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Calculating the Optimal Time of Fishing Operations During Drilling in the Gachsaran Oil Field

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Highlights

- Investigating fishing and sidetracking operations in the Gachsaran oil field;
- Using the collected data in a machine-learning model to calculate the cost of sidetracking;
- Analyzing formulas for calculating the cost of fishing and sidetracking to estimate the cost of fishing;

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Abstract

Fishing operations are one of the most essential parts of drilling operations. If the fishing operation fails, the other direction should be considered to continue drilling and reach the desired depth, which can be achieved using sidetracking operations. Long-term fishing operations increase the cost and time of the drilling operation; therefore, we should try to have a successful fishing operation in the shortest possible time. It can be stated that the execution of the fishing operation is economical as long as the costs are less or at least equal to the cost of the sidetracking operation. Therefore, the optimal fishing time must be determined to make the drilling operation economical. Many statistical analysis methods have been used to determine the optimal time, but they are not popular due to insufficient accuracy and time-consuming calculations. This study used a machine-learning (ML) model with a regression algorithm to estimate the optimal time for fishing operations in the Gachsaran oil field. The fishing cost rate and depth as input data were first collected and categorized based on different sections of the Gachsaran oil field to calculate the optimal fishing time. Then, the sidetracking cost was predicted by the machine learning model, and this cost was equated to the fishing cost in the worst conditions. As a result, the optimal fishing time was calculated for each section. The result showed that the model could estimate the cost of sidetracking with an error of less than 2%. Using the designed model and the input data of the Gachsaran oil field, considering the optimal fishing time, it was possible to save $1 million and 16 h in drilling a well.

Keywords: Fishing, Sidetracking, Gachsaran Oil Field, Machine Learning, Optimum Time

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1. Introduction

In oil or gas well drilling operations, fishing removes lost or stuck objects from the wellbore (Almeida et al., 1997). When fishing problems occur, drilling costs always increase. Thus, the optimal fishing time should be determined for a cost-effective drilling operation. The most economical way for fishing operations is to do them as quickly as possible (Mullainathan et al., 2017).

The overshot method, which swallows the fish, is involved with the outer diameter of the fish and does not release it to the surface until it is pulled up. Further, in the lower part of the tool, a surface with drilling capability is created so that if the fish is metal parts, a little hole is made and put out. However, the tap taper has strong threads on its outer part, and applying force can create a thread on the fish and pull it up. This tool has an extended tip like a screw, but it is conical in shape. The taper tap is used in shallow wells and lightweight fish.

However, unpredictable factors can cause a fish even if it is planned. Human error, unknown hole conditions, metal fatigue in drilling pipes, and defective equipment are just a few examples of these cases (Keller et al., 1984). Once a fish is generated, drilling, work, and completion will be stopped, and the fish must be carried out before normal operations can be resumed (Adkins, 1993).

The duration of fishing operations has an economic impact on the project. Fishing should be an economical solution to release fish from the well. Hence, before starting fishing, it is better to consult with all well managers, such as geologists and reservoir engineers (Mohanna et al., 2012). Various articles, studies, formulas, and models help make economic decisions about implementing fishing and how long it will take if applicable (Slinker et al., 2008). Almost all companies accomplish their experience to predict the fishing time. However, many factors influence decision-making (Torne et al., 2011). Advances in drilling science, modern fishing methods, and extensive and acceptable data from fishing operations have made it easier for operators to decide about these operations (Harrison, 1982).

In fishing operations, whenever there is no success and the fish does not come out of the well, the sidetracking operation must be implemented by deviating the wellbore from the main path (Sharma et al., 2009). Sidetracking is not risk-free but has a success rate of over 90%. The methods have also made sidetracking an economical alternative to conventional fishing operations (Safari, 2003). To determine which method to choose to release the fish and continue drilling, it must be seen which method is more successful and economical (Adkins, 1993).

