical analysis (Fisher F-criterion $p < 0.001$) and high determination coefficients ($R2 > 0.94$). The models were constructed based on Student's t-test, and the statistical significance of all regression coefficients was determined. The results of the empirical-statistical analysis show that the application of the requirements of the ISO 9001:2015 and ISO 7101:2023 standards have a direct impact on the determining changes in the quality of medical laboratory services. The identified quality indicators and mathematical models can be applied in other medical laboratories.

Key words: indicator, standard, ISO 9001:2015, F-criterion, model.

Introduction. A schematic map of the sequence of actions to be performed in this article is shown in Figure 1, the requirements of international standards for the selection of quality indicators were studied and analyzed, and a questionnaire was sent to medical institutions. Positive letters were received from medical institutions regarding the validity of the questionnaire. When obtaining statistical data, data from the "XYZ" clinic in Andijan were used, and the study was conducted in that institution. Quantitative data of questions were analyzed using statistical methods for visualization and correlation determination [1].

First, the input and output indicators, frequently used in previous studies, were listed. Others developed three categories of hospital admission indicators, including capital investments, labor, and operating expenses. Production indicators are divided into two categories, including medical services and economic profit. Based on the availability of data, a database of alternative indicators was created

ISSN NO: 2770-4491
April 2026

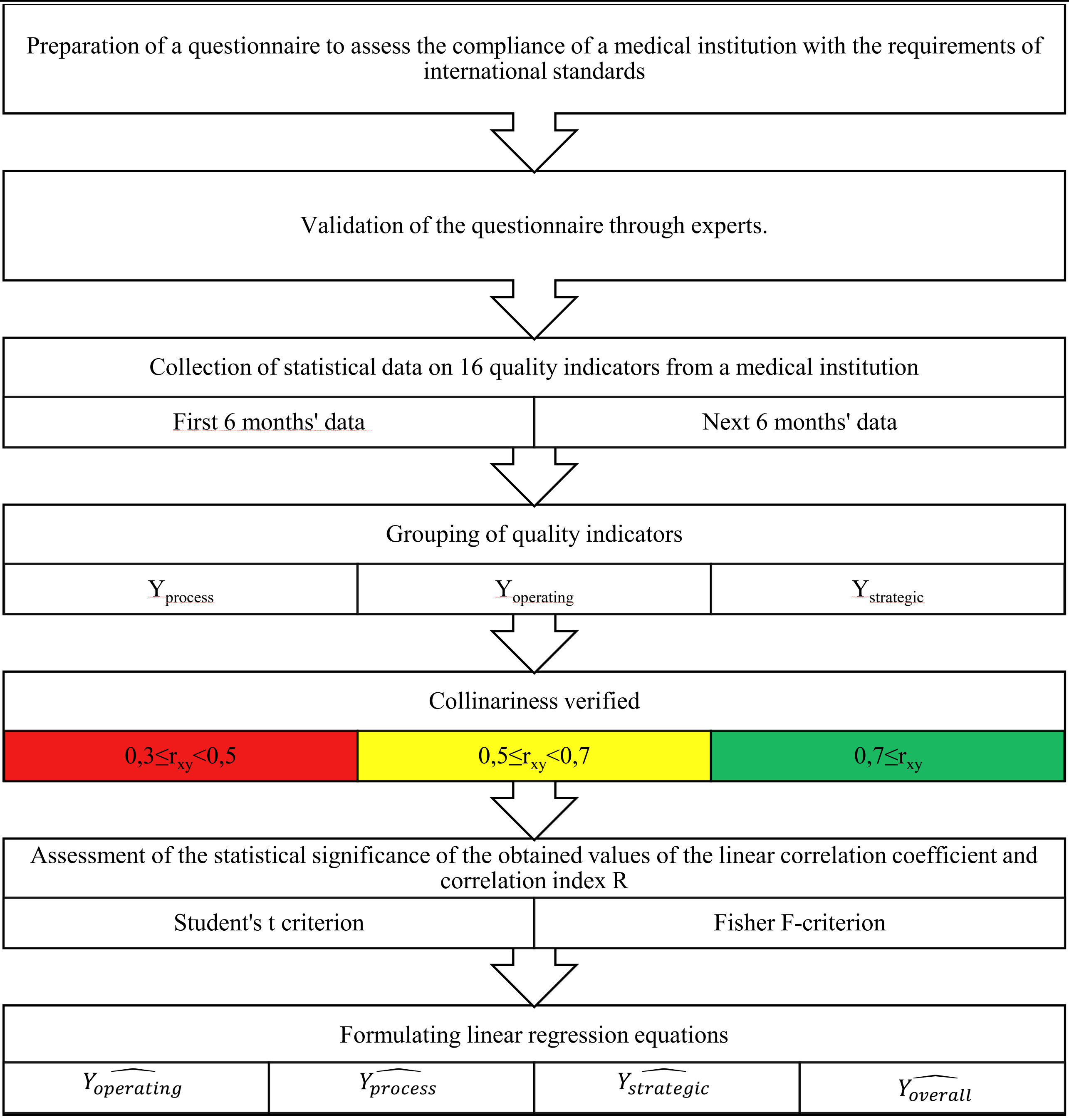

Figure 1. Process of determining and analyzing quality indicators

Table 1

Quality indicator types	
Input indicators	
$Y_{process}$	X3: Compliance with transportation standards, X6: Calibration, X7: Test obtained under quality control, X9: Effectiveness of medical equipment, X10: Reduction in re-analysis
