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Drilling Engineering Assessment and Cost Analysis of Oil and Gas Wells Drilled in Onshore of Turkey

Adil Ozdemir[1]*, Ahmet Güllü[2], Ergül Yaşar[2], Yildiray Palabiyik[3]

[1] *Adil Ozdemir Engineering & Consulting, Ankara, Turkey*
[2] *Department of Petroleum and Natural Gas Engineering, Iskenderun Technical University, Hatay, Turkey*
[3] *Department of Petroleum and Natural Gas Engineering, Istanbul Technical University, Istanbul, Turkey*

INFORMATION

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Contact
*Adil Ozdemir
adilozdemir2000@yahoo.com

ABSTRACT

Since the advanced technology used in oilwell drilling is difficult and costly, the drilling must be completed in the most appropriate conditions, in the shortest time, with cost-effective and the targeted depths and purposes. This requirement has further increased the importance of drilling optimization. There are many literature studies on this subject. In this study, the data of oil and gas wells drilled in onshore Turkey were evaluated by investigating the studies on drilling optimization. It is aimed to create a new source for the literature by statistical analysis. For this purpose, the reports of 470 oil and gas wells drilled in 1963 - 2021 in onshore Turkey have been analyzed. The well locations, their average well depths, drilling operation results, drilling times and costs, log and perforation operation costs, Drill Stem Test (DST) operation costs, acidizing operation costs, workover operation costs, cement costs, drill-bit types according to commonly used International Association of Drilling Contractors (IADC) codes for drilled formations, total costs and costs per meter for the oilwells have been evaluated.

1. Introduction

Developing technology and increasing consumption have brought new dimensions to the utilization of natural resources and a rapid development period has entered in terms of discovering and operating subsurface resources. The limited existence of the industry's basic raw materials (petroleum, gas and other precious metals) in nature has increased the importance of better utilization of known resources and revealing new resources. Throughout history, the demand for energy has been increasing day by day. Researchers continue to work with new projects to meet the ever-increasing energy demand from clean and renewable energy sources. However, a significant part of the energy need in the world is still met from fossil fuels. For this reason, oil and gas still maintain their dominance in the energy market in the world. Oil companies, on the other hand, always have to drill more oil and gas wells to balance this supply and demand. This demand, on the other hand, pushes the sector to multidimensional researches. The highest cost in the petroleum sector is encountered by drilling operations.

As hydrocarbons produced from existing reservoirs are no longer meeting demand, oil companies have begun to spend enormous budgets to explore and discover new oil and gas reserves. Drilling costs increase significantly, as most of the exploration for new reserves is carried out offshore or at hard-to-reach depths.

A successful, safe and economical drilling operation is only possible with a comprehensive drilling program and design. Drilling of oil and gas wells has always been costly. Cost differences and high investment amounts in transition from onshore to deep-sea drilling have increased the importance of drilling optimization. These amounts today exceed one hundred million US dollars.

Oil and gas production is a difficult process that requires advanced technology. Oil and gas well drillings are also a costly project because it is necessary to conduct studies to prevent waste of resources during the drilling operations for hydrocarbon production. These studies should be considered both in terms of time and cost saving and should be evaluated together. Therefore, oil and gas well drilling should be completed in the shortest time and with the minimum cost in line with the targeted depth and purpose. This can only be achieved through a drilling optimization process.

In this study, the previous studies on oil and gas wells drilled in onshore Turkish have been comprehensively examined in detail and it has been further investigated whether there are similar studies in the literature. As a result, it has been determined that three studies exist on the subject. In these studies:

Gümüş and Altan (1995), in their studies entitled "History of Petroleum and Oilwells Drilled in Turkey" have presented the coordinates, information about the companies, results of drilling operations of 2676 oilwells drilled in Turkey between 1934 - 1993.

In Görgün (2013)'s study, the efficiency and productivity of totally 94 production wells drilled onshore Turkey by the Turkish Petroleum Corporation during the period 2008-2010 have been tested employing Data Envelopment Analysis (DEA). In the study, it has been observed that the active wells are the ones with an average drilling depth of 1300-1500 meters, drilling duration of 15-25 days, costs between $ 300,000-800,000 and oil production amounts generally not exceeding 50,000 barrels.

Ozdemir (2016) inspected the costs of oilwells drilled in onshore Turkey in 2008-2010 according to their depths (Table 1).

Table 1. The costs of oilwells drilled in onshore Turkey in 2008-2010 according to their depths (Ozdemir, 2016)

Depth (m)	Number of Wells (pcs)	Ratio (%)	Average Cost (US $)	Average Drilling Time (days)
1000 - 1500	68	78	575 000	21
1500 - 2500	13	15	1 185 000	44
2500 - 3250	6	7	2 550 000	90
Total	87	100	-	-

Within the scope of the study, well-completion reports of real oil and gas drilling wells have been inspected, then the data have been converted into graphics and statistics, and interpretations of the drilled wells have been analyzed. Numerous data such as drilling times of the wells, the well depths and costs have been investigated in detail. In this way, during the well drilling decision phase, which is a dynamic process, this study will aim to serve as an example, by taking the recommendations and suggestions of this study into consideration while making a decision to drill a risky and costly well in the future, and by contributing to make effective well investments in the oil and gas sector.

Therefore, although it is not known whether an analysis/optimization has been made in the internal structures of the companies/institutions, there is no analysis/optimization study in the national and international literature on the drilling engineering assessment of oil and gas wells excavated in onshore Turkey. From here, it is thought that this study, which has been statistically evaluated to reveal the technical details and costs of the wells drilled in onshore Turkey, will make a great contribution to the sector and the literature.

