Nafta-Gaz 2025, no. 10, pp. 703–711, DOI: 10.18668/NG.2025.10.06

Analysis and evaluation of the effectiveness of geological and technical measures in oil field development: methods, approaches, and future prospects

Analiza i ocena skuteczności środków geologicznych i technicznych w zagospodarowaniu złóż ropy naftowej: metody, podejścia i perspektywy rozwoju

Samira Abbasova, Jiaojiao Wang

Azerbaijan State Oil and Industry University

ABSTRACT: This article examines modern methods for analyzing and evaluating the effectiveness of geological and technical measures (GTM) employed in oil field development. GTM comprise a set of activities aimed at improving the efficiency of oil and gas production, as well as enhancing the characteristics of oil and gas wells. Such activities include the management of hydrocarbon filtration and extraction processes, that is, the regulation of oil and gas movement within the reservoir to ensure their most efficient inflow into the well, carried out on the basis of geological and technological data analysis on the condition of the reservoir and wells. The objective of the study is to develop methods that enhance the efficiency of oil production processes by improving GTM evaluation. The primary focus of the study is the need to select optimal methods that align with the technological and economic conditions of specific sites. The relevance of the work stems from the objective to increase the efficiency of hydrocarbon field development through the use of advanced technologies and mathematical modeling methods. A review of the literature demonstrates the diversity of existing approaches to the classification and evaluation of GTM, including horizontal well drilling, hydraulic fracturing, enhanced oil recovery methods, and treatment of the near-wellbore zone. The article discusses forecasting techniques based on the analysis of physical, technological, and field data. It highlights the importance of software systems such as EOR-Office for automating processes and increasing the accuracy of evaluations and decision substantiation. The article underscores the significance of a comprehensive approach to evaluating the effectiveness of operations, which includes the analysis of technological effects and oil displacement characteristics. Methods of data extrapolation and their limitations related to forecasting duration and accuracy are discussed. A comparative analysis of various approaches, including the use of hydrodynamic models and probabilistic-statistical methods, is provided.

Key words: geological and technical measures, probabilistic method, rank and partial correlations, additional production, decision making, quantitative and qualitative factors.

STRESZCZENIE: Artykuł przedstawia współczesne metody analizy i oceny skuteczności środków geologiczno-technicznych stosowanych w zagospodarowaniu złóż ropy naftowej. Środki te obejmują zestaw działań mających na celu zwiększenie efektywności wydobycia ropy i gazu oraz poprawę parametrów otworów wiertniczych. Do działań tych zalicza się m.in. metody zarządzania procesami filtracji i wydobycia węglowodorów, które są realizowane na podstawie analizy danych geologicznych i technologicznych dotyczących stanu złoża oraz odwiertów. Celem badania jest opracowanie metod zwiększających efektywność procesów wydobycia ropy poprzez udoskonalenie oceny skuteczności środków geologiczno-technicznych. Główna uwaga została skupiona na konieczności doboru optymalnych metod, dostosowanych do warunków technologicznych i ekonomicznych konkretnych lokalizacji. Znaczenie pracy wynika z dążenia do zwiększenia efektywności zagospodarowania złóż węglowodorów przy wykorzystaniu nowoczesnych technologii i metod modelowania matematycznego. Przegląd literatury ukazuje różnorodność istniejących podejść do klasyfikacji i oceny środków geologiczno-technicznych, w tym wiercenia otworów poziomych, szczelinowania hydraulicznego, metod intensyfikacji wydobycia (EOR) oraz zabiegów w strefie przyodwiertowej. W artykule omówiono techniki prognozowania oparte na analizie danych fizycznych, technologicznych i polowych. Podkreślono znaczenie systemów informatycznych, takich jak EOR-Office, w automatyzacji procesów oraz zwiększaniu dokładności ocen i zasadności podejmowanych decyzji. Zwrócono uwagę na konieczność kompleksowego podejścia do oceny skuteczności działań, obejmującego analizę efektów technologicznych i charakterystyki wypierania ropy. Przedstawiono metody

Corresponding author: J. Wang, e-mail: *1724736732@qq.com*

Article contributed to the Editor: 22.01.2024. Approved for publication: 30.07.2025.

ekstrapolacji danych i ograniczenia z nimi związane, wynikające z czasu prognozy i dokładności wyników. W artykule dokonano także analizy porównawczej różnych podejść, w tym wykorzystania modeli hydrodynamicznych i metod probabilistyczno-statystycznych.

Słowa kluczowe: pomiary geologiczne i techniczne, metoda probabilistyczna, korelacje rangowe i częściowe, dodatkowa produkcja, podejmowanie decyzji, czynniki ilościowe i jakościowe.