Artificial intelligence (AI) today estimates, predicts, or categorizes events. AI in engineering, especially in petroleum engineering, has dramatically helped predict events to reduce costs and save time for operations. AI is intelligence demonstrated by machines, unlike the natural intelligence displayed by humans and animals, which involves consciousness and emotionality (Mani et al., 2021). Frank Chen defines the difference between AI, machine learning, and deep learning: Artificial intelligence is a set of algorithms and intelligence to mimic human intelligence. Machine learning is one of them, and deep learning is one of those techniques (Mani et al., 2021). In machine learning, algorithms are trained to find patterns and features in large volumes of data for decision-making and prediction based on input data. The more appropriate the algorithm, the more accurate the decisions and predictions because it will process more data (Goodfellow et al., 2016). In the following, two cases of research that used machine learning in fishing are stated.

In 2012, Banshi and Ahmadian predicted the fishing time with the help of artificial neural networks. In their research, information on 120 wells in the fields of southern Iran was studied, and 85% of them were evaluated for fishing operations. This information included 16 parameters related to the characteristics of wells and drilling mud and the type of fish. Finally, only three parameters of mud weight, plastic viscosity, and fishing depth were selected as the input of the neural network, and the fishing time was chosen as the output of the network. After normalization, 80% of the data were selected for training and the rest for testing. The multi-layer network was created with two hidden layers. The activity functions in the hidden layers were sigmoid, and in the output layer, linear. The number of neurons in the first hidden and second layers was 7 and 3, respectively (Ahmadian Loraki et al., 2012).

Many algorithms are selected and implemented to have a suitable machine-learning structure in their work. The number of neurons in each layer of the neural network algorithm and the type of activation functions were shown to have an essential role in learning the network. In predicting the outputs, Trainlm performed best among all kinds of optimization functions (Liang et al., 1996). A back propagation neural network was designed, and the duration of fishing operations was estimated with an appropriate approximation. The result is shown in Figure 1. In Figure 1, the *y*-axis is the time of the fishing operation in hours, and the *x*-axis is the testing samples. As shown, the times obtained from machine learning are very similar to those obtained from real-time fishing operations. This research revealed that with the help of an artificial neural network, it was possible to provide a suitable estimation of the fishing operation time and make the necessary decisions to continue the work (Ahmadian Loraki et al., 2012).

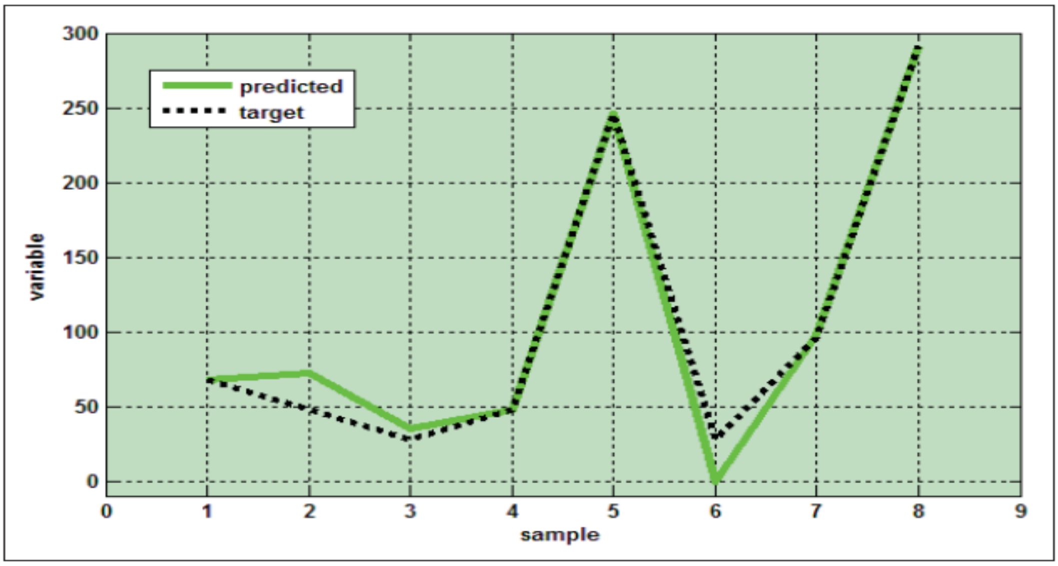

Figure 1

Target data and predicted database versus the sample number (Ahmadian Loraki et al., 2012)