2. Drilling and Completion Data Along with Cost Analysis of Oil and Gas Wells in Turkey

2.1. Data and methodology

In the context of this study, the raw data of 470 oil and gas wells drilled in Turkey's onshore basins are used and interpreted. Information on oil and gas wells are as follows:

1. Locations of the wells: Most of the wells (79%) of which data are evaluated the wells drilled in the Southeastern Anatolia and Thrace basins where almost all of Turkey's oil and gas production are performed. Majority of the wells is situated in the provinces of Southeastern Anatolia basin (Adıyaman, Batman, and Diyarbakır) and Thrace basin (Kırklareli and Tekirdağ) (Fig. 1).

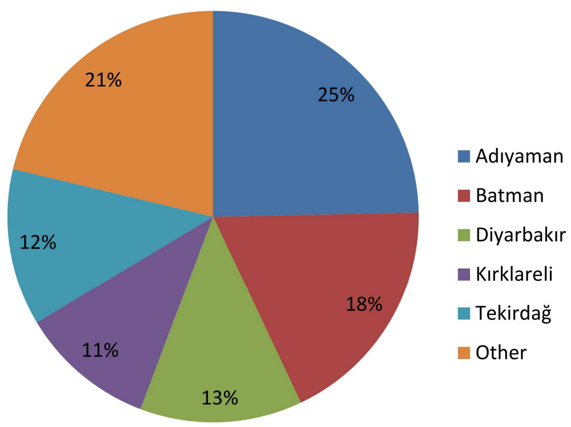


Fig. 1. Distribution percentage of oil and gas wells by provinces

2. The years when the wells were drilled: The data related to the wells drilled between 1963 and 2021have been evaluated. In terms of the cost and duration evaluations of the wells to be representative, the distributions of the wells over the years have been considered as homogeneous as possible (Fig. 2).

3. Types of the wells: The wells studied have been chosen from exploration, extension, and production wells to be as homogeneous as possible. Storage and injection wells have been also included, albeit limited, in the data (Fig. 3).

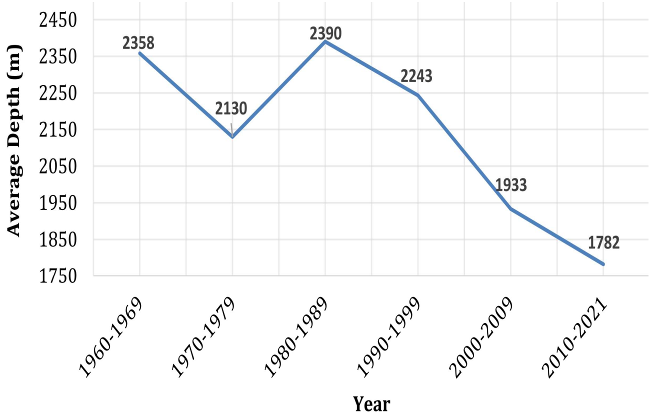


Fig. 2. Average depths of the wells by years

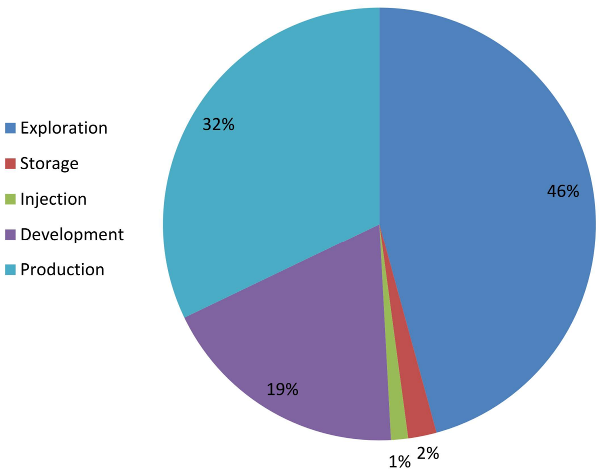


Fig. 3. Distribution of the wells by types

4. Depths of Wells: The depths of the wells, whose data are evaluated, are 500 - 5000 meters. Additionally, 86% of the wells are 1000 - 3000 m deep. Furthermore, the average well depth is calculated as 1959 m (Fig. 4).

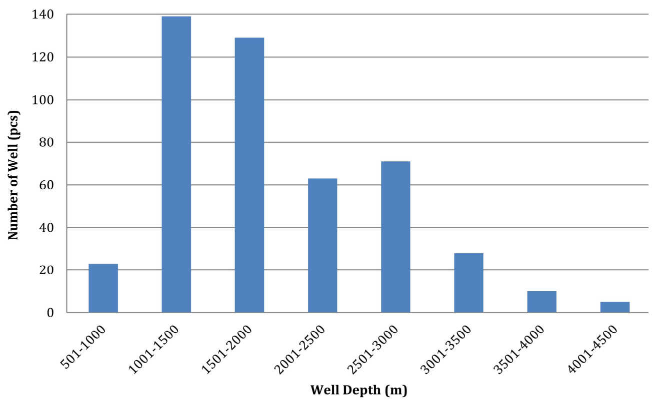


Fig. 4. Distribution of the wells according to their depths

5. Operational results: Operational results obtained from wells has been described as well completed with oil, well completed with gas, well completed with oil & gas, well with gas show, well with oil show, dry or wet well, and the abandoned wells due to technical issues (Fig. 5).