$Y_{strategic}$	X11: Timely results, X14: Patient satisfaction, X15: Patient safety, X16: Change in the number of complaints
$Y_{operating}$	X1:Sample rejection, X2:Timely sampling, X4:Labeling errors, X5:Test accuracy, X8:Target tests, X12: Critical value message time, X13:Give error-free information

ISSN NO: 2770-4491
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Table 2. Results of monitoring quality indices for 12 months

Month	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	Requirement fulfillment
medium	1,1	97,3	98,3	0,06	5,06	100,0	95,0	100,0	96,9	93,6	99,6	12,0	98,5	0,0	99,2	83,5	

Table 3. Standardized table of quality indices.*
***Here, quality indices were standardized based on 1 standard**.

results*	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	Y_p	Y_s	Y_o	$Y_{overall}$
Medium	0,23	0,98	0,99	0,47	0,00	0,70	0,90	0,98	0,97	0,92	0,97	0,91	0,97	0,74	0,99	1,04	0,90	0,75	0,57	0,74

Table 3.a. Distribution of input sizes in colors.

Selected size color	Output size
(yellow)	$Y_{process}$
(blue)	$Y_{Strategic}$
(green)	$Y_{operating}$

First of all, we divide the obtained 16 quality indicators into three parts: Process, Operational, and Strategic. Quality indicators are directly related to these three parameters.

$$Y_{process} = \frac{X_3+X_6+X_7+X_9+X_{10}}{5} \quad (1)$$

$$Y_{Strategic} = \frac{X_{11}+X_{14}+X_{15}+X_{16}}{4} \quad (2)$$

$$Y_{operating} = \frac{X_1+X_2+X_4+X_5+X_8+X_{12}+X_{13}}{7} \quad (3)$$

$$Y_{overall} = \frac{Y_{process}+Y_{Strategic}+Y_{operating}}{3} \quad (4)$$

To conduct correlation and regression analysis, we must select the factors influencing the process.

Correlation and regression analysis methods are widely used to identify and describe relationships between experimental data and random variables and are created based on probability theory and mathematical statistics methods.

In correlation analysis, it is assumed that there is a correlation between the (output value) and (input) variables, where the distribution of the latter changes as the quantity of the former changes. The correlation coefficient is used to assess the degree of relationship between the values.