Introduction

Achieving and maintaining a high level of oil production is largely associated with the outcomes of geological and technical measures (GTM), which have wide practical application.

Geological and technical activities are operations conducted at wells with the aim of regulating oil field development and maintaining target oil production levels. Through geological and technical measures, oil companies ensure the fulfillment of the design indicators for field development.

GTM are carried out at all stages of field development but are most intensive during the later stages. In mature fields with declining production and increasing water cut, the implementation of GTM is particularly relevant. GTM differ from other activities at oil wells, as they typically result in increased oil production. Each oil-producing company independently determines which activities are classified as GTM and which are considered other types of repairs (capital and underground (current) repairs). In most cases, GTM are associated with capital repairs of wells.

Although each oil-producing company has its own standards for classifying well interventions as GTM, the following types are generally included: hydraulic fracturing (HF), treatment of the near-wellbore zone, transfer to the overlying horizon (TOH), drilling of lateral wellbores, and workover-insulation work (Zaboeva et al., 2024). These activities are conducted based on an analysis of geological and technological data concerning the condition of the field and wells.
However, despite extensive experience in implementing many types of GTM, their effectiveness is often insufficient in certain cases.

The primary direction for improving the efficiency of GTM is refining the selection of targets, types, and technological parameters of the implemented processes. Addressing these issues requires identifying and considering a large number of factors characterizing the state of the "well-reservoir" system and the effectiveness of specific interventions. Meanwhile, the diversity and complexity of the processes occurring in this system, combined with insufficient information about them, significantly complicate the decision-making process for optimal GTM implementation.

In this regard, further research into developing methods for identifying and regulating the key factors determining the effectiveness of GTM remains highly relevant.

It is known that well-justified decisions made during the development of oil fields and aimed at increasing the efficiency of ongoing activities through new technologies play a major role in this process. The development of enhanced oil recovery (EOR) technologies and the involvement of a wide range of geological and technical measures determine the relevance of selecting particular methods, which influence efficiency from both technological and economic perspectives under specific conditions. Despite increased interest from researchers, several problems remain in assessing geological and technical measures in relation to specific conditions. In addition, the need to improve the efficiency of GTM based on the analysis of physical and technological information is becoming particularly pressing. Thus, the problem of increasing the efficiency of the development process can be addressed through a thorough analysis of the conditions under which various geological and technical measures are applicable, in combination with modern methods and appropriate software. Research aimed at improving the efficiency of field development processes has been ongoing for a long time. Moreover, the applicability of a particular GTM under specific conditions is also of considerable scientific and practical interest (Gasumov and Gasumov, 2019; Kozhin et al., 2021).

The purpose of this work is to analyze and forecast the effectiveness of GTM aimed at enhancing reservoir oil recovery and intensifying oil production. Within the framework of the research, the key reservoir and geological factors influencing the selection of enhanced oil recovery methods are identified, and their impact on the outcomes of GTM is evaluated.

Overview of research in geological and technical activities

The development period of hydrocarbon fields is characterized by geological and technical measures such as drilling horizontal wells, hydraulic fracturing (HF), and treatment of the near-wellbore zone. In addition, EOR methods and other techniques aimed at intensifying oil production are becoming increasingly widespread (Gumersky et al., 2000).

Currently, a wide range of analytical methods exists for assessing the effectiveness of specific activities (Fakhretdinov et al., 2001). The activities carried out in the fields are classified as follows: technical, workover, intensification of hydrocarbon production processes, EOR methods, and treatment of the near-wellbore zone.

An analysis of the literature reveals numerous models that support production forecasting aimed at assessing the effectiveness of geological and technical measures (Efendiyev et al., 2025). Forecast indicators are determined based on current production trends and the degree of efficiency of planned activities. Research on forecasting the efficiency of GTM enables the implementation of programming and automation processes to obtain projected indicators of production-enhancing methods used under specific conditions (Zaboeva et al., 2024). Particularly noteworthy is the EOR-Office software package which automates a range of tasks and supports specialists in making informed decisions (Khasanov et al., 2001; Hashemi et al., 2013). Among the methods for assessing GTM effectiveness, extrapolation is considered the most effective. This method involves constructing baseline production levels and comparing them to actual production data following GTM implementation and the forecast data obtained by extrapolating historical data. However, even minor errors can lead to inaccuracies in the selection and planning of optimal measures (Kazakov, 2003). The practical effectiveness of GTM is often assessed using methods that characterize oil displacement by water. The overall efficiency indicator is divided into the effect attributable to the nature of the displacement and the effect resulting from intensified fluid extraction (Hashemi et al., 2013). The effectiveness of GTM is determined based on oil production decline curves.