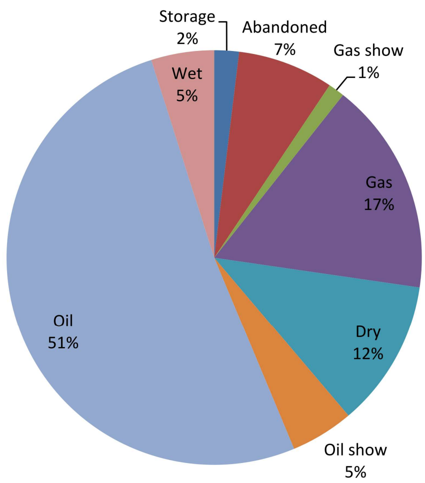


Fig. 5. Percentage distribution of the wells by operational results

6. Drilling time of the wells: The time (in day) from the start of the drilling of the well to the completion of the well and the well completion (in day) is a significant operation that increases the total cost. Compaction of the casings, fishing operations, and any problems occurring in the drill rig also increases the expenses as they will extend the drilling time. Sometimes it can even be the reason for "Abandoned due to technical reasons" of the well. The drilling durations according to the depths of the wells evaluated based on their data are given in Fig. 6.

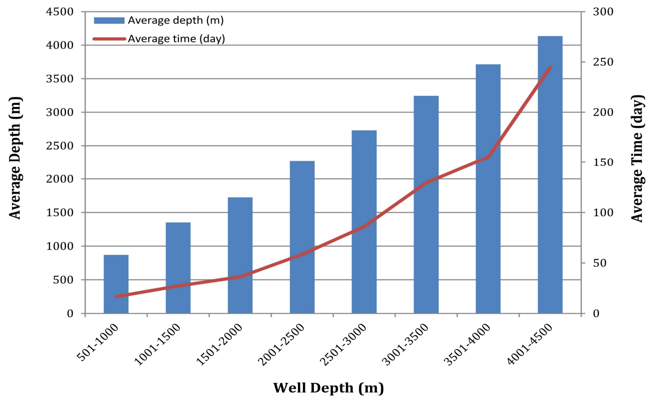


Fig. 6. Depth-time graph of the wells

2.2. Costs of the wells

Cost of Well: It is the sum of all costs incurred for the well. Cost per Meter of Well is calculated as Total Cost of Well / Well Depth. In the study, the well costs are calculated in US dollars. Total cost, total cost percentage, and cost per meter of well of the 470 oil and gas drilling wells examined within the scope of the study are given in Figs. 7 and 8. Costs of the wells are $ 465,555 for depths of 500 - 1000 m, $ 718,572 for depths of 1001 - 1500 m, $ 1,096,571 for depths of 1501 - 2000 m, $ 1,548,744 for depths of 2001 - 2500 m, $ 1,905,853 for depths of 2501 - 3000 m, $ 2,098,452 for 3001 - 3500 m depths, $ 2,598,213 for 3501 - 4000 m depths, and $ 2,909,631 for 4001 - 4500 m depths. The well total costs obtained from this study are consistent with the results of the study of Ozdemir (2016) (Table 1).

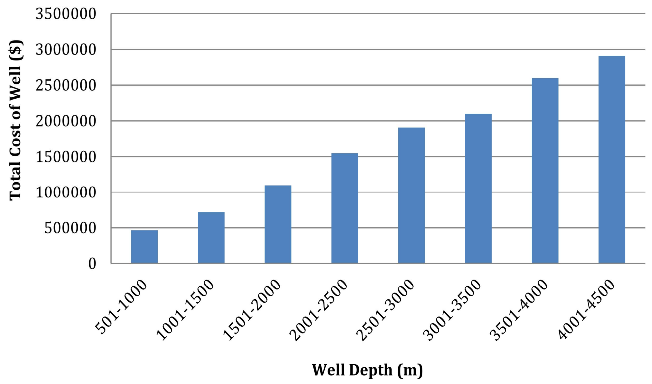


Fig. 7. Total costs of the wells

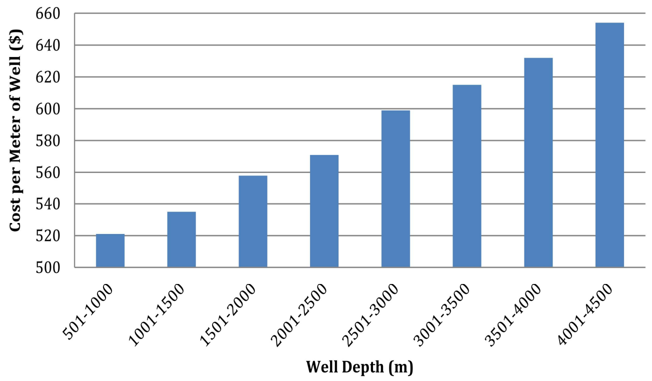


Fig. 8. The cost per meter of the wells

The cost per meter of the wells is $ 521 for depths of 500 - 1000 m, $ 535 for depths of 1001 - 1500 m, $ 558 for depths of 1501 - 2000 m, $ 571 for depths of 2001 - 2500 m, $ 599 for depths of 2501 - 3000 m, $ 615 for depths of 3001 - 3500 m, $ 632 for depths of 3501 - 4000 m, and $ 654 for depths of 4001 - 4500 m (Fig. 8).