Abbas et al. (2019) used machine learning to predict how to release the stuck pipe. Their field data sets included drilling operation parameters, formation type, and fluid mud characteristics collected from 385 wells drilled in southern Iraq from various fields. The inclination (degree), rate of penetration (m/h), flow rate (l/min), weight on bit (ton), rotation per minute (rev/min), torque (klb/ft), lithology, BHA length (m), hole size (in), mud weight (g/cc), yield point (g/100 cm^2), plastic viscosity (cP), marsh funnel viscosity (s), gel 10” (g/100 cm^2), gel 10’ (g/100 cm^2), circulating pressure (psi), fluid loss (cm^3/min), solids content (vol. %), azimuth (degree), and measured depth (m) data were used as input and fishing methods as output data of machine learning. The algorithms used in their research were artificial neural networks (ANN) and support vector machines (SVM). The SVM algorithm performed better than ANN. Input parameters such as slope (INC), penetration rate (ROP), and flow rate (FR) had a significant impact on the output of machine learning methods (Abbas et al., 2019).

One of the problems that can be raised in fishing operations is the issue of not paying attention and not taking into account the time limit for fishing. This leads to the continuation of fishing activities so that the cost and time of the operation even increase to the extent that it exceeds the sidetracking. Finally, the fishing operation may be unsuccessful (Abbas et al., 2019).

A formula was obtained to calculate the optimal time for fishing operations using statistical data analysis. It is unusable due to the time-consuming calculations and the limitation of the formula to the contractors' rules and its specificity for a specific location (Safari, 2003). Therefore, setting a time limit for fishing operations is better to save time and money.

This paper aims to estimate the optimal time for fishing operations in the Gachsaran oil field. No rules and principles are specified for implementing fishing in drilling operations in this field. To calculate the optimal time of the fishing operation, field data are collected from the final drilling report and categorized for each sector of the Gachsaran oil field. In the following part of this study, the machine learning model designed (Khajehniyazi, 2022) is used to estimate the sidetracking cost and calculate optimal times for fishing in each sector. Ultimately, it is checked which regions' fishing operations are economically beneficial and which are not.

2. Methodology

To achieve the goal of this paper, first, required data from the drilling information of the Gachsaran oil field are examined. In the next step, the cost of sidetracking operations was estimated using a formula (Khajehniyazi, 2022) for each sector. Then, the cost of fishing is compared to the price of the sidetracking operation. The economic and optimal fishing time will be calculated in the next step. The total process of the studied work is summarized in the following workflow shown in Figure 2.

2.1. Data gathering

Gachsaran field is one of the largest oil fields in Iran, with three oil reservoirs. Gachsaran oil field is located 220 km southeast of Ahvaz. This field includes Asmari and Bangestan carbonate fissure formations, which are located in the general direction northwest–southeast of the anticlines of the southern Iran oil fields. The primary oil production formation of this field is the Asmari formation, which is mainly composed of carbonate rocks. Production of this reservoir began in 1318 with well number 13 (NISOC, 2011). Gas injection in the reservoir began in 1977 and has continued with more than 900 million cubic feet daily through 17 injection wells. The northwest part of the field is the widest, the Leishter area. The stratigraphic thickness of the Asmari formation is about 500 m. The excavated thickness in the places where the slope of the formation is high reaches over 760 m. The study of the drilling operations of the Gachsaran oil field in May 2019 started with the data collection stage. Since then, 363 wells have been drilled in this field, 56 of which were drilled in the Bangestan formation and 307 in the Asmari formation (NISOC, 2011).

The collected information was extracted from the following sources: daily drilling reports file (computer reports taken from the existing database), daily drilling reports file (hard copy reports), and daily drilling reports file (computer reports taken from geoscope).

