Optimized Well Construction Cost Estimate in South of Iraqi Fields/ Case Study from Zubair Field

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Abstract

Cost estimation and control is a crucial activity for well engineering and construction. In addition to the technical preparation before drilling an oil well, well construction cost is one of the essential activities leading to AFE (authorization for expenditure). Recently the probabilistic method for cost estimate became necessary for understanding the risk and uncertainty of a certain cost range instead of a single (deterministic) value. This work describes the main types of drilling contracts have been used in Basra oilfields and discusses the principles of well construction cost estimate according to those contracts. In addition, it summarize the relevant cost breakdown for drilling operations. The research also illuminates the probabilistic method for effective well cost estimating along with deterministic method. the study subdivided the process of well construction into segments for cost tracking, emphasized the main aspects influence the well cost and leading to a methodology that can be applied by the operator for onshore well in the south of Iraqi fields. The methodology used in this work includes, first, analyzing data from offset wells to facilitate the possible cost out comes, and second, subdivide the well construction activities into fixed costs, time dependent and depth dependent costs. A probabilistic model (Monte Carlo simulation) for cost estimating is constructed using @ Risk software. The results released for risked drilling operation, which includes the NPT. While revising the historical cost performances in Zubair field, it has found that the best practices and lesson learned of the previous activities has significantly contributed in time and cost reduction of well operation. The findings of this work contributes to improve the decision-making by managers for best investment, enhance the planning for next activities and confident choice of well budget. It also helps to investigate the critical factors and actions

that can be applied on operational and contractual parameters to achieve cost reduction. A case study from Zubair field will be presented in order to illuminate the mentioned points.

الاحتساب الامثل لكلف بناء الابار التخمينية في حقول العراق الجنوبية/ دراسة حالة من حقل الزبير النفطي

الخلاصة

يعد تقدير التكلفة التخمينية والسيطرة عليها نشاطًا مهمًا وحاسما لكل من هندسة وبناء الآبار. قبل الشروع بالإعداد الفني لبرنامج حفر بئر نفطي، فإن تخمين تكلفة إنشاء البئر هي واحدة من الأنشطة الأساسية التي تؤدي بالنهاية الى اعداد (استمارة ترخيص للنفقات) الواجب التصديق عليها من قبل مدير عمليات الابار. في الآونة الأخيرة أصبحت الطريقة الاحتمالية لتقدير التكلفة واسعة الاستخدام وضرورية جدا" لفهم المخاطر واحتواء عدم الدقة ضمن نطاق تكلفة معين بالمقارنة مع الطريقة التقليدية في استخدام قيمة واحدة (حتمية). يهدف هذا العمل الى وصف الأنواع الرئيسية لعقود الحفر، ويناقش مبادئ تقدير تكلفة إنشاء الآبار وفقًا لتلك العقود، كذلك يتطرق الى المراحل الاولية لاحتساب الكلف التخمينية قبل الدعوة لتقديم العطاءات لعمليات الحفراعتمادا على الكلف التخمينية المعدة سلفا. يصف البحث ايضا وبشكل مفصل مميزات استخدام الطريقة الاحتمالية لتقدير تكلفة البئر بشكل فعال مقارنةً بالطريقة القطعية (استخدام قيمة واحدة). لتحقيق هذا الهدف، تقسم الدراسة العمليات الفنية لانشاء الآبار إلى أجزاء لتسهيل احتساب التكاليف، وتوضح وبشكل مفصل العوامل الرئيسية التي تساهم في زيادة او نقصان تكلفة البئر، وبناء نموذج احتمالي (محاكاة مونت كارلو) باستخدام برنامج Risk @ لتقدير تلك الكلفة، ان النتائج المتوقع الحصول عليها هي الخروج بمنهجية واضحة يمكن تطبيقها لاحتساب تكاليف الابار في الحقول النفطية لجنوب العراق. كما وجدت الدراسة من خلال المراجعة الدقيقة للبيانات السابقة أن الممارسات الفنية المثلى وكذلك الدروس المستفادة من الأنشطة السابقة قد ساهمت بشكل كبير في تقليل الوقت وخفض تكاليف تشغيل الآبار في حقل الزبير النفطي. تساهم نتائج هذا العمل في تحسين عملية اتخاذ القرارات من قبل المديرين والتخصيص الفعال للكلف المالية المحددة لإنجاز العمليات الفنية وتحقيق التقارب ما بين الكلف التخمينية والفعلية وكذلك اختيار التخطيط المناسب والموثوق لتصميم البئر. كما أن البحث يساهم في التحقيق في اهم العوامل والإجراءات الحاسمة التي يجب اتخاذها في المعايير التشغيلية والتعاقدية من أجل تقليل كلفة العمليات الفنية في ظروف من عدم الدقة. تم استخدام دراسة حالة من حقل الزبير النفطي لإلقاء الضوء على النقاط المذكورة.