2.3. Time analysis of the wells

Using the drilling and well data of previously drilled wells is of great importance in terms of estimating the drilling and well completion programs required for the new wells to be drilled and concluding the drilling in a successful way. From this point forth, similar results can be obtained or differences can be determined by applying the data of a well that has been drilled in similar conditions to another field. Time analysis of 470 oil and gas drilling wells examined is given in the Fig. 9. According to the graph, it is seen that the most important time consumption belongs to the well drilling process with 38.3%. Another important time consumption is caused by the tripping process with 16.28% and circulation with 9.2%. The ratio of them in the total drilling time is 65.68%.

2.4. Amount of bentonite used in the wells

Bentonite is a basic additive used in almost all mud compositions from fresh water-based to salt water-based drilling muds and used in high temperature and different chemical environments. Bentonite provides important flow characteristics of the drilling mud as well as a very efficient fluid loss control due to its special particle shape and size. Bentonite bags are generally supplied from the market in packages of 50 kg each. Amounts of bentonite used in the wells are given in Fig. 10. As can be seen in the figure, the amount of bentonite used increases as the depths of the wells increase. The reason for this is that as the depths of the well increase, it is necessary to keep the drill mud density in balance in order to balance the hydrostatic pressures inside the well.

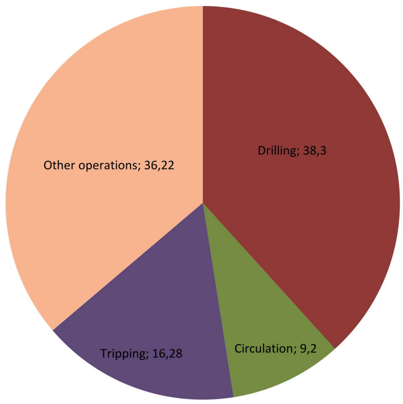


Fig. 9. Time analysis of wells whose data are evaluated

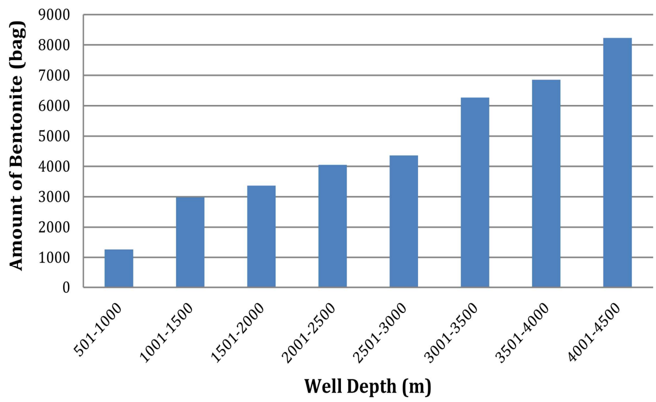


Fig. 10. Amount of bentonite used in the wells

2.5. Drilling well program

In drilling well programs prepared according to geological formation characteristics, attention is paid to evaluating two basic elements together. These are:

- Drilling safety
- Drilling cost

These two factors have a very close relationship with each other. When safety factors are desired to be increased, drilling costs also increase or safety factors are reduced when drilling costs are desired to be reduced (Fig. 11). It is undesirable to increase drilling costs unnecessarily, and it is also inconvenient to apply within insufficient safety limits. For this reason, the balance of drilling safety and costs with respect to each other is recommended as a suitable well programming technique. In the first exploration wells where field data are partially insufficient, safety factors are deliberately kept somewhat high.

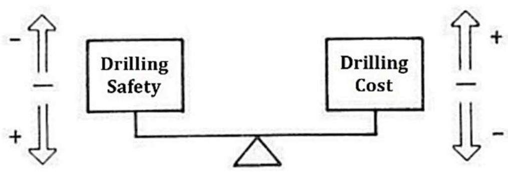


Fig. 11. Relationship between drilling safety and drilling cost (Akman, 1990)

2.5.1. Casing program

Casing costs constitute a significant part of drilling well costs. In order to perform safe and economical drilling applications, the casing pipe is lowered to certain depths according to the geological formation characteristics to be drilled. In the selection of the setting depths of the casings, loss circulation zones, formation pore and cracking pressure gradients or various other formation features are effective. However, keeping the pressure formations encountered in deep wells under control and not cracking the formations at shallower depths is the primary factor in the selection of depth. In the selection of the surface and intermediate casing depths, the intermediate casing depths and then the surface casing depth is chosen from the bottom up for convenience (Fig. 12). The diameter and properties of the casings used are given in the wells whose data are evaluated in Table 2.

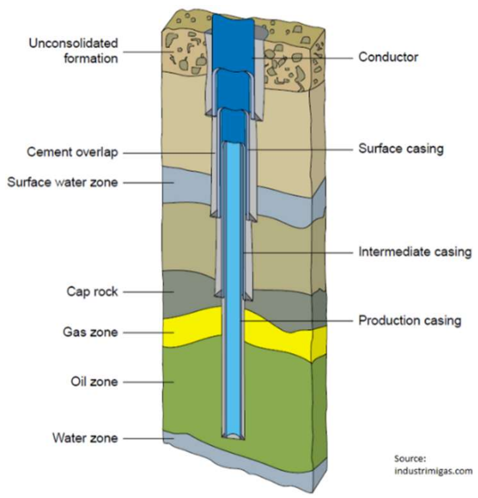


Fig. 12. Casing design in a well

2.5.2. Wellhead equipment program (well control equipment)

During drilling, the well is controlled by the drill mud. If the drilling mud weighs more than it should be, the static pressure can overcome the formation pressure and create a loss circulation. If the mud weight is lower than it should be, this situation may cause the fluid in the formation to enter the well. This situation is called kick. When the formation fluid enters the well under high pressure, as it rises in the annulus, its volume increases as the pressure on it decreases (especially at gas inlets) and becomes difficult to control. If this fluid is flammable or poisoner, well control becomes even more important. When the well control is lost, there are safety valves (blow-out preventer) on the surface as a preventative.

