

# The algorithm of forecasting of the oil well intervention effect

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**Abstract.** The paper reviews stages of oil well intervention effect forecasting. The proposed algorithm based on regression equation solution automates the process of oil well intervention effect forecasting. An assessment of the hydraulic fracturing effect was provided as a validation of the algorithm. According to assessments results, the suggested regression algorithm allows a 1.87-time decrease of an estimation error according to the error of central tendency.

## 1. Introduction

An effective well operation process requires some measures of different kind: geological, technical, technological (so, called, well intervention - WI). There are several goals to provide well intervention. Among them is an increase of the well efficiency (well operational lifetime), base production maintenance, stimulation of well production, oil recovery improvement.

An expedience and capability of well intervention depend on engineering capabilities and the well general condition that is defined within well testing. To explore the well condition, one should provide measures of several types. The choice of the definite well intervention type is not an obvious task – on the one hand, there are several suitable solution variants, on the other hand, any intervention to the well operation process causes definite repercussion. So, mistakes or wrong choices of well intervention lead to direct costs of well intervention providing, as well as lost profits.

Let us outline main stages of the decision-making process of the well intervention choice:

- detection of oil producing well with underused capacity.
- prediction of well capacity after providing the technological process optimization and well interventions.
- decision-making of well interventions.
- well interventions providing.
- efficiency analysis of the provided well interventions.

The paper presents development stages and the algorithm that allows one to automate the stage of oil well intervention effect forecasting.

## 2. The algorithm of oil well intervention effect forecasting

In a process of the well intervention effect, computation can be considered as a forecasting problem. A multidimensional regression model was chosen as a main method of forecasting problem solving.



In the present case, the main goal is to build the model with a vast number of factors and to define how well an intervention effectiveness index is influenced by every single factor determined and by cumulative impacts of the whole number of factors. In other words, it is necessary:

- to choose an interaction form (regression equation);
- to define parameters of the chosen regression equation;
- to analyze and verify adequacy of the equation.

As a result, a generalized regression model equation can be presented as:

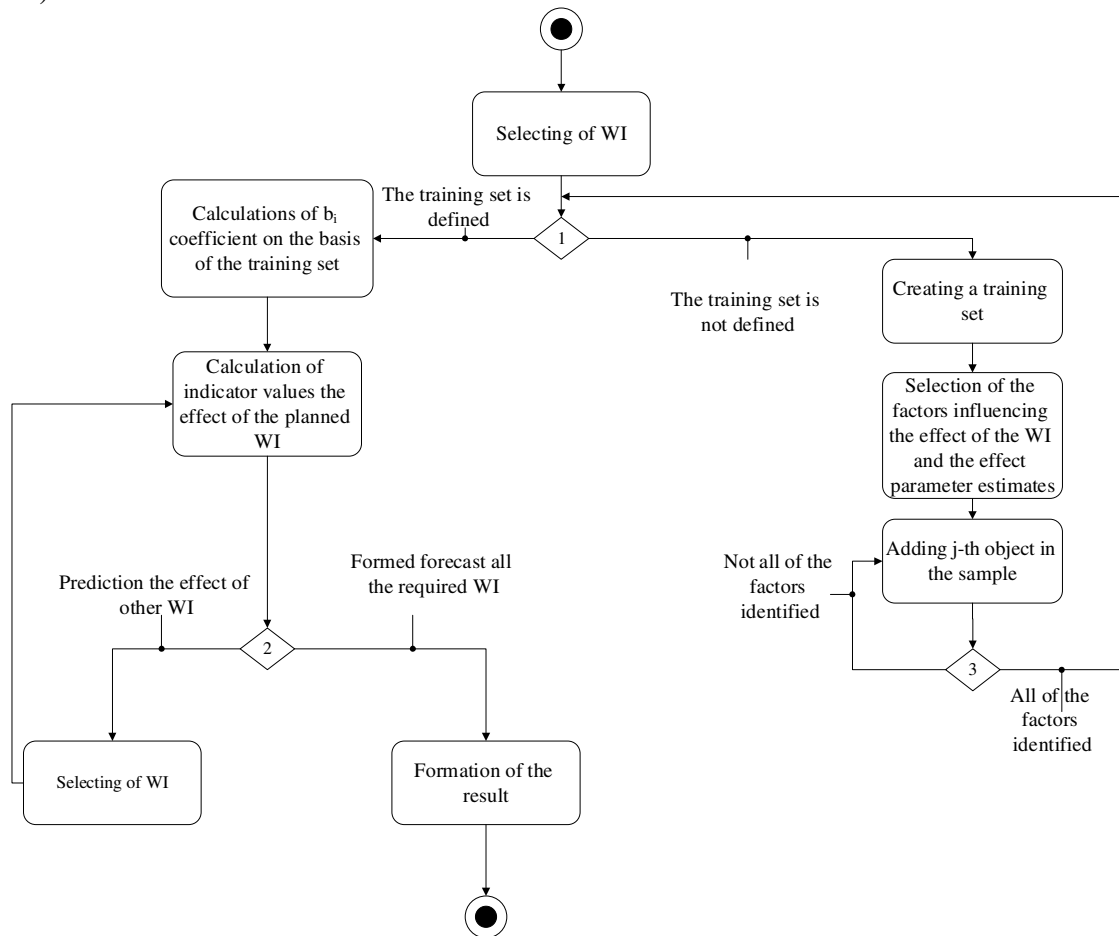
$$y = b_0 + b_1x_1 + b_2x_2 + \dots + b_mx_m,$$