Currently, several dozen displacement characteristics exist (Syrtlanov et al., 2002). The main challenge lies in selecting the most optimal characteristic that best matches the development history and ensures accurate extrapolation for forecasting. Glukhikh et al. (2002) addresses the selection of methods that provide the most accurate evaluation of GTM. The authors also present dependencies that illustrate differentiation in the technological effects of increased oil production. According to the authors, calculating the expected effect of GTM using extrapolated oil production curves – both actual and baseline – combined with the characteristics method is not always reliable. According to the authors, this is due to the limited duration of the GTM effect; for example, the effect of hydraulic fracturing generally lasts from 5 to 7 years. The reliability of forecasts using water cut curves is high only when water cut values range from 50 to 70%. Lower water cut values reduce the forecast duration in early stages, typically to 3–6 months. It should be noted, however, that measures are more often implemented in wells characterized by a waterless production period or low water cut.

It is also reported that representative post-GTM production data from 4 to 6 points allow for reliable extrapolation of displacement characteristics (Glukhikh et al., 2002). In such cases, it is more appropriate to use a forecasting method based on oil production decline coefficients. If the available production data are not representative, coefficients from other wells with longer post-GTM operational periods may be used (Glukhikh et al., 2002). Therefore, improving methods that use displacement characteristics remains highly relevant.

The nature and sequence of planned activities require multivariate calculations, necessitating the use of modern mathematical tools (Mirzadzhanzade et al., 2004). Authors of a unified model propose an approach in which the technological efficiency of GTM is calculated using advanced mathematical modeling techniques and modern computing capabilities (Sarvaretdinov et al., 2001; Shakhverdiev and Rybitskaya, 2003). This includes a continuously operating multidimensional controlled model that describes filtration processes, and a low-parameter probabilistic-statistical model based on development history.

In the first case (multidimensional controlled mode the creation of geological and filtration models, along with access to suitable software that describes reservoir processes, is essential. This approach, however, involves increased time and cost (Sarvaretdinov et al., 2001).

In the second case (low-parameter probabilistic-statistical model), effectiveness assessment is possible without using a filtration model. Methods as rank correlation, regression analysis, and extrapolation of baseline production levels are employed to analyze GTM effectiveness. These approaches allow the identification of statistical patterns without requiring a detailed description of the physical processes occurring in the reservoir. This method also requires significantly fewer resources and less time, making the performance assessment of GTM more efficient (Shakhverdiev and Rybitskaya, 2003).

Assessment of the reliability of initial data, theoretical foundations, testing of proposed methodologies, and instructions for the associated software can significantly improve the quality and reliability of decision-making (Kazakov, 2003).

Syrtlanov et al. (2002) analyzed methodological provisions for assessing GTM effectiveness and presented results of a numerical using the "Baspro-characteristics" approach for the Samotlor field. Actual data and calculated results were compared with those from an idealized three-dimensional hydrodynamic model. Experimental calculations based on hydrodynamic models and real reservoir conditions were carried out using the Tempest MORE (Roxar) and Eclipse (Schlumberger) software packages. This comparison yielded high-precision data for assessing planned GTM effectiveness, notably through VNIIneft methodology (Sarvaretdinov et al., 2001; Kazakov, 2003; Shakhverdiev and Rybitskaya, 2003; Lysenko, 2004).

Sarvaretdinov et al. (2001) proposed a concept for developing and applying empirical knowledge in assessing GTM effectiveness. This system is organized by creating "event–condition" pairs. Situation formalization, algorithm development for situational analysis, and search procedures are performed using the mathematical apparatus of hypergraphs.

The situational method is based on identifying and applying analogies, from prior field experience with GTM. In practice, specialists often place greater trust in field experience than in mathematical modeling results. However, the most reliable GTM effectiveness assessment result from an integrated approach to problem-solving. Fakhretdinov et al. (2001) addressed the creation of a GTM database for wells and discussed the collection of data on reservoir layers, including parameters such as current oil-saturated thickness (greater than 2 meters), perforation, and permeability (greater than 0.07 μm^2). The next step involves calculating the predicted flow rates for the formations. Well placement is compared with maps of current oil-saturated capacities, and the selected wells are then included in the GTM database. The authors highlight the advantage of this approach, as this eliminates the need for manual well selection. This enables a focus on key factors that most significantly influence GTM effectiveness, while minimizing the time and resources required to gather additional data.

Abasov et al. (2003) addressed the development of GTM database for wells recommended for production using the fuzzy set method. A fuzzy set is defined as an object whose membership is assessed with a certain degree of confidence. The method involves examining wells and classifying them among a set of "recommended for production". The multicriteria nature of the problem often complicates the decision-making process. Under such conditions, the authors propose reducing a multi-criteria problem to a single-criteria problem and solving it using the fuzzy set method (Zoveidavianpoor et al., 2012; Strekov et al., 2013; Filho and Castro, 2014; Moldabayeva et al., 2023). This criterion is understood as the feasibility of implementing specific activities. This enables rapid ranking of solution options according to their feasibility when forming the most appropriate operation schedule.