Due to the size and distribution of wells in the Gachsaran oil field, the field was divided into three main parts in this study: East (Sector 9), West (Sectors 5,6), and Leishter (Sectors 1,2), which is shown in Figure 3:

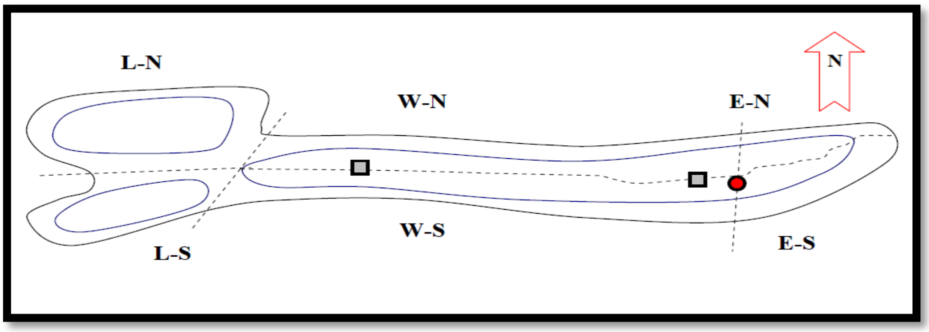

Figure 3

The separated sectors of the Gachsaran oil field

2.1.1. Number of well data

Out of 363 wells whose information was examined in the drilling report, only 121 wells had fishing and sidetracking operations. Many of these operations have been carried out in the wells drilled in the Leishter area.

2.1.2. Number of fishing and sidetracking operations

The total number of fishing operations in this field is listed in Table 1, most of which are in the Leishter region, and their area is unknown for three wells where fishing has been done (NISOC, 2011).

Table 1

Number of fishing operations in different areas

Region	Number	Percentage
E-N	6	9.68
W-S	4	6.45
W-N	7	11.29
L-N	21	33.87
L-S	21	33.87
Nun	3	4.84
Total	62	100

The total number of side-tracking operations in this field is as tabulated in Table 2; most have been done in the western region and the least in the eastern region (NISOC, 2011).

Table 2

Number of sidetracking operations in different areas

Region	Number	Percentage
E-N	4	6.9
E-S	4	6.9
L-N	15	25.9
L-S	6	10.3
W-N	12	20.8
W-S	14	24.1
Nun	3	5.1
Total	56	100

In the sidetracking operation, 9 8/5-inch and 7-inch casing hole sizes were the sizes of the central holes in which most of the operations (more than 90%) were performed. The data of 13 3/8 and 18 5/8 casing sizes have been removed, and two separate models are designed for the 9 5/8-inch and 7-inch casing sizes presented in Table 3.

Table 3

Dispersion of sidetracking operations in different casing sizes

Casing size (inch)	Number	Percentage
18 5/8	2	**2.9**
13 3/8	4	**5.8**
9 5/8	37	**53.6**
7	26	**37.7**
Total	69	**100**

2.1.2. Average time of fishing and sidetracking operations in each area

The average time of fishing and sidetracking operations separately for different sectors is shown in Figure 4. It can also be seen that no sidetracking operations have been implemented in Sectors 5,6. On the other hand, very little time has been spent implementing fishing operations in that sector. In Sector 9, the fishing operations are done faster, but sidetracking takes longer (NISOC, 2011). In Sectors 1,2, fishing and sidetracking operations are very time-consuming, indicating that many pipes are stuck and much time is spent solving the problem in this area.