Introduction

Drilling wells is a major expense for the upstream petroleum industry. The field development plan of a petroleum projects relies on a sound understanding of well costs and containment of the risks involved. In addition to the field development operation. Well costs are an important consideration in assessing the prospectivity of an exploration license. Drilling cost is fundamentally a function of well duration (days), rig cost ($/day), time independent costs, and fixed costs ($) [2]. Well costs are influenced by many factors including management, markets, environment, geology, target depth and technology [5]. Cost Estimating is the process of developing an approximation (estimate) of the cost of the resources needed to execute and complete project activities. As a predictive process, estimating must address risks and uncertainties. The outputs of estimating are used primarily as input for budgeting, cost or value analysis, decision making in business, asset and project planning, or for project cost and schedule monitoring and control processes [1]. In general, inputs to Cost Estimating come from Scope Definition, Activity Duration Estimating, Resource Planning and Risk Management Planning. The drilling operation aims drill a well as fast as possible without compromising tools and equipment, equality and HSE standards. Achieving that objective is constrained by time, location and personnel, and these are subjected to significant risk and uncertainty. Over the past few years, various methods have been proposed to evaluate the drilling costs. Isolation the factors affecting well cost and evaluation their contribution is one of the valuable methods to understand the drilling process [3]. Although well characteristics are measured directly, many unobservable factors also influence drilling performance such as well planning and engineering, project management, communication skills and personnel experience [1]. For the past years, Deterministic method represented the traditional for well cost estimation. The well construction cost regarding deterministic has been based on a single value, usually the average value of the previous activities. The method gives quick result that is easy to communicate. However, this approach does not consider the probability that the true well cost will hit [3].

Probabilistic estimating delivers non-biased process of forecasting the time and cost of a drilling and completion project. The process also enables the engineers and fellow team members to recognize the uncertainties that are a part of well construction and to analyze offset well data. Input includes time & cost information, probability of occurrence for each event, and associated consequences of that event for each phase in well construction process. A Serious of cost and time probability distribution curves is the output of Monte Carlo simulation. The estimating technique considered a reliable tool for AFE determination and other forecasts during project execution [3]. The outline of this study can be concluded as following: summarizes the main factors that characterize the drilling activity in south of Iraqi fields, produce detailed analysis for real well costs from various well types, depicts the cost performance of the past few years in zubair field and best achievement of systems approach to cost estimation.

Main types of drilling contracts:

Based on the risk sharing between the parties, the most common drilling contracts are classified into the following:

- **Lump sum contract:**

With this kind of contract, the operator pays the drilling contractor a lump sum to drill a well of a certain depth in a given area. Upon the drilling contract, the operator has the right to provide all the tangibles such as wellhead, x-mass tree, casing & tubing and their requirements, organize the third party services and inspect the rig at any time on the well. On other hand the contractor, generally comply with all the normal operator's roles on the well [5]. Because, the contractor will carry the vast majority of the risks involved, the usual criticism of turnkey drilling by contractors is their downtime due to the risks of well problems. Consequently, they might insist on 'hole problem' or 'Fishing' escape clauses from the turnkey contract during which they go on to a more conventional day rate. For example in zubair field, drilling contract mentioned that operational problems should be included in lump sum per phase with the following limitations: In case of mud losses, all LCM pills and up to three (3) cement plug jobs per well shall be considered in the lump sum per meter. For additional cement plugs, the daily rates of rig unit shall be applicable in this regard; all materials are charged separately to company based on actual utilization. However, hence the operator who writes the contract, most oil companies have very definite standard procedure covering the most important items particularly for practices that influence the well life.

There are some examples from south of Iraqi fields for lump sum drilling contract:

- Lump sum /well: the company pays for the contractor a lump sum amount per well. An example of this contract is Iraq drilling company (IDC) with ENI in Zubair field.
- Lump sum/phase/well: operator pays to the contractor lump sum amount for each phase with predetermined depth. Any extra meters over the planned depth will be considered as daily rate. Baker Hughes contract with ENI in Zubair field is good examples of that type.
- Lump sum/meter/phase/well: the contractor will charge a predefined lump sum amount for each meter actually drilled for each phase. The current contractors dealing with that contract in south of Iraqi fields are Schlumberger and Halliburton. This type of contract

can be subdivided into two groups: Lump sum with tangibles: contractor should provide the tangibles and Lump sum without tangibles: operators have the right to provide the tangibles.

Fixed unit price:

This type of contract is widely used in most petroleum countries. The operator pays a specified rate to the contractor for each day that he spends on the well. The operator bears most of the risks involved thus; the drilling contractors prefer this type of contract. The contractor will not receive a bonus for the best performance but he can be penalized for negligence [5]. The contractor should supply drilling rig, equipment and personnel and there is no compensation for the damage in such equipment. Before operating this type of contract, the company should have very well trained supervisors to detect delaying tactics of the contractor. Prudent drilling team is also required to follow up the application of the technical and contractual issues by contractor.