Table 2. The properties of the casings used in the wells whose data have been evaluated

Well Diameter (inch)	Casing	Casing Diameter (inch)	Steel Grade	Weight (lb/ft)	Thread Type
16"	Surface	13-3/8"	J-55	54,5	BTC
12-1/4"	Intermediate	9-5/8"	N-80	43,5	LTC
8-1/2"	Production	7"	N-80	26	LTC

The wellhead is designed and diversified according to the depth of the well and the expected pressures. Due to the well control equipment, after the arrival from the well is detected, the well is closed from the surface. The well can be circulated under pressure. At this time, while the formation fluid is discharged from the well, heavy mud with higher hydrostatic pressure is put in its place. If necessary, the drill string is moved and formation fluid is expelled without harming personnel and equipment. the properties of the wellhead equipment used in the wells whose data are evaluated are given in Figs. 13-15.

Wellhead Equipment	Upper Flange Diameter (inch)	Upper Flange Pressure (psi)	Lower Flange Diameter (inch)	Lower Flange Pressure (psi)	Length (cm)	Total Length (cm)
Conductor	20		20		250	250

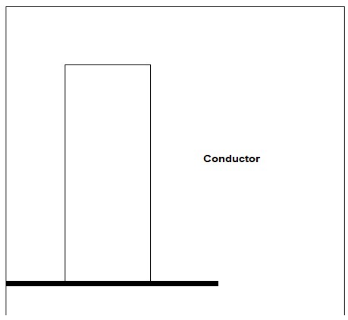


Fig. 13. A conductor pipe used in the wells whose data are evaluated

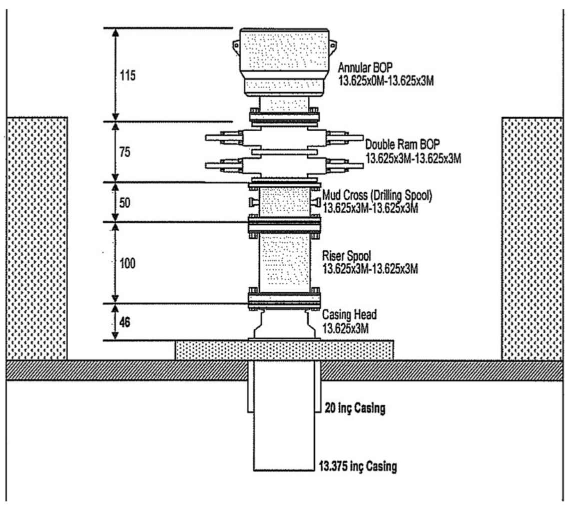


Fig. 14. A wellhead assembly for 13 3/4" casing used in the wells whose data are evaluated (3000 psi)

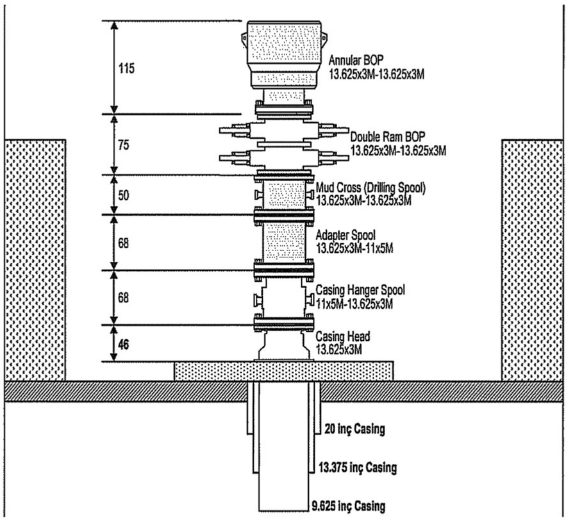
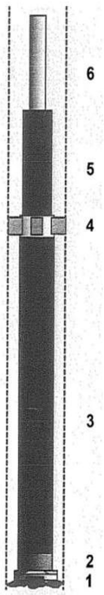


Fig. 15. A wellhead assembly for 9 5/8” casing used in the wells whose data are evaluated (3000 psi)

2.5.3. Drill string program

In the drill string program, the well diameter, the engine power of the mast, the hook capacity of the mast, and the mud pump power are taken into account. Hence, the pulling capacity of the drill rig and the engine power should be compatible with each other for the drilling sequence to be selected. Drill string stuck/sticking problems are frequently experienced in wells due to problems arising from the formation or drilling mud in wells. It may be necessary to pull with a load in excess of the tool weight to recover the tool string. When choosing the drill string, the drill string load that the deck engine can carry according to its power is taken into account.