Correlation analysis aims to examine the density of relationships between variables without separating them into dependent and representative variables. The answer to these questions can be given by calculating correlation indicators or coefficients. [3].

Dependencies by analytical expression

$$y = a_0 + a_1 x \quad (5)$$

are divided into linear types with respect to the factor x, which is determined by the relation, and nonlinear types that apply to all other expressions [4].

$y = a_0 + a_1 x + a_2 x^2 + a_3 x^3$, $y = a_0 + a_1/x$, $y = a_0 + a_1^x$

and so on. The calculation of correlation coefficients is based on the study of the joint use of data from the variables x and y, which is convenient to represent using the table below. [4].

Table 4. Tracking data

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	X			Y
1	X_1	…	X_{k1}	Y_1
2	X_2	…	X_{k2}	Y_2
…	…	…	…	…
n	X_n	…	X_{kn}	Y_n

The density of the linear relationship between factors can be expressed using the linear correlation coefficient r_{xy}. [5].

$$r_{xy} = \frac{\frac{1}{n} * \sum (x_i + \bar{x}) * (y_i + \bar{y})}{\sigma_x * \sigma_y} = \frac{cov(x,y)}{\sigma_x * \sigma_y} \quad (6)$$

where n - number of observations, k - number of factors, x_i, y_i- observational data, $\bar{x}$, $\bar{y}$- mean values of variables x and yσ_x, σ_y - standard deviations of variables x and y. [3].

$$\sigma_x = \sqrt{\frac{1}{n} \sum (x_i - \bar{x})^2} \quad (7)$$

$$\sigma_y = \sqrt{\frac{1}{n} \sum (y_i - \bar{y})^2} \quad (8)$$

r_{xy}- Linear correlation coefficient -1 ≤ r_{xy} ≤ 1 takes values in the range. r_{xy}>0 The relationship in is correct, r_{xy}<0 it will be the opposite at [4].

$|r_{xy}|$ the closer the value is to 1, the denser the linear relationship and the better the linear relationship matches the observational data.. Agar $r_{xy} = 1$ functional dependence, i.e.$y = a_0 + a_1 x_i$ the relation will be executed for all observations. In practice, the communication density levels shown in Table 4 below are used.

Table 5. Quantitative conditions for assessing the connection density

Correlation coefficient value	Relationship description
$\|r_{xy}\| < 0,3$	Almost unavailable
$0,3 \le \|r_{xy}\| < 0,5$	Weakly
$0,5 \le \|r_{xy}\| < 0,7$	Average
$0,7 \le \|r_{xy}\|$	Strong

$\hat{y} = f(x)$ The density of the nonlinear relationship given by the relation is estimated using the correlation index R.

$$R = \sqrt{1 - \frac{\sum_{i=1}^{n} (\hat{y}_i - y_i)^2}{\sum_{i=1}^{n} (y_i - \bar{y}_i)^2}} \quad (9)$$

where n is the number of observations, x_i, y_i are the observation data, $\bar{x}$, $\bar{y}$ are the average values of the variables x and y, $\hat{y}_i$is the value of the variable calculated according to the dependence equation.

The correlation index R varies within the following range. 0 The closer the value of R 1 is to 1, the more the dependence y ̂= $f(x)$ is consistent with the observational data. If R=1, then the relationship is functional, i.e., the relation y ̂= $f(x)$ holds for all observations.

The linear correlation coefficient r_{xy} or near-zero values of the correlation index R indicate the absence of a relationship between the variables x and y, or the randomness of r_{xy} or R. Student's t-test is used to assess the statistical significance of the obtained value of the linear correlation coefficient r_{xy}. If

$$t_r = \frac{r_{xy}}{\sqrt{\frac{1 - r_{xy}^2}{n-2}}} > t_{jadv} \quad (10)$$

the value of r_{xy} is considered statistically significant, where n is the number of observations, t_jadv=t_ (1-α,n-2) is the tabulated value of Student's t-condition. The significance level of is usually assumed to be =0.05 or =0.01. To assess the statistical significance of the obtained values of the correlation index R, Fisher's F-test is used, according to which the value of R is significant if the following condition is met..