Rig rates can be broken down based on the operation type into the following:

- Rate A (T1) - Operating Rate with drill pipe in hole (100% Daily rate).
- Rate B (T2) - Stand-by Rate with Crew (usually 90% of Daily rate).
- Rate C (T3) – Repair Rate (about 75% of Daily rate).
- Rate D (T4) – Standby Rate without Crew (almost 50% of Daily rate).
- Rate E (T5) - Stand-by Rate at Zero Cost (0% Daily rate).

The main type of wells in Zubair field:

The current well types in Zubair field are classified according to well target, inclination and purpose of the well as following in Table (1):

Table (1) Well types in Zubair Oilfield

Target formation	type	inclination	sections	Last casing size (inch)	Estimated final depth (m)	purpose
Mishrif	vertical	Less than 5 degree	Three	9 5/8	2450	Water injection
Mishrif	deviated	> 4° - 45°	Four	7 liner	2800	Oil production
Mishrif	High deviated	> 45°- 70°	Four	7 liner	3300	Oil production
Nahr-Umar	vertical	Less than 5 degree	Three	9 5/8	3150	Water source
Zubair 3rd&4th pay	Vertical	Less than 5 degree	Four	7 liner	3400	Oil production
Zubair 3rd&4th pay	Deviated	Up to 45°	Four	7 liner	3600	Oil production
Zubair 3rd&4th pay	High deviated	45°- 70°	Four	7 liner	3950	Oil production

Case history of drilling performance in Zubair oilfield:

There is big difference in average drilling time to drill the same well to the same target by different contractors working in the same field. Actually, this is so common due to the variance in experience, personnel, equipment and technology. The reason behind that variance is the way that each contractor used to deal with the formation problems, which controls the NPT as shown in Figure (1). As the variance increases, the well cost estimation and procurement of tangibles decision becomes more complicated. However, the lesson learned from the offset wells efficiently improved the drilling performance and duration and consequently reduced the NPT as shown in Figure (1). The competitors who could not able to achieve the progressing performance have left the oilfield.

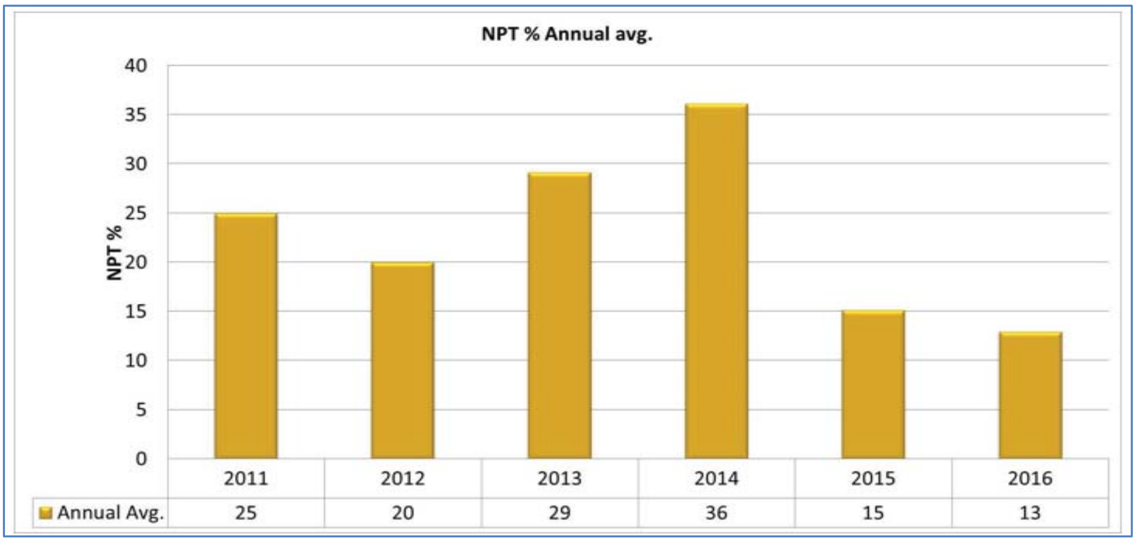

Fig. (2) The average annual NPT for all contractors

The main lessons learned and best practices have implemented in Zubair field:

- Utilize 23" PDC bit with shock sub, the ROP increased by 30%.
- Using thixotropic materials for curing losses in Dammam such as sentinel cement.
- Implement acquiring open-hole logs with drill string instead of wireline like Geo tape for acquiring pressure points.
- Introduce casing drive system for casing running instead of conventional equipment.
- Implement Auto-drill on rigs to increase ROP.
- Modify well trajectory design to drill well path smoothly and increased ROP

All these practices together helped to improve the drilling performance, reduced the well duration, and delivered the well earlier**.**

- To avoid the erratic torque and reduce the stick slip, it is recommended to run a pendulum BHA with the stabilization points at 0 & 10 m.

Well construction cost break down in Zubair oil field:

The most common type of contracts in south of Iraqi field is the lump sum. In order to clarify the main items of cost break down in this contract, well construction cost of Zubair oilfield is categorized into the following:

- **Rig unit mobilization lump sum:**

applicable for rig unit moves to first rig location under new contract with company and this includes two rates based on whether the rig come from outside of the country or exist inside the country. The lump sum shall cover all the cost for the rig unit, equipment, material, transportation, duties, fees, personnel, material consumption, equipment modification or any other cost incurred by contractor/sub-contractor if any to comply with the scope of work.