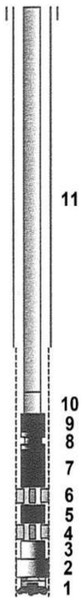
No	Drill String Component	Diameter (inch)
6	Drill Pipe	4 1/2"
5	Drill Collar	8"
4	Stabilizer	9 1/2"
3	Drill Collar	9 1/2"
2	Bit Sub	9 1/2"
1	Bit	16" or 17 1/2"

Fig. 16. A drill string program applied to the 16" or 17 ½" wells whose data are evaluated

First of all, after calculating the power that the engine can transmit to the draw-works, the maximum drilling string load that the draw-works can pull is calculated. How much of this load is the calculation of the load that must be applied to the drill string, and the amount of drill collar required for this load can be determined in this manner. Accordingly, the most suitable rods for the diameter of the well are determined by subtracting the total weight of the drill pipes from the load that the draw-works can pull (Toka, 2011). Then, subs to connect these different drill string components (drill collars and drill pipes) and the type and specifications of drill bit suitable for the formation to be drilled are selected. The properties of the drill string applied to the wells whose data are evaluated are illustrated in Figs. 16-18.

No	Drill String Component	Diameter (inch)
11	Drill Pipe	4 1/2"
10	Heavy Weigh Drill Pipe	4 1/2"
9	Drill Collar	8"
8	Dailey Jar	7 3/4"
7	Drill Collar	8"
6	Stabilizer	12 1/4"
5	Short Drill Collar	8"
4	Stabilizer	12 1/4"
3	Drill Collar	9 1/2"
2	Bit Sub	9 1/2"
1	Bit	12 1/4"

Fig. 17. A drill string program applied to the 12 1/4" wells whose data are evaluated



No	Drill String Component	Diameter (inch)
11	Drill Pipe	4 1/2"
10	Heavy Weigh Drill Pipe	4 1/2"
9	Drill Collar	6 1/4"
8	Dailey Jar	6 1/4"
7	Drill Collar	6 1/4"
6	Stabilizer	8 1/2"
5	Drill Collar	6 1/4"
4	Stabilizer	8 1/2"
3	Short Drill Collar	6 1/4"
2	Near Bit Stabilizer	8 1/2"
1	Bit	8 1/2"

Fig. 18. A drill string program applied to the 8 ½" wells whose data are inspected

2.6. Cementing and well completion operations

The main purpose of casing cementing operation is to isolate this area by cutting the connection between the casing setting into the well and the formation (annulus) from the surface and the next section to be drilled. Fig. 19 presents the costs of cementing and well completion operations in the wells whose data are inspected.

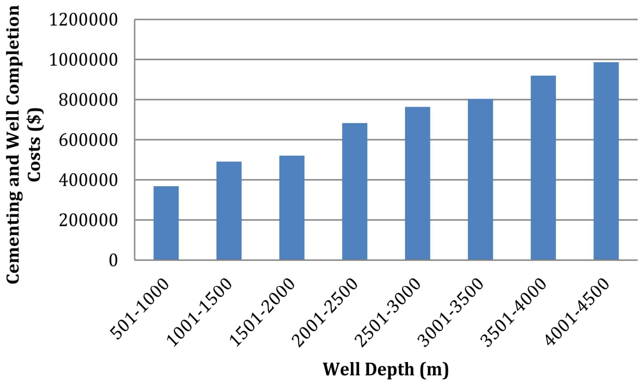


Fig. 19. The costs of cementing and well completion operations in the wells whose data are assessed

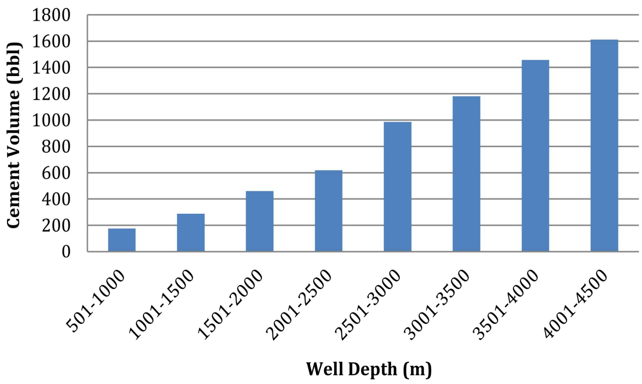


Fig. 20. The cement volume used in the wells whose data are evaluated

In Figs. 20-23, the volumes of cement used and its costs are given as well. It is observed that the amount of cement used increases as the depth of the well increases. That's why this is caused by the increase in the amount of casing lowered into the wells as the depths of the wells increase and the need for cementing processes increases due to the formation of loss circulation in drilling mud in parallel with drilling operation in the wells.

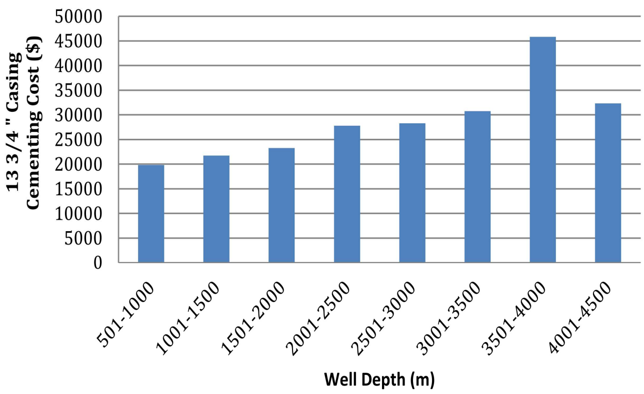


Fig. 21. The cementing costs for 13 3/4" casing in the wells whose data are assessed