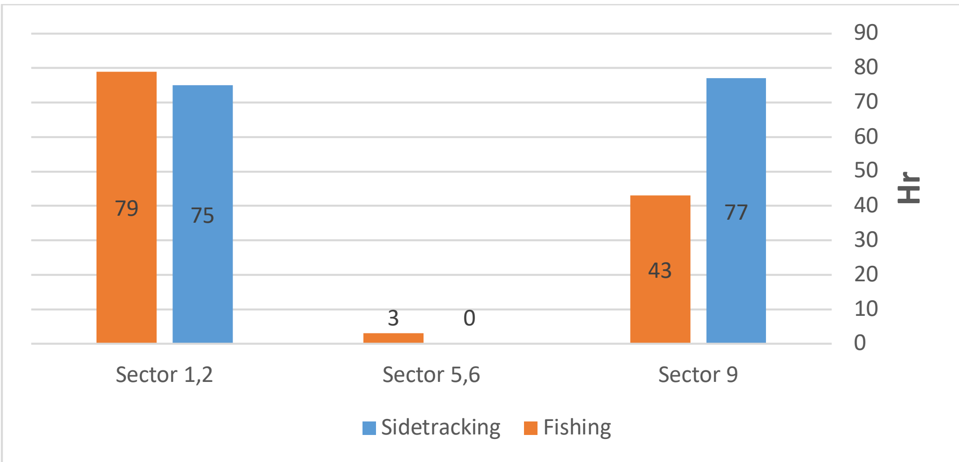

Figure 4

Time of the sidetracking and fishing operation in each sector

Moreover, due to the nature and importance of the subject, an interview was conducted between the authors and people with work experiences in fishing and sidetrack operations in this field. The individuals were selected from contractors of the National Iranian South Oil Company (NISOC) and the Research Institute of Petroleum Industry (RIPI). Some people were also selected from private sidetrack operating companies such as Petro Kariz and Omid Kish Company.

In interviews with experienced people and companies, we had the following questions:

- In which casing size and at what depth did the largest sidetracking operation happen?

- How much is the cost of sidetracking operations?
- How much are the costs of sidetracking operations subgroups?
- What was the average time of fishing and sidetracking operations in the area?
- How much was the area's average fishing operation cost?
- How much is the average cost of subgroups of fishing operations in the area?

In summary, the data used in this article are divided into two categories, as given in Table 5: field data and interview data.

Table 5

Summary of the data used herein

Field data	Data obtained from the interview
Fishing depth	Fishing cost rate
Number of fishing operations	Sidetracking cost
Number of the sidetracking operation	
Average time of drilling operations	
Average time of fishing and sidetracking operations	

The data collected for the 7 and 9 5/8-inch casings and their general characteristics are listed in Table 6.

Table 6

The average sidetracking cost and fishing cost rate

Data	Fishing cost rate in 7" casing size ($/Day)	Fishing Depth in 7" casing size (ft)	Fishing cost rate in 9 5/8" casing size ($/Day)	Fishing Depth in 9 5/8" casing size (ft)
Count	23	23	24	24
Mean	53,990	2,244	53,943	1,687
Min	53,306	1,048	53,301	772
Max	54,683	2,870	54,554	2825

2.2. Estimation sidetracking cost

First, the formulas obtained by the machine learning method are used to predict the sidetracking cost for the 7 and 9 5/8-inch casing sizes in the Gachsaran oil field (Equations (1) and (2)).

For 7-inch casing size:

$$Y = 0.66A + 0.339B + 82488134.42 \tag{1}$$

For 9 5/8inch casing sizes:

$$Y = 0.157A + 0.842B + 40714727.88 \tag{2}$$

where, A is the fishing depth, B indicates the fishing cost rate, and Y denotes the sidetracking cost.

2.3. Calculation of fishing job cost

The cost of a fishing operation is equal to the sum of the following values given in Equation (3) (Adams, 1985):

$$Fishing\ cost = Fishing\ time \times \frac{cost}{day} Rig + Fishing\ operation\ cost\ + Damaged\ tools\ cost \tag{3}$$

2.4. Economize fishing operation time

To economize fishing time in this step, the cost of fishing is equal to the sidetracking cost obtained by the formulas derived from the machine learning algorithms.

$$Fishing\ operation\ cost = Sidetracking\ cost \tag{4}$$

2.5. Optimization of fishing operation time

To optimize the fishing operation time, the worst conditions for fishing operations were considered in this study, as follows:

- Loss of all tools below the stuck pipe depth: BHA tools are the most expensive.
- The costliest fishing tools and operators used in that area

The optimum fishing time can be calculated by considering these situations in Equation (5).

$$Optimum\ Fishing\ time = \frac{Side\ tracking\ cost - Fishing\ Operation\ cost - Damaged\ tools\ cost}{Rig\ cost} \tag{5}$$

Finally, by performing the steps described above, with the appropriate input data, the cost of sidetracking can be calculated first by machine learning algorithms. Then, the optimal time of the fishing operation can be obtained.