- **Rig unit moving between well locations:**

Drilling package-moving charge between well site locations dynamic security included. This charge is structured as lump sum up to 25 km of distance and an additional charge for each additional kilometer).

- **Demining service:**
    - Demining Access Road without mines found (lump sum per km).
    - Demining Access Road with mines found (lump sum per km).
    - Demining Location single well site without mines found (lump sum per km).
    - Demining Location single well site with mines found (lump sum per km).
- **Civil works:**

This service shall be provided only on company's request at documented cost plus 10-15% markup. Contractor shall provide company with at least two alternatives offers according to the market condition. Company's request can be for:

- Access Road for single or cluster well site
- Single well site location with water well and relevant production facilities
- Cluster either single well and multi wells cellar with water wells and relevant production facilities. Usually installation the conductor pipe is included in civil work services.

- **Well site services**

The following services are included in the rate (well site service), which is a lump sum/well:

a- Project management team:

- Integrated contract manager
- field integrated coordinator

b- Communication and data transmission system, logistic services and transportation.

- **Well site static security:**

This service is applicable both either during lump sum per meter or during on call plus at documented cost per month per well plus 15% mark up. There are two ways:

a- Oil police service: contractor shall provide accommodation and logistic services.

b- Private security service.

- **Tangible cost:**

The cost of tangible includes wellhead, x- mass tree, tubing, conductor pipe, casing, and liner hangers.

- **Wellhead installation service:** usually lump sum per well, in some cases operator asks contractor to perform the job through third party.
- **Fuel supply:** conducted by contractor and charged on company as cost/liter/ month. According to the MOO prices.
- **Water supply:** the contractor shall provide the water to fulfill all work related activities and charge it as lump sum per well. Alternatively, it can be included in well site services**.**
- **Fuel transportation:** contractor is responsible for transportation of BOC provided fuel and charge it as cost per liter actually transported.
- **Handover and end of well acceptance:** contractor shall deal with the waste management as per company policy. The cost of this service can be included in integrated drilling services.
- **Integrated drilling services defined as Lump sum per meter per phase**

This rate shall be applied to the meters actually drilled and refers to the measured depth. The lump sum starts from the end of the rig up, once the rig has been accepted and the bit is lowered through the rotary table. The ends of this rate been when the CBL in production casing/liner has been completed.

The lump sum per meter per phase as per turnkey section of Zubair field geological, drilling & well suspension master program shall include the following services:

Table (2) The Components of the Drilling Lump Sum

Drilling Rigs + Rig Camp + Accommodation Camp
Drilling tools and drilling bits
Surface Logging
Drilling & Completion Fluids
Cementing, casing accessories and X-overs
Tubular running
Fishing, Milling and Cutting
Waste management
Wire line logging
Slick Line
Wellhead and Xmas Tree installation service
Liner hanger
Well suspension operations in case of Company decision to execute the final completion by another rig unit.

The well construction cost break down is categorized according to the percentage of each item to the total well cost. Figure (2) shows that integrated drilling services (lump sum per meter/ phase) has the biggest share of total well cost. It is representative by the cost of 8 1/2", 12 1/4", 17 1/2" and 23" consequently. However, moving charge, well site services and civil work also have considerable contribution which 9%, 6% and 3%. The next valuable cost is fuel consumption, while wellhead installation, fuel transportation and running kill string are about the same percentages.

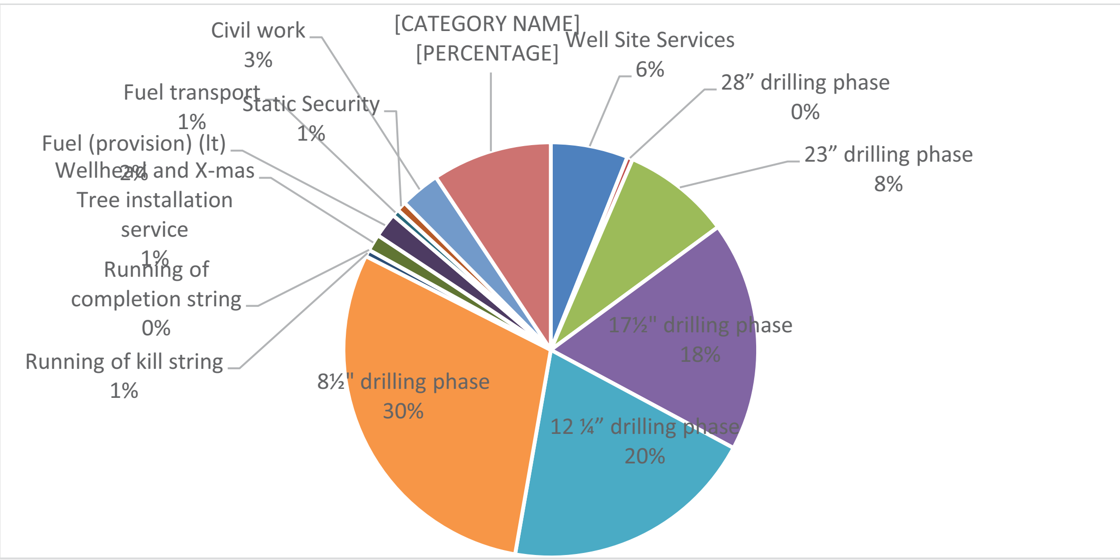

Fig. (3) Well cost breakdown (fourth pay deviated).