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$$F_r = \frac{R^2}{1-R^2}(n-2) > F_{jadv} \qquad (11)$$

where n is the number of observations, F is the tabulated value of Fisher's F-criterion.

Stage I. Operational and seven factors influencing it are selected according to formula (19).

Testing factors for collinearity. Selection of non-collinear factors. We construct a correlation matrix using the formula (22) for expressing the density of linear relationships between factors using the linear correlation coefficient r_{xy}

Table 6. Correlation matrix.

	$Y_{operating}$	X_1	X_2	X_4	X_5	X_8	X_{12}	X_{13}
$Y_{operating}$	1,00							
X_1	0,92	1,00						
X_2	0,58	0,43	1,00					
X_4	0,96	0,80	0,58	1,00				
X_5	0,00	0,00	0,00	0,00	1,00			
X_8	0,73	0,54	0,81	0,75	0,00	1,00		
X_{12}	0,95	0,81	0,54	0,88	0,00	0,68	1,00	
X_{13}	0,52	0,61	0,27	0,55	0,00	0,39	0,25	1,00

As can be seen from the matrix in Table 6, based on Table 4, we will select factors with strong relationships. the values r_{x1y}, r_{x4y}, r_{x8y}, $r_{x12y}$are strongly collinear with each other, from which it is clear that we exclude those that do not have strong collinearity between the factors. Thus, regressions are constructed for factors X_1, X_4, X_8, X_{12}.

Multifactor regression factor R = 0.99 Coefficient of determination $R^2 =$0.99

Fisher statistics = F = 2281,900516

$$\boldsymbol{Regression} = \frac{1}{n}\sum(\hat{y}_i - \bar{y})^2;\ \text{Residual} = \frac{1}{n}\sum(\hat{y}_i - y_i)^2;\ Total = \frac{1}{n}\sum(y_i - \bar{y})^2.$$

In the table F gives the calculated value of the Fisher F-criterion and the smallest value of the significance level of the regression equation "Level of Significance F" When > 0, the regression equations are considered significant. [4].

Table 7 Results of regression analysis.

Indicators	**Coefficients of the regression equation**	**Standard error in determining coefficients**	**t-statistic**	**α Probability error**	**Limits below 95%**	**Limits above 95%**
Y- anticipated	0,1771	0,0852	2,0795	0,0761	-0,0243	0,3785
X_1	0,1344	0,0081	16,6561	0,0000	0,1154	0,1535
X_4	0,1427	0,0066	21,5297	0,0000	0,1270	0,1583
X_8	0,2024	0,0902	2,2447	0,0597	-0,0108	0,4156
X_{12}	0,1027	0,0084	12,2419	0,0000	0,0828	0,1225

The coefficients of the desired linear regression equation are taken from the "Indicators" column of the regression analysis results table, and the regression equation looks as follows.

$$\hat{Y}_{\text{operating}} = \mathbf{0,1771 + 0,1344} * \boldsymbol{X_1} + \mathbf{0,1427} * \boldsymbol{X_4} + \mathbf{0,2024} * \boldsymbol{X_8} + \mathbf{0,1027} * \boldsymbol{X_{12}} \quad (12)$$

In stage II, the process and the four factors influencing it are selected according to formula (17).

Testing factors for collinearity. Selection of non-collinear factors. Using the formula (22) for expressing the density of linear relationships between factors using the linear correlation coefficient . r_{xy}we construct a correlation matrix.

Based on the results of the above calculations, we obtained the following results.