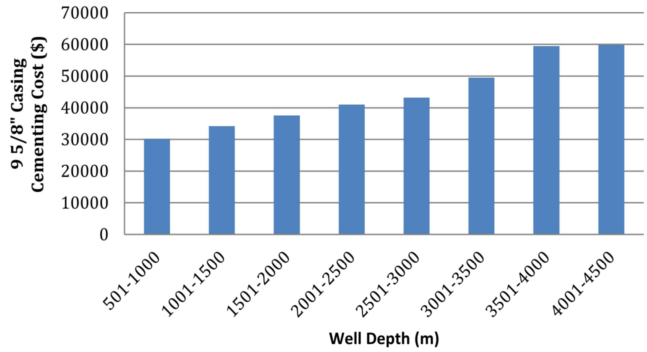


Fig. 22. The cementing costs for 9 5/8" casing in the wells whose data are evaluated

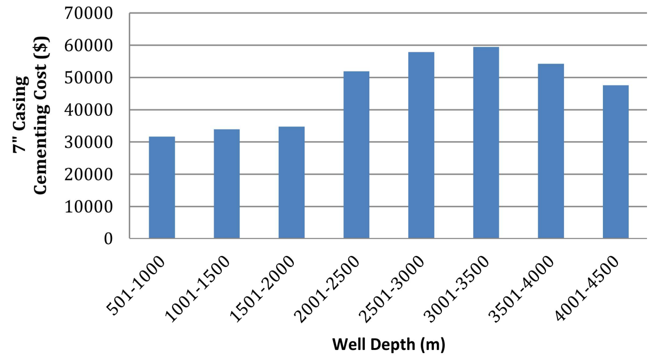


Fig. 23. The cementing costs for 7" casing in the wells whose data are assessed

2.7. Workover operations

The workover operations can be defined as the processes associated with the repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons or the process of performing major maintenance or remedial treatments on an oil or gas well. In many cases, workover implies the removal and replacement of the production tubing string after the well has been killed and a workover rig has been placed on a location. Through-tubing workover operations, using coiled tubing, snubbing or slickline equipment are routinely conducted to complete treatments or well service activities that avoid a full workover where the tubing is removed. This operation saves considerable time and expense. Fig. 24 shows the costs of workover operations in the wells whose data are analyzed.

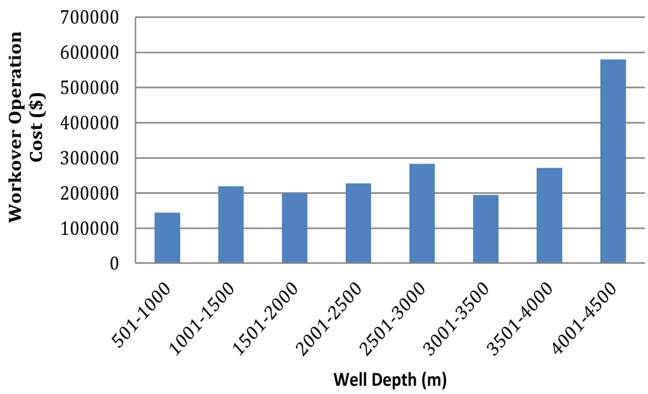


Fig. 24. The costs of workover operations in the wells whose data are evaluated

2.8. Logging and perforation operations

Well logs are used to detect formations with hydrocarbon potential underground. Perforation is the process of drilling holes in pipes in order to have sufficient contact between the zones to be produced and the well wall. Fig. 25 exhibits the costs of well logging and perforation operations in the wells whose data are assessed.

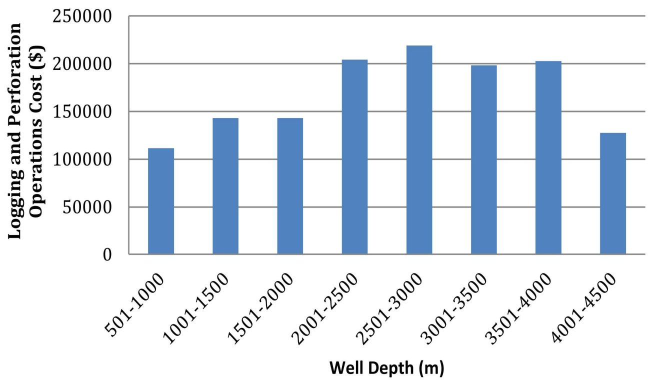


Fig. 25. The costs of well logging and perforation operations in the wells whose data are evaluated

2.9. DST operation

At reservoir levels, DST operation is performed to obtain information about the content of the formation and the reservoir characteristics. In Fig. 26 can be seen the costs of DST operation in the wells whose data are evaluated.