Probabilistic versus deterministic:

Deterministic approach:

The deterministic well cost estimation is the traditional way of budgeting. The method is quick, simple and reveal a single well cost value. However, this approach does not includes risk and uncertainty involved in the drilling operation and the costs of that risk. Simply the deterministic method can be expressed by the following formula:

The deterministic cost = (sum of fixed cost + average variable cost from offset data) + contingency. An example from Zubair oilfield shown in Table (3).

Table (3) Deterministic well cost estimation

Zubair 4th pay deviated well			Duration 57 days	
SERVICES REQUIRED	Payment method	Rate with water base mud (USD)	QUANTITY	TOTAL AMOUNT (USD)
Well Site Services (refer to note1 below)	lump sum / well	483,965	1	483,965
28” drilling phase with preinstalled Conductor Pipe (without fuel)	lump sum /m/phase	887	40	35,472
23” drilling phase (without fuel)		1,021	666	680,119
17½" drilling phase (without fuel)		1,100	1309	1,439,900
12 ¼” drilling phase (without fuel)		1,239	1293	1,601,768
8½" drilling phase (without fuel)		4,700	508	2,387,600
Running of kill string (without fuel)	lump sum / well	43,533	1	43,533
Running of completion string (without fuel)	lump sum / well	355,575	0	0
Wellhead and X-mas Tree installation service	lump sum / well	105,050	1	105,050
FUEL (provision) (lt)	as per Iraqi Oil Ministry regulation	0.34	456000	155,040

Storage, transport, load and unload of fuel required to perform the operations / Cubm (FUEL)	lump sum/m³	97	456	44,232
Well site Static Security / Private Security service	cost + mark-up %	52,500	1	60,375
Civil work	cost + mark-up %	217,500	1	250,125
Moving charge between well site location (up to 25 km)	lump sum / well	752,081	1	752,081
Total cost with kill string (without tangibles)				8,039,260
Tangible cost				1,591,500
Total cost with kill string (with tangibles)				**9,630,768**

Probabilistic approach:

Probabilistic approach for well construction cost estimation consider the uncertainty in each activity in well construction and express the final well cost by probability distribution. The well construction cost is divided into several items based on the relevant experience. These items consist of fixed cost, time dependent and depth dependent costs. Because of the drilling contract is lump sum per meter per section, the measured depth represents the main uncertain factor as revealed in Figure (3). The application of Monte Carlo simulation was conducted for the uncertain parts (time and depth dependent). The data used in this case study are the actual costs of the deviated wells drilled in period (2017-2019) in Zubair oilfield. The probabilistic approach can be expressed by the following formula:

Probabilistic approach= sum fixed cost + mean of probabilistic variable costs for (time dependent + depth dependent) + tangible cost.

The proposed methodology for estimating well cost can be summerize as following:

1- Identify the well sections from well design.
2- Estimate the probabilistic number of days for the well including NPT (probabilistic approach).
3- Calaulate the time dependent cost based on that estimation.
4- Define the cost per meter per phase from offset wells.
5- Estimate the probable depth of each section (probabilistic)
6- Calculate the drilling cost for each section by multiply the section depth * cost/m.

7- Total drilling cost with out tangibles is equal to sum of drilling cost for each section.
8- Quantify the total cost of tangibles incluing well head & x-mass tree, tubing and casing, (cost of casing/tubing = estimated depth * cost /m).
9- Calculate the fixed cost per well such as (civil work, demining, well head installation..etc) (deterministic).
10- The total cost of a well is the summation of steps 7, 8 and 9.

Depth dependent cost:

Monte carlo simulation was used for depth sensitive cost to minimize the ranges of possible outcomes. The integrated drilling services represent the crucial item in this part. It depends on bit selection, formation thickness and properties, and the undesired events. the minimum, maximum depths of each section for deviated well (4^{th} pay) are obtained from actual records. Using excel spread sheet for statistical decription to find the min, max and standard deviation values. Since, the cost per meter per phase are known, by multiplying with corresponding optimized section depth we get cost per section.

Time dependent:

To estimate the time dependent cost the well duration estimation is needed. The duration of the well is estimated using historical data of more than 20 wells from different rigs and conttracts. In this model the duration (NPT included) is forcasted using monte carlo simulation to estimate the P10, the mean, and P90. The monte carlo simulation is conducted in (100000) trials to forcast the possible time outcomes. As shown in Figures (4, 5, 6 and 7).