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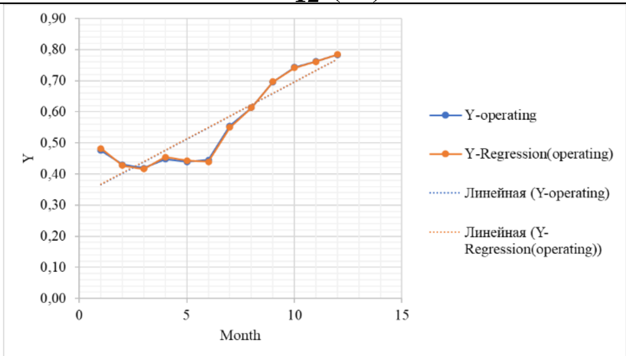
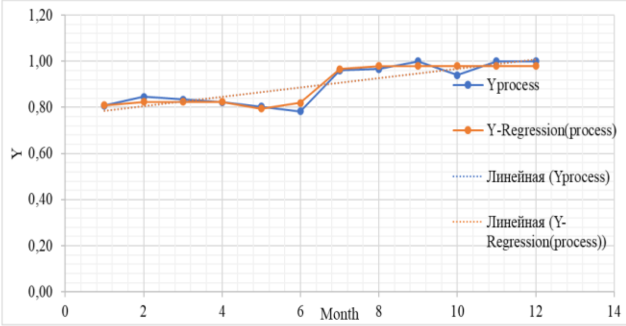
$$\hat{Y}_{operating} = 0,1771 + 0,1344 * X_1 + 0,1427 * X_4 + 0,2024 * X_8 + 0,1027 * X_{12} \quad (27)$$



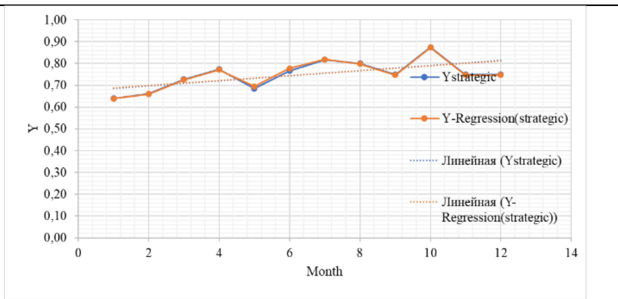
R = 0.99 R^2 = 0.99
F = 2281, 9

$$\hat{Y}_{process} = 0,2091 + 0,5119 * X_3 + 0,2591 * X_6 \quad (28)$$



R = 0.96 R^2 = 0.94
F = 70.79

$$\hat{Y}_{strategik} = 0,2415 + 0,2517 * X_{11} + 0,2536 * X_{16} \quad (29)$$



$$\hat{Y}_{total} = 0,1754 + 0,3863 * Y_{process} + 0,3810 * Y_{operating} \quad (30)$$

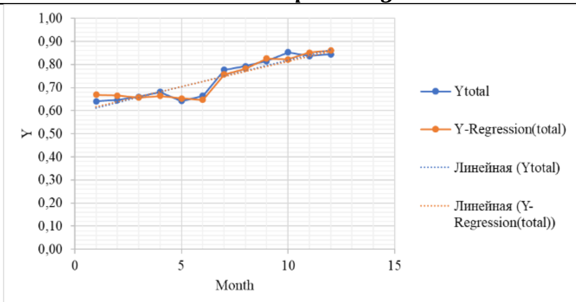


Figure 2. Analysis of regression model graphs.

Conclusion.

Globally, 134 million unfavorable cases of access to medical services occur annually in hospitals of low- and middle-income countries, resulting in 2.6 million deaths. [7].

Errors in taking prescription medications in high-income countries: The results showed that the most common poor-quality medical care mistake in high-income countries is due to errors in taking medications. In particular, about 5% of hospitalizations are associated with errors in medication intake. In particular, in the United States, the most common type of injury caused by errors in medication intake is caused by adverse drug reactions.

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ISSN NO: 2770-4491
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