To assess GTM effectiveness, Lysenko (2004) and Abbasova and Koyshina (2023) propose a concept involving two scenarios: a baseline scenario without GTM, and one with GTM aimed at intensifying production and increasing ultimate oil recovery. However, reliable determination of the initial recoverable hydrocarbon reserves requires extensive and accurate data on the target objects. This has prompted growing research interest in GTM assessment and the development of sound scientific and methodological approaches, underscoring the relevance of finding effective evaluation and selection strategies. The broad scope of studies reviewed in this brief review necessitates the creation of appropriate guidance documents for assessing the effectiveness of implemented measures. These research findings serve as a foundation for addressing GTM implementation across various settings. Additionally, they allow for the assessment of the effectiveness of specific interventions for defined targets. In conclusion, there is a need to develop new approaches that provide an adequate technological and economic assessment of both individual activities implemented under specific conditions and the overall effectiveness of GTM. This enables the rational selection of measures for individual wells and entire fields. Accordingly, Abasov et al. (2003), Moldabayeva et al. (2023), Filho and Castro (2014), Zoveidavianpoor et al. (2012), Strekov et al. (2013), Abbasova and Koyshina (2023), and Suleymanov and Abbasov (2011) have explored the calculation of qualitative GTM characteristics based on technological, physical-geological, and field data. These characteristics form an information base that allows for the characterization of the target objects, the implementation technologies, and the degree of influence on outcomes.

Statement of the problem and its solution

However, the absence of an approach that accounts for the multi-criteria nature of GTM selection complicates the decision-making process. The assessment of ongoing activities is further hindered by the incompleteness of geological, geophysical, and technological data sets. It should be noted that the development of mathematical tools and information technologies, when effectively applied in practice, makes it possible to solve such problems even under conditions of limited information. This aspect has been considered in a number of works discussed in the review.

A large number of studies devoted to determining the influence of geological, physical, and technological factors on activity outcomes are based on the processing of actual field material using probabilistic-statistical methods. Variance analysis, Kullback information measures (Mirzajanzade and Stepanova, 1977; Gaskarov, 1978; Galyamov et al., 1982; Mirzajanzade et al., 2004), and non-parametric tests are all used to identify influencing factors (Mirzajanzade and Stepanova, 1977).

However, solving this problem is mainly limited to an alternative approach that assesses the results of activities by identifying factors whose values determine the effectiveness or ineffectiveness of a given indicator. Equally important is assessing the relationship between factors and the degree of variation in a particular indicator, for example, the amount of additional oil production resulting from an intervention. Solving the problem in this formulation significantly enhances understanding of the conditions under which GTM are effective and, accordingly, makes it possible to improve regulation of their implementation.

The mathematical framework for identifying connection between qualitative characteristics, as proposed by Mirzajanzade and Stepanova (1977), can be used to obtain a solution. This framework enables the identification of relationships between data expressed in categorized form, i.e. as frequencies of observations classified into certain categories or classes. In a particular case, a categorized variable may represent a classification into groups of a numerical variable.

Accordingly, the results of geological and technical activities for a given indicator can be grouped and expressed as a variable that takes on qualitative values corresponding to different degrees of effectiveness. Both numerically defined factors (e.g. porosity, permeability of the near-wellbore zone during hydraulic fracturing) and qualitative characteristics (e.g. types of fracturing fluids, sand fractions) may be used as input variables. The statistical relationship between characteristics expressed in categorized form is determined using rank and partial correlation methods.

Let us consider the general case when two variables are classified into r and c categories, respectively (Galyamov et al., 1982). The number of occurrences in each possible subgroups can be presented in the form of a contingency table ($r \times c$), where r is the number of rows, and c is the number of columns in the table.

Contingency table of attributes (geotechnical factors and performance indicators) expressed in categorized form:

$$\begin{array}{ccc|c} n_{11} & n_{12} \ldots n_{1c} & & n_1 \\ n_{21} & n_{22} \ldots n_{2c} & & n_2 \\ n_{r1} & n_{r2} \ldots n_{rc} & & n_3 \\ \hline n_{.1} & n_{.2} \ldots n_{.c} & & n \end{array}$$

In the case of independence between the variables under consideration, the frequency in the cell at the intersection of the i-th row and the j-th column of the table is equal to $n_i n_j / n$. The deviation from independence in this cell can be measured by the quantity:

$$D_{ij} = n_{ij} - n_i n_j / n \qquad (1)$$

The relationship between variables is determined by calculating the value (Gaskarov and Shapovalov, 1978):

$$X^2 = \sum \frac{D_{ij}^2}{n_i n_j n} \equiv n \left\{ \sum \frac{n_{ij}^2}{n_i n_j} - 1 \right\} \qquad (2)$$

If the hypothesis of independence is satisfied, the value of X^2 asymptotically follows a-χ^2 distribution with the number of degrees of freedom $(df) = (r-1)(c-1)$, and independence is assessed accordingly by comparing X^2 with the critical values of χ^2.

