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**Comprehensive Approach to Oil Well Drilling Cost  
Estimation**

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**Abstract**

*The comprehensive approach to oil well drilling cost estimation was presented. A formular was derived from the existing drilling cost estimation formulae that considered a parameter known as host community cost ( $H_{CC}$ ), which was introduced into the existing formula to make it more comprehensive. The host community cost included; cost of acquiring the location, cost of provision of basic amenities, cost of access road to the location, and cost of settlement of unrest within the community. An excel spreadsheet was also developed based on the comprehensive formular that can estimate the drilling cost. It was discovered that the comprehensive formular if adopted provides room for the effective implementation of the drilling program, helps in rural development, improves host community versus company relationship and finally saves time and cost.*

**Key words:** rotary drilling, oil rig, oil well, drill bit, cost estimation, host community, excel spreadsheet, basic amenities

### **Introduction**

An oil or gas well is a borehole drilled in the subsoil to reach a hydrocarbon deposit. The primary objective may be exploration (prospecting for a deposit) or development (bringing a deposit on stream). A well fulfills the following functions:

- gain access to the underground deposit,
- make a connection with the producing formations,
- allow the hydrocarbon effluent to reach the earth's surface safely and effectively,
- support equipment on the surface to control production and allow maintenance (wireline and workover operations, etc)

The large investments required to drill for oil and gas are made primary by oil companies. Many specialized talents are required to drill a well safely and economically. As in most complex industries, many different service companies, contractors, and consultants each with its own organization, have evolved to provide necessary services and skills. Specialized groups within the major oil companies also evolved. A member of staff of drilling engineers is generally identifiable as one of these groups.

A well is classified as a wildcat well if its purpose is to discover a new petroleum reservoir. In contrast, the purpose of a development well is to exploit a known reservoir. Usually, the geological group recommends wildcat well locations, while the reservoir engineering group recommends development well locations. The drilling engineering group makes the preliminary well designs and cost estimate for the proposed well. The local group secures the necessary drilling and production rights and establishes clear title and