wherein  $x_i$  – score of a factor, that influences the well intervention effectiveness index.

Hence, the problem of well intervention effect forecasting comes to determination of  $b_i$  indexes values. In this case, the following stages are suggested:

- a well intervention type selection (the selection process is based on alternative generation algorithm results);
- a determination of the learning sample for  $b_i$  index value calculation (the pre-existing or new learning sample can be used);
- an automated solution of the regression equation and calculation of  $b_i$  index values (based on the determined learning sample);
- a calculation of the well intervention effectiveness index.

An algorithm of well intervention effect forecasting is presented in figure 1 (UML action diagram notation).



**Figure 1.** An action diagram of well intervention effect forecasting

Factors that influence the well intervention effect and parameters for effect evaluation are different

for various well intervention types. To match the optimal set of factors and parameters, experimental researches are needed. A special built-in tool is provided for setting and editing the necessary set of regression equation parameters. It also eliminates the need for eventual algorithm redesign.

### 3. Results of algorithm functioning modeling

A method of multidimensional regression analysis was chosen as a base for well intervention effect forecasting.

Hence, the generalized problem of well intervention effect forecasting comes to the following statements:

Here,  $Y$  –  $n$ -dimensional column vector of dependent variable inquiry.

$$Y = \begin{pmatrix} y_1 \\ y_2 \\ y_3 \\ \dots \\ y_n \end{pmatrix}$$

$X$  –  $n$  by  $m$  matrix, wherein string  $i$  ( $i = 1, 2, 3, \dots, n$ ) represents inquiry  $i$  of argument  $X = X_1, X_2, \dots, X_m$  of the vector:

$$X = \begin{pmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{pmatrix}$$

$B$  – the column vector of the dimension by  $m$  parameters of the multiple regression equation.

$$B = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ \dots \\ b_m \end{pmatrix}$$

According to the least-squares method, the column vector of  $B$  indexes can be defined in the following way:

$$B = (X^T X)^{-1} (X^T Y)$$

Let us validate the algorithm using real data of the hydraulic fracturing process, provided by joint stock company «Tomskneft» VNK.

The following parameter values were chosen as inquiries:

- fracturing pressure;
- fissure half-spacing;
- the liquid rate before the hydraulic fracturing procedure;
- the oil flow rate before the hydraulic fracturing procedure.

Predicted post-frac fluid rate values are:

- for the object «Well №12» – 85.5385235 tons per day;
- for the object «Well №13» – 83.42483429 tons per day;
- for the object «Well №14» – 95.38515503 tons per day;
- for the object «Well №15» – 77.23942145 tons per day;
- for the object «Well №16» – 72.13574829 tons per day;
- for the object «Well №17» – 71.97671414 tons per day.