Tabular χ^2 values for the corresponding degrees of freedom are standard values used in statistics for hypothesis testing. They represent critical values of the χ^2 distribution, which can be found in specialized distribution tables χ^2 (Gaskarov, 1978). These values depend on two parameters:

1. Number of degrees of freedom (df):

This number represents the count of independent elements in a dataset that can vary freely. For a contingency table ($r \times c$), the degrees of freedom are calculated using the formula:

$$(df) = (r-1)(c-1) \qquad (3)$$

where:

r – number of rows,

c – number of columns in the contingency table.

2. Significance level (α):

This is the probability of a Type I error (typically accepted as 5% or 0.05).

For a given number of degrees of freedom (df) and significance level (α), the value from the table indicates the threshold above which the null hypothesis is rejected.

In this study, the number of degrees of freedom was calculated from the dimensions of the contingency table ($r \times c$), where r is the number of categories for the first variable, and c is the number of categories for the second variable.

For each table corresponding to specific qualitative and quantitative characteristics of geological and technical measures, the degrees of freedom are calculated using formula (3).

These values were then compared with the calculated statistic χ^2 to test the significance of the relationship between variables. If the calculated value is greater than the tabular value, the decision is made to reject the null hypothesis. In this case, the hypothesis of independence between the variables is rejected, and the relationship between the variables is considered significant.

This makes it possible to justify the influence of geological and technical factors on the effectiveness of oil production.

It should be noted that an important advantage of this method is that it does not require any assumptions about the type of distribution of the analyzed characteristics.

Let us consider the application of this approach to the problem of identifying factors that determine the amount of additional oil production from hydraulic fracturing in one of the fields in the south eastern part of Azerbaijan, which is under development by the state oil company. To solve the problem, factual material was used based on the results of hydraulic fracturing operations in 98 wells in this field. The influence of the following factors on the amount of additional production was studied:

- porosity;
- permeability;
- oil saturation;
- filter thickness;
- additional perforation;
- amount of pumped sand;

- oil production before hydraulic fracturing;
- hydraulic fracturing pressure.

As can be seen, the factor "additional perforation" is qualitative and can take two values: "not carried out" and "carried out". The remaining factors are quantitative.

The application of the χ^2 analysis was conducted to assess the statistical relationship between various factors (such as porosity, permeability, fracture pressure, and others) and additional oil production. During the analysis, a value χ^2 was calculated for each factor and then compared with the critical tabular value χ^2 for the corresponding significance level and degrees of freedom.

The amount of additional oil production resulting from operations was expressed as a categorized variable that could have five values: "absent", "low", "satisfactory", "good" and "high". For this purpose, a classification approach was used to group the results based on the degree of achievement of target values, where:

"Low": This category includes results in which the outcomes of geological and technical measures (GTM) are significantly below the target indicators. Such a level of oil production indicates the inefficiency of the intervention under specific geological and technological conditions. Low production may be associated with inappropriate parameters of the applied technologies, low permeability, or poor reservoir conditions;

"Satisfactory": This category represents additional production that reaches the minimum acceptable levels. This level implies that the intervention has yielded certain results, but they only meet basic expectations. In such cases, the results are often within the range of minimal economic feasibility;

"Good": This category includes interventions that resulted in a noticeable increase in oil production. The outcomes of the GTM meet or exceed the targets, indicating an appropriate choice of technology and its successful implementation under existing conditions;

"High": This is the highest level of effectiveness, where the interventions led to a significant increase in oil production. This result substantially exceeds the expected indicators, demonstrating strong synergy between the selected method and the geological and technical conditions.

The classification of results not only allows for the evaluation of the effectiveness of each intervention but also facilitates the adaptation of approaches to enhance oil recovery and optimize production in the future.

The dataset used in this study was obtained from a combination of field measurements, well documentation, and laboratory analyses provided by the operating oil company of Azerbaijan. Permeability, porosity, and oil saturation values were determined from core sample laboratory tests and well logging (geophysical) interpretations conducted during drilling and workover operations. Filter thickness and the presence of additional perforations were identified from well completion and workover reports. The amount of pumped sand (proppant) and the hydraulic fracturing pressure were taken directly from the official hydraulic fracturing operation reports supplied by the service contractor. Oil production rates before hydraulic fracturing were extracted from daily production records maintained by the operator. The authors gratefully acknowledge the Oil and Gas Production Department (OGPD) of Bibi-Eybat field for providing access to these operational and geological data, which made this research possible.