The model out puts:

The model shows a normal distribution for both well duration and meters drilled in each section. The result revealed are the most common percentile P10, P50 and P90. P10 is the value below which 10% of the results fall, while P90 represent the value that 90% of the results will not exceed it. The remaining 80% of the results are laying between P10 & P90 therefore there is 80% certainty that the results are within this limit as shown in Figure (9). From the meters actually drilled of each section, the forecast mean values that fall between P10 & P90 has been taken. The comparison of the deterministic values with the probabilistic values for the same well profile showed considerable variation in time dependent and depth dependent. The difference between the two well cost value is about (500,000 $). This value will be inflated if it is considered for the entire wells of yearly plan. The variation between the results lead to an ambiguity about the actual results. Difference in delivering time of the wells between the actual and planed have big impact on the field development operations and budgeting.

Conclusion:

In well operations, it is important that to deliver oil wells in their projected time and cost. For achieving that target, the company should understand the financial requirement of the drilling team. Using a suitable application for risk and uncertainty management is an effective tool. This tool facilitates the decision makers to make informed decision in the presence of risk and uncertainty. Technical advances of well design and advanced drilling technologies along with the lesson learned have big contribution in well cost reduction. The positive effect of these factors should be assessed and considered for any forecast work. Due to the acceptable certainty of Monte Carlo results, in probabilistic approach less contingency range can be added to the total well cost in comparison with deterministic.