Table 1 contains a comparative assessment of well intervention effect forecasting algorithm results.

It should be noted, that the accuracy of algorithm results completely depends on the sample quality that is used for regression indexes calculation (vector  $B$ ) and on parameters defined for inquiry-matrix formation ( $X$  – matrix).

**Table 1.** An assessment of the well intervention effect forecasting algorithm

№	Well Number	Actual results	Predicted results
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1	12	86	85.53852
2	13	82	83.42483
3	14	94	95.38516
4	15	86	77.23942
5	16	64	72.13575
6	17	75	71.97671
7	18	86	85.53852

Let us consider two parameters: a standard error of the mean and a determination index in order to evaluate and compare predicted values and actual data.

A standard error of the mean (S.E.M.) illustrates average deviation of points (predicted results) from initial data form regression curve along the Y axis.

A S.E.M. of evaluation is rated in the following way:

$$E_{ct} = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n-m-1}},$$

wherein m – the number of arguments.

To get results (Table 1), the S.E.M. value is equal to  $E_{ct} = 12.5$  tons per day.

Let us compare the S.E.M. of evaluation and the value of the central tendency error

$$\bar{E}_{ct} = \sqrt{\frac{1}{n-m-1} \sum_{i=1}^n (y_i - \bar{y})^2} = 23.34 \text{ tons per day.}$$

By this means, (for the case when the data of predicting variables values are not considered) the typical forecasting error is 23,34 tons per day. In this way, application of the regression algorithm allows one to decrease an estimation error from 23,34 to 12,5 tons per day (1.87 times).

To characterise the behaviour of output variables, let us consider three quadratic sums: total quadratic sum Q, regression quadratic sum Q<sub>r</sub>, remainder quadratic sum Q<sub>e</sub>.

Calculation results of Quadratic sums calculation results are presented in Table 2.

**Table 2.** Quadratic sum calculation for hydraulic fracturing data

Well №	Liquid rate after hydraulic fracturing procedure (actual results) (y)	Liquid rate after hydraulic fracturing procedure (predicted results) ( $\hat{y}$ )	$y_i - \hat{y}_i$	$(y_i - \hat{y}_i)^2$	$y_i - \bar{y}$	$(y_i - \bar{y})^2$	$\hat{y}_i - \bar{y}$	$(\hat{y}_i - \bar{y})^2$
12	86	85.53	0.461	0.212	4.833	23.361	4.371	19.1131
13	82	83.42	-1.42	2.030	0.833	0.694	2.258	5.09921
14	94	95.38	-1.38	1.918	12.83	164.6944	14.218	202.165
15	86	77.23	8.760	76.74	4.833	23.36111	-3.927	15.4232
16	64	72.13	-8.13	66.1	-17.166	294.6944	-9.030	81.5574
17	75	71.97	3.023	9.140	-6.166	38.02778	-9.189	84.4552
<b>Q</b>								<b>544.833</b>
<b>Q<sub>e</sub></b>								<b>156.240</b>
<b>Q<sub>r</sub></b>								<b>407.813</b>

As far as the value of Q<sub>e</sub> is less than Q, it is a fair assumption to say that involving the information about input variables within a regression task solution provides more accurate results (comparing with noninvolvement of information of such kind).

To evaluate the regression correspondence degree (as an approximation of linear order relation between input and output variables), let us calculate a determination factor of the determination index:

$$r^2 = Q_r/Q = 407.8138/544.8333 = 0.7485.$$

As far as the determination index varies between 0 and 1 inclusively, and the higher value of  $r^2$  is, the more regression model corresponds to real data, it is possible to conclude that the regression model is significant within the process of hydraulic fracturing effect forecasting.

#### 4. Conclusion

The suggested well intervention effect forecasting algorithm increases economical efficiency of oil field production through increasing an operational efficiency of the decision-making process. It also allows one to decrease 1.87 times the forecasting estimation error compared to the error of central tendency (according to validation results). The algorithm reviewed is a part of the program-algorithm complex for well intervention planning and efficiency evaluation.

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