The distribution of additional production values for each of the considered factors is presented in Tables 1–4. For instance, in Table 1, the following numerical ranges are used to classify each category of additional oil production: "Low" – less than 5 tons per day [t/d]; "Satisfactory" – 5 to 10 t/d; "Good" – 10

Table 1. The results of the distribution of additional production from hydraulic fracturing by the factors "permeability", porosity" and "oil saturation"

Tabela 1. Rozkład dodatkowej produkcji w wyniku szczelinowania hydraulicznego według czynników „przepuszczalność", „porowatość" i „nasycenie ropą"

Additional production	Permeability [10–12 m²]					Porosity [%]						Oil saturation				
	0.1–0.3	0.3–0.5	0.5–0.7	>0.7	Σ	11–14	14–17	17–20	20–23	23–26	Σ	up to 0.6	up to 0.7	up to 0.7	up to 0.9	Σ
Absent	19	6	3	2	30	7	11	7	4	1	30	3	4	12	11	30
Low	7	5	0	2	14	3	3	7	1	0	14	0	3	6	5	14
Satisfactory	6	7	0	5	18	0	7	6	1	4	18	0	2	5	11	18
Good	10	5	3	2	20	2	6	7	3	2	20	0	3	9	8	20
High	8	4	3	1	16	3	5	4	4	0	16	2	2	4	8	16
Σ	50	27	9	12	98	15	32	31	13	7	98	5	14	36	43	98

Table 2. The results of the distribution of additional production from hydraulic fracturing by the factors "filter thickness", "additional perforation" and "sand of quantity"

Tabela 2. Rozkład dodatkowej produkcji w wyniku szczelinowania hydraulicznego według czynników „grubość filtra", „dodatkowa perforacja" i „ilość"

Additional production	Filter thickness [m]						Additional perforation			Sand quantity [10^3 kg]				
	up to 3	3–6	6–10	10–15	15–20	∑	was not carried out	was not carried out	∑	up to 3	3–6	6–10	10–20	∑
Absent	3	8	11	8	0	30	22	8	30	17	9	3	1	30
Low	1	4	7	0	2	14	9	5	14	8	2	4	0	14
Satisfactory	3	6	6	3	0	18	8	10	18	5	8	5	0	18
Good	1	5	4	9	1	20	9	11	20	4	8	7	1	20
High	2	5	6	2	1	16	7	9	16	2	5	8	1	16
∑	10	28	34	22	4	98	55	43	98	36	32	27	3	98

Table 3. The results of the distribution of additional production from hydraulic fracturing by the factor "oil production before hydraulic fracturing"

Tabela 3. Rozkład dodatkowej produkcji w wyniku szczelinowania hydraulicznego według czynnika „produkcja ropy przed szczelinowaniem hydraulicznym"

Additional production	Oil production before hydraulic fracturing [$11.57 \cdot 10^{-6}$ m^3/c]						
	up to 2	2–5	5–10	10–20	20–50	higher 50	∑
Absent	12	4	6	3	2	3	30
Low	7	4	2	1	0	0	14
Satisfactory	8	3	3	2	1	1	18
Good	5	3	6	4	1	1	20
High	5	3	2	5	1	0	16
∑	37	17	19	15	5	5	98

to 20 t/d; "High" – more than 20 t/d. Table 5 shows the values of X^2 calculated by expression (2) for each factor, as well as the tabulated values of χ^2 for the corresponding numbers of degrees of freedom (Gaskarov and Shapovalov, 1978). The table shows that $X^2 > \chi^2$ only for the "fracturing pressure" factor. Thus, this factor is the only one among those considered that is associated with the amount of additional oil production.

Table 4. The results of the distribution of additional production from hydraulic fracturing by the factor "fracturing pressure"

Tabela 4. Rozkład dodatkowej produkcji w wyniku szczelinowania hydraulicznego według czynnika „ciśnienie szczelinowania"

Additional production	Hydraulic fracturing pressure [MPa]				
	10–20	20–30	30–40	40–50	∑
Absent	10	10	8	2	30
Low	0	4	10	0	14
Satisfactory	1	7	10	0	18
Good	2	9	6	3	20
High	4	7	5	0	16
∑	17	37	39	5	98

Based on the results of the statistical analysis conducted for the specific reservoir, the "fracturing pressure" factor was the only one demonstrating a statistically significant relationship with additional oil production. However, it does not exclude the influence of other factors (e.g. permeability), but rather indicates their insufficient statistical significance within this particular dataset. These findings reflect the unique conditions of the analyzed reservoir and do not rule out the possibility that, in other reservoirs, factors such as permeability, porosity, or fluid properties may play a more significant role in similar analyses.