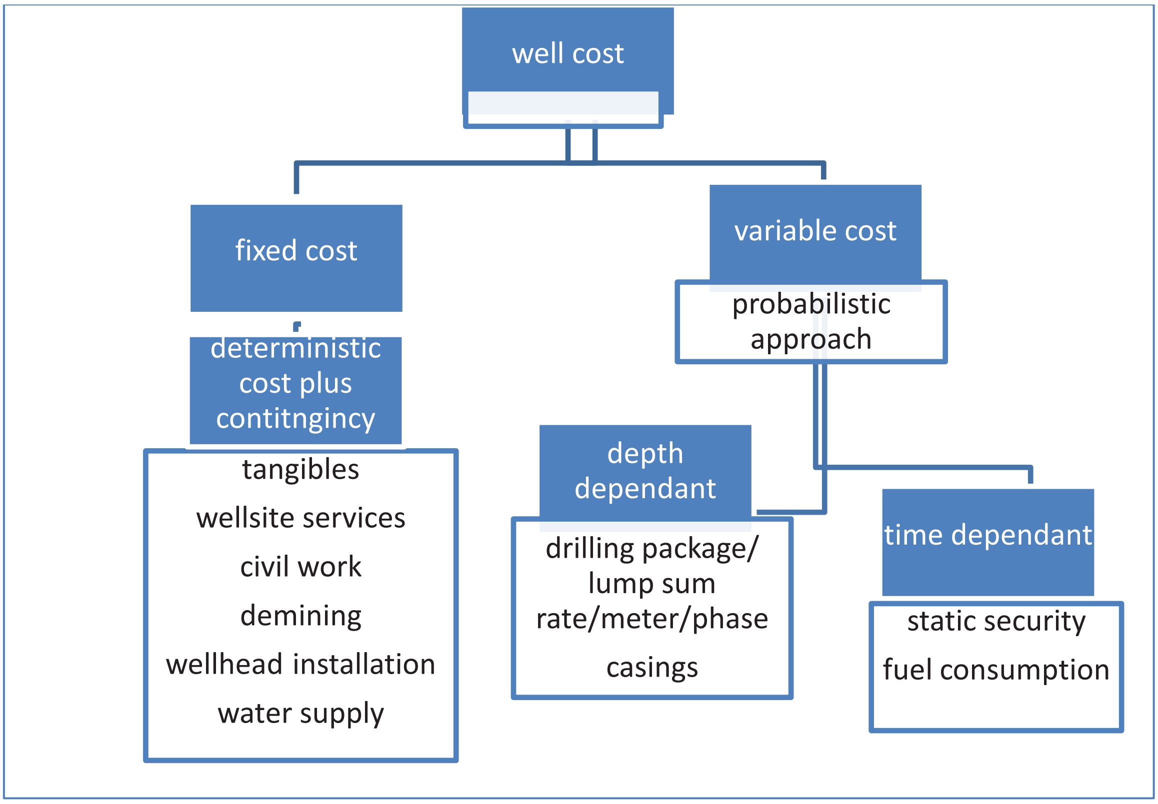

Fig. (4) Probabilistic approach diagram

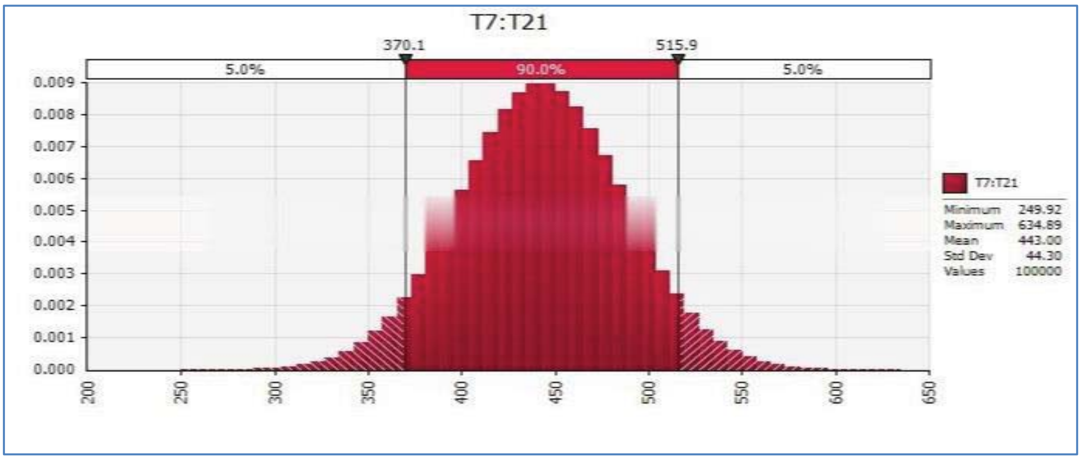

Fig. (5) Probability distribution for meters actually drilled in section size 8 1/2".

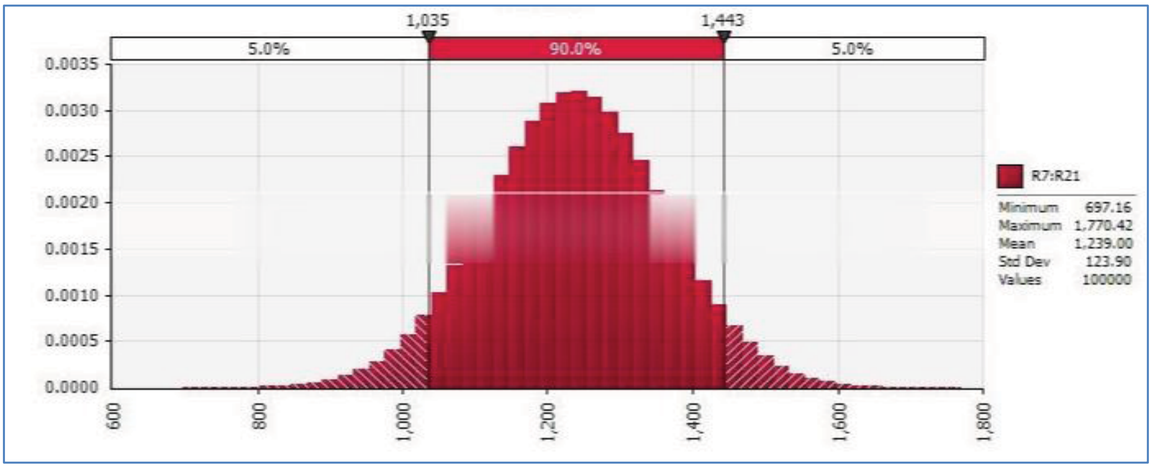

Fig. (6) Probability distribution for meters actually drilled in section size 12 1/4".

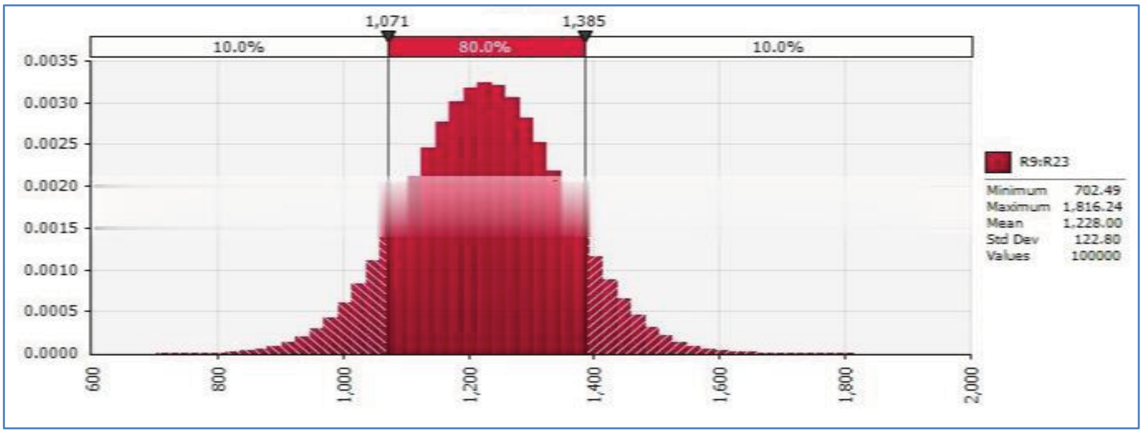

Fig. (7) Probability distribution for meters actually drilled in section size 17 1/2".