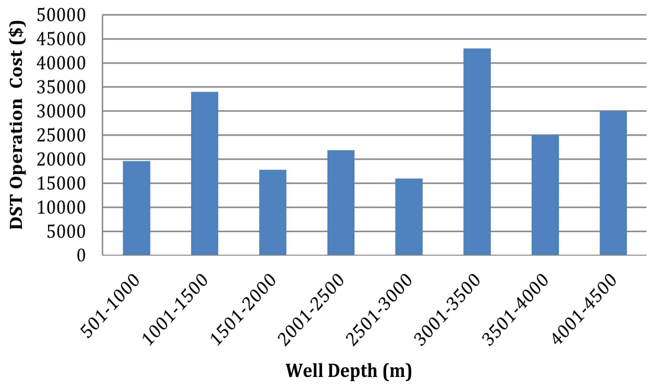


Fig. 26. The costs of DST operations in the wells whose data are evaluated

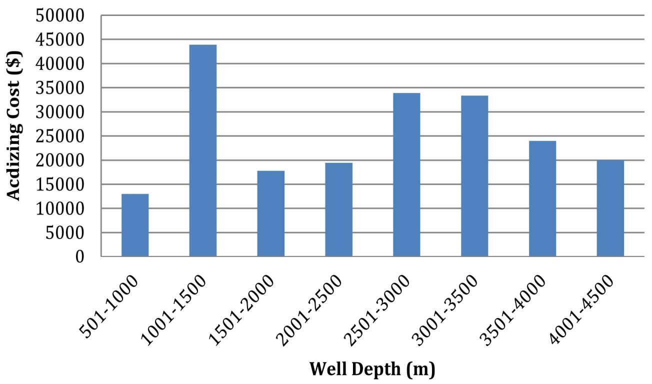


Fig. 27. The costs of acidizing operations in the wells whose data are evaluated

2.10. Acidizing operations

Acidizing operations are performed to eliminate the contamination on the well wall and increase permeability and production. In Fig. 27, it can be observed that the costs of acidizing operations in the wells whose data are evaluated.

2.11. Drill bits

Drill bits are cutting elements attached to the lowest end of the drill string, which break the rock under the influence of rotation and weight. While the drill is drilling the formation, the drilling fluid (mud) passing through the drill string and the drill pushes the chips cut by the drill out of the well. While the weight is given to the drill with the help of the drill collars in the drill string; rotational movement is transmitted by the rotary table, top drive system, or mud motor in rotary drilling. While the rotary table or top drive rotates the drill string, the drill bit rotates with the drill string. Although there are various types of drill bits, three-cone roller/tricone bits are generally used in oil and gas drilling wells (Fig. 28). The tricone bit types used according to IADC codes are given in Fig. 29.

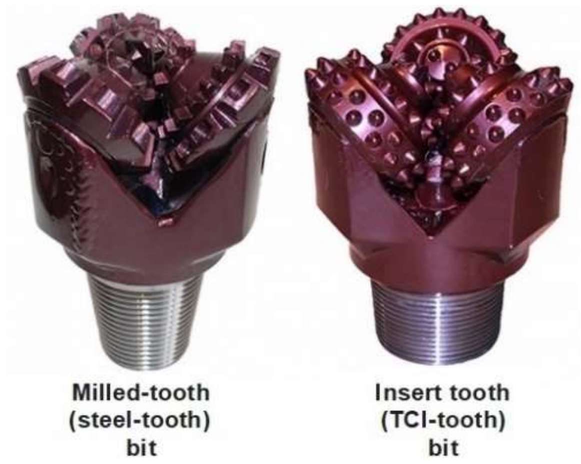


Fig. 28. Three-cone roller/tricone bit types

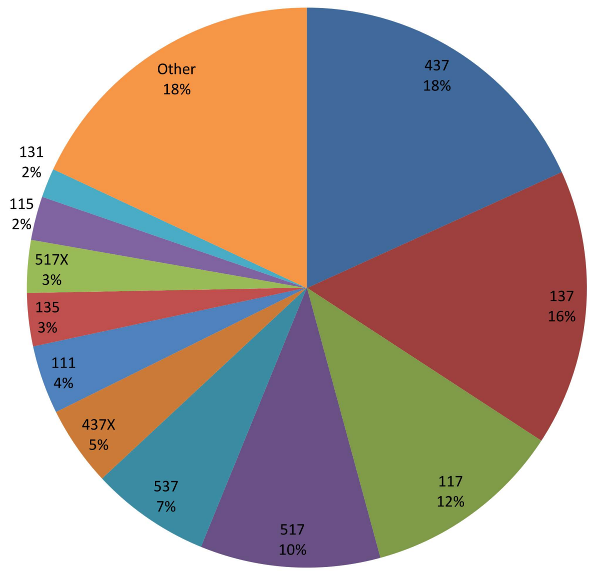


Fig. 29. Percentage distribution of tricone bits commonly used in wells according to IADC codes

3. Conclusions

The widespread use of statistical analyzes in the drilling industry is an indication that these analyses were successful in the previous studies. Performing oil and gas wells, time and cost evaluations with statistical analysis gives successful results and more data can be revealed. As can be seen in this study, the aforementioned analyses help clearly come the reasons into existence that increase time and cost in drilling operations.

The depths of the examined wells, whose data are evaluated, have 500 - 5000 meters whereas 86% of the wells have 1000 - 3000 m deep. The average well depth is calculated as 1959 m. It has been determined that the total well costs are $ 450,000 - 3,000,000, and the costs per meter are about $ 500 - 650. It has also been determined that the total cement costs are $ 370,000 – 985,000, and the total volumes of cement used are 175 - 1,611 bbl. It has been determined as well that the costs of log and perforation operations are $ 111,428 - 127,500, the costs of DST operations are $ 19,600 - 30,000, the costs of acidizing operations are $ 13,000 - 20,000, and the costs of Workover operations are $ 144,857 - 579,501.

According to time analysis of 470 oil and gas drilling wells, it is seen that the most important time consumption corresponds to the well drilling process with 38.3%. Another important time consumption is the tripping process with 16.28% and circulation with 9.2%. The ratio of them in the total drilling time is 65.68%.

The most commonly used drills in IADC codes are as follows; 137 and 117 (milled-tooth, sealed friction bearing and gauge protected), 217 (milled-tooth, sealed friction bearing and gauge protection), 437 (milled-tooth, sealed friction bearing and gauge protection), 517 and 537 (insert-tooth, sealed friction bearing and gauge protection), 616 (insert-tooth, sealed friction bearing and without gauge protection), 714 (insert-tooth, sealed roller bearing and without gauge protection).

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