This analytical approach can also be applied to other types of geological and technical measures (GTM). For example, a similar statistical analysis can be conducted for factors such as the type of injected fluids, sand fraction composition, location and number of perforations, etc. Each of these factors

Table 5. Calculated X^2 and tabulated χ^2 for the factors under consideration

Tabela 5. Obliczone wartości X^2 i zestawione wartości χ^2 dla rozpatrywanych czynników

Factor	X^2	Number of degrees of freedom	χ^2
Permeability	7.8	12	21.0
Porosity	18.3	16	26.3
Oilsaturation	10.1	12	21.0
Filter thickness	13.2	16	26.0
Additional perforation	6.9	4	9.5
Amount of sand	20.5	12	21.0
Oil flow rate before hydraulic fracturing	5.1	20	31.4
Hydraulic fracturing pressure	23.5	12	21.0

can be analyzed using the same methods as those applied to hydraulic fracturing. Once such analyses are conducted for other interventions, the results can be compared to select the most effective methods for each specific reservoir.

An analytical approach to evaluating the effectiveness of various GTM under specific conditions, based on accumulated experience combined with comprehensive calculations, will help identify trends and guide the selection of the most effective GTM across various reservoirs.

The study results confirm the relevance of developing new approaches to improve the technical and economic efficiency of GTM, enabling the rational planning of interventions for both individual wells and entire fields.

Conclusion

In the process of oil field development, the selection of the most effective geological and technical measures (GTM) plays a key role in achieving maximum technical and economic efficiency. The conducted analysis allows to draw several important conclusions:

1. Relevance of Developing GTM Methods: Despite significant progress in the study and application of GTM, the issues of improving their efficiency and the accuracy of their evaluation remain relevant. The problem of selecting suitable methods for specific development conditions requires a comprehensive approach, including the use of modern mathematical models, software, and analysis of geological and physical data.
2. Need for a Multi-Choice Approach: Multi-criteria analysis and the use of ranking methods enable the optimization of GTM selection and planning. This is particularly important in situations with limited data or the multi-objective nature of the development process.
3. Factors Influencing GTM Effectiveness: The effectiveness of additional interventions, such as hydraulic fracturing, is significantly influenced by parameters such as permeability, porosity, oil saturation, and pressure. Studies conducted on the example of the investigated reservoir show that the key factor determining effectiveness is fracture pressure.
4. Methodological Basis: The proposed statistical methodology for analyzing the influence of various factors on oil production is universal and can be adapted for analyzing other types of GTM across different reservoirs. It can also be used to justify technological solutions, particularly those aimed at enhancing oil recovery.
5. Comprehensive Evaluation Approach: This approach not only enables the analysis of current results but also supports the identification of parameters that most significantly influence oil production. To obtain reliable results, it is necessary to consider the relationship between geological, physical, and technological parameters. The combination of empirical data and mathematical modeling allows for more accurate forecasting of intervention outcomes.

Thus, the implementation of new approaches and methods for analyzing the effectiveness of GTM is a necessary condition for the rational planning and execution of interventions. This will enhance the economic efficiency of field development, optimize costs, and increase ultimate oil recovery.

References

Abasov M.T., Efendiev G.M., Strekov A.S. et al., 2003. Assessment of the comparative effectiveness of geological and technical measures using comprehensive information. *Oil Industry*, 10: 70–73.

Abbasova S.V., Koyshina A.I., 2023. Decision-Making on the Selection of Geological and Technical Measures: Assessment of Current State and Development Prospects. *Oil Industry*, 10: 10–16.

Efendiyev G.M., Moldabayeva G.Z., Abbasova S.V., Tuzelbayeva Sh.R., 2025. Models and methods of analysis and decision-making in problems of control of technological processes in oil and gas production under uncertainty. *SOCAR Proceedings*, 1: 058–066. DOI: 10.5510/OGP20250101044.

Fakhretdinov R.N., Kaledin Y.A., Zhitkova M.V., 2001. The potential of modern information technologies in assessing the effectiveness of methods for increasing oil recovery. *Oil Industry*, 3: 54–55.

Filho V., Castro A., 2014. Selecting oil wells for hydraulic fracturing: a comparison between genetic-fuzzy and neuro fuzzy systems. *American Journal of Operations Research*, 4(4): 202–216. DOI: 10.4236/ajor.2014.44020.

Galyamov M.N., Olifer S.A., Sultanova L.G., 1982. Application of computers in oil production. *Nedra*, 118.