3. Results

All the data of the unsuccessful fishing operations that are forced to be sidetracked are entered into the formulas obtained from machine learning. The costs of sidetracking are predicted, and optimal times are calculated for each sector using the stated formulas and assumptions. The average fishing time obtained for each area is calculated in Table 7.

Table 7

Results from the best models for any size in each region

	Sector 9	Sectors 1,2	Sectors 5,6
Optimum fishing time (h)	26.02	63.96	14.35

3.1. Comparison of the optimal time and the actual time of fishing operations

To confirm our work, the average optimal fishing time of each area was calculated and then compared with the data of the drilling report during the fishing operation (see Figure 5). From comparing the average optimal time of fishing operations with the average reported fishing time in each area, it can be concluded that in any area where our average reported fishing time is less than the average optimal time, no sidetracking operations were performed, and the fishing operations were more successful (Sectors

5,6). On the other hand, in each area where the average reported time became more than the average optimal time, more sidetracking operations were performed, and more time and cost were spent on drilling, resulting in longer drilling operations (Sector 9 and Sectors 1,2).

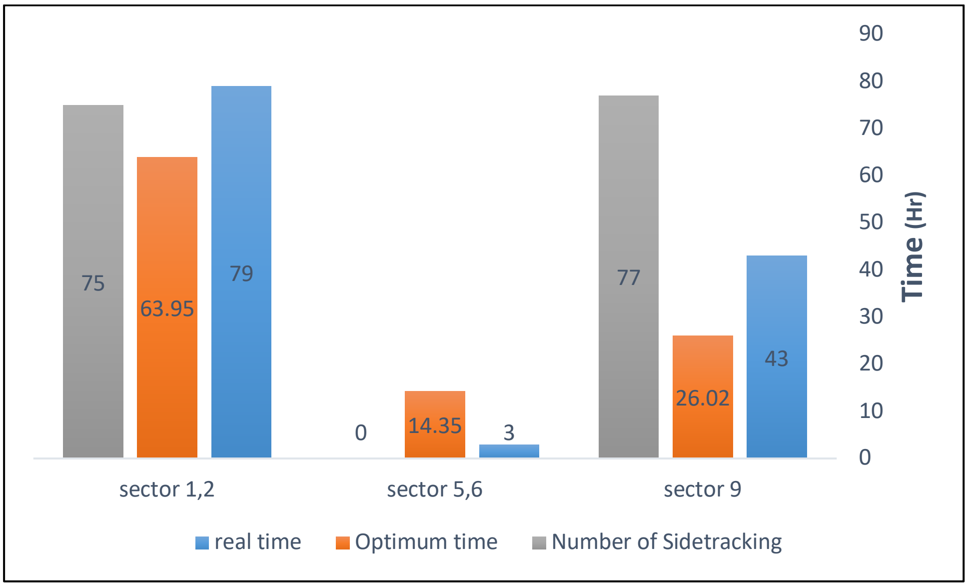

Figure 5

Comparison of the calculated optimal fishing time and the reported average fishing time

4. Conclusions

The following conclusions could be drawn from the results obtained from the research:

- The data could be analyzed and predicted with high speed and accuracy using artificial intelligence machine learning;
- Determining the optimal fishing operation time for each area demonstrated that in areas where the fishing operation time was longer than the calculated time, the success rate was lower, and the number of sidetracks was higher. However, in the area where the fishing operation time was longer, the success rate was higher, and less time was spent on sidetrack operations.
- Using the results and formula obtained, the optimal time of the fishing operation could be obtained in each desired area in the Gachsaran field by having depth and fishing cost rate data.
- Using the optimal time of fishing operations in this field, an average of 15 h and $806,000 in Sectors 1,2 and an average of 17 h and $910,000 in Sector 9 could be saved.

Nomenclature

BHA	Bottom hole assembly
KOP	Kick-off point (ft)
ML	Machine learning
NISOC	National Iranian South Oil Company
RIPI	Research Institute of Petroleum Industry

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