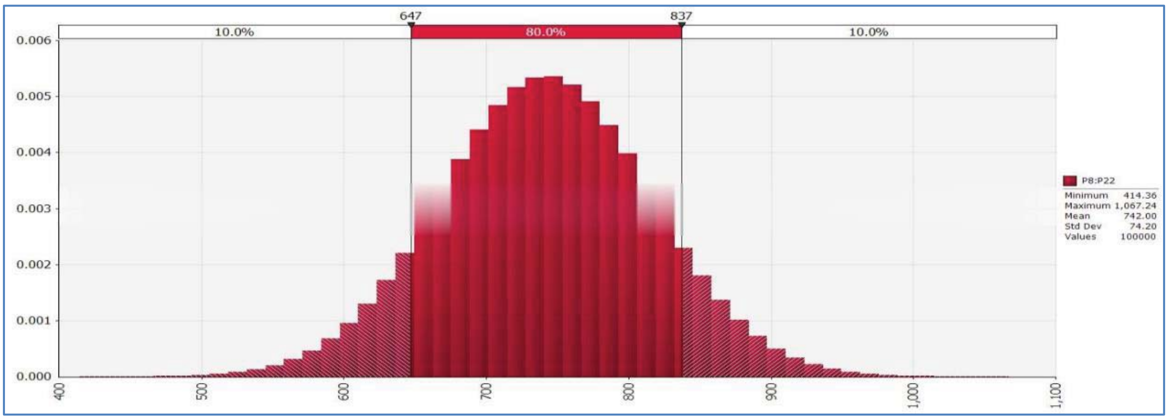

Fig. (8) Probability distribution for meters actually drilled in section size 23".

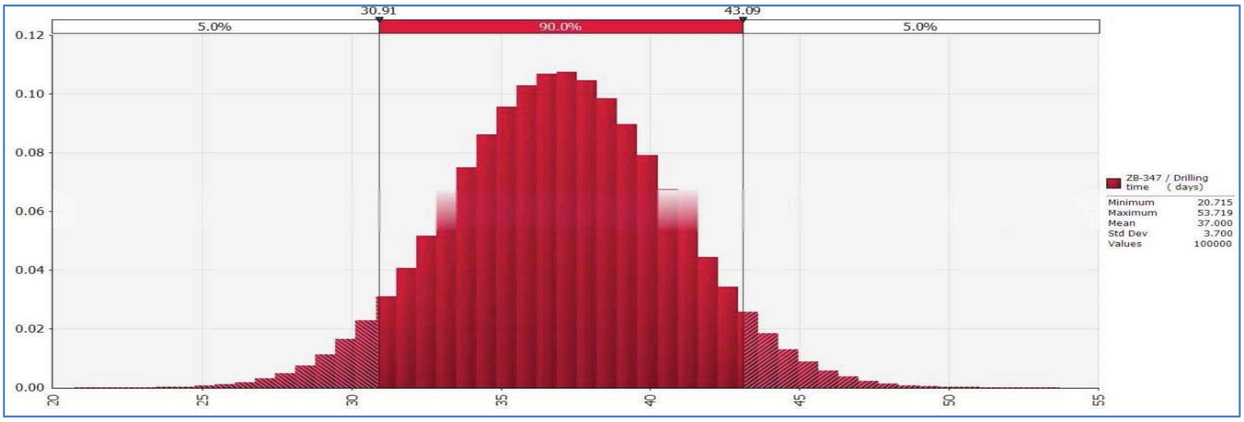

Fig. (9) Probability distribution for well duration.

Table (4) Probabilistic well cost breakdown.

Zubair 4th pay deviated well			Duration 37 days	
SERVICES REQUIRED	Payment method	Rate with water base mud (USD)	QUANTITY	TOTAL AMOUNT (USD)
Well Site Services (refer to note1 below)	lump sum / well	483,965	1	483,965
28” drilling phase with preinstalled Conductor Pipe (without fuel)	lump sum /m/phase	887	40	35,472
23” drilling phase (without fuel)		1,021	742	757,582
17½" drilling phase (without fuel)		1,100	1228	1,350,800
12 ¼” drilling phase (without fuel)		1,239	1239	1,535,121
8½" drilling phase (without fuel)		4,700	443	2,082,100

Running of kill string (without fuel)	lump sum / well	43,533	1	43,533
Running of completion string (without fuel)	lump sum / well	355,575	0	0
Wellhead and X-mas Tree installation service	lump sum / well	105,050	1	105,050
FUEL (provision) (lt)	as per Iraqi Oil Ministry regulation	0.34	296	100,000
Storage, transport, load and unload of fuel required to perform the operations.	lump sum/m³	97	296	28,712
Well site Static Security / Private Security service	cost + mark-up %	52,500	1	60,375
Civil work	cost + mark-up %	217,500	1	250,125
Moving charge between well site location (up to 25 km)	lump sum / well	752,081	1	752,081
Total cost with kill string (without tangibles)				**7,584,916**
Tangible cost				1,591,500
Total cost with kill string (with tangibles)				**9,169,832**

List of abbreviations:

ITT: invitation to tender

ROP: rate of penetration

AFE: authority for expenditure

NPT: nonproductive time

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