Gaskarov D.V., Shapovalov V.I., 1978. Small sample. *Statistics*, 248.

Gasumov R.A., Gasumov E.R., 2019. Improving the Efficiency of Gas Condensate Field Development Through the Use of Innovations. *East European Scientific Journal*, 9(49): 43.

Glukhikh I.N., Pyankov V.N., Zabolotnov A.R., 2002. Situational models in corporate knowledge bases of geological and technological activities. *Oil Industry*, 6: 45–48.

Gumersky K.H., Gorbunov A.T., Zhdanov S.A., Petrakov A.M., 2000. Enhanced oil recovery using systemic stimulation technology. *Oil Industry*, 12: 12–15.

Hashemi A., Shadizadeh S.R., Zoveidavianpoor M., 2013. Selection of Hydraulic Fracturing Candidates in Iranian Carbonate Oil Fields: A Local Computerized Screening of Zone and Well Data. *International Petroleum Technology Conference, Beijing, China*. DOI: 10.2523/IPTC-17192-MS.

Kazakov A.A., 2003. Development of unified methodological approaches for assessing the effectiveness of geological and technical measures to increase oil recovery. Reservoirs and intensify oil production (For discussion). *Oil Industry*, 4: 26–29.

Khasanov M.M., Mukhamedshin R.K., Khatmullin I.F., 2001. Computer technologies for solving multi-criteria problems of monitoring the development of oil fields. *Bulletin of the YUKOS Engineering Center*, 2: 26–29.

Kozhin V.N., Roshchin P.V., Nikitin A.V., Kireev I.I., Amirov A.A., Khafizov V.M., Smirnov E.A., Chernova E.A., Vasiakin E.M., 2021. Experience in the use of decorating reagents to intensify oil production in the wells of Samaraneptegaz JSC. *The Eurasian Scientific Journal*, 13(6): 24–36.

Lysenko V.D., 2004. Determining the effectiveness of measures to increase oil recovery and intensify oil production. *Oil Industry*, 2: 114–118.

Mirzadzhanzade A.K., Khasanov M.M., Bakhtizin R.N., 2004. Modeling of Oil and Gas Production Processes. *Institute of Computer Research, Moscow*, 367.

Mirzajanzade A.K., Stepanova G.S., 1977. Mathematical theory of experiment in oil and gas production. *Nedra*, 228.

Moldabayeva G.Z., Efendiyev G.M., Kozlovskiy A.L., Buktukov N.S., Abbasova S.V., 2023. Modeling and Adoption of Technological Solutions to Enhance the Effectiveness of Water Inflow Control Measures in Oil Wells under Conditions of Uncertainty. *ChemEngineering*, 7(5): 89. DOI: 10.3390/chemengineering7050089.

Sarvaretdinov R.G., Gilmanova R.K., Khisamov R.S. et al., 2001. Formation of a database for the development of geological and technical measures for optimizing oil production. *Oil Industry*, 8: 32–35.

Shakhverdiev A.K., Rybitskaya L.P., 2003. Assessment of technological efficiency when influencing hydrocarbon deposits. *Oil Industry*, 4: 65–68.

Strekov A.S., Mamedov P.Z., Koyshina A.I., 2013. Decision-making on the selection of geological and technical measures under uncertainty. *The Seventh International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control, Izmir, Turkey*, 381–384.

Suleymanov A.A., Abbasov A.A., 2011. The Identification of Data Distribution in Oil Production. *Petroleum Science and Technology*, 29(23): 2480–2486. DOI: 10.1080/10916461003735079.

Syrtlanov V.R., Kadochnikova L.M., Trushnikova O.M., 2002. Methods for assessing the effectiveness of geological and technological measures based on three-dimensional hydrodynamic modeling. *Oil Industry*, 6: 38–40.

Zaboeva M.I., Plazun A.V., Osukhovskaya S.S., Kaimanova D.Z., 2024. Results of Well Intervention Measures Application in Oil and Gas Reservoir Development Conditions. *Scientific Forum, Siberia*, 10(1): 49–51.

Zoveidavianpoor M., Samsuri A., Shadizadeh S.R., 2012. Fuzzy logic in candidate-well selection for hydraulic fracturing in oil and gas wells: A critical review. *International Journal of Physical Sciences*, 7(26): 4049–4060. DOI: 10.5897/IJPS12.042.

Samira ABBASOVA, Ph.D.
Associate Professor at the Department of Oil and Gas Engineering
Azerbaijan State Oil and Industry University
31 Khagani Street, AZ1010 Baku, Azerbaijan
E-mail: *samira.abbasova@asoiu.edu.az*

Jiaojiao WANG
Doctoral Student
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave., AZ1010 Baku, Azerbaijan
E-mail: *1724736732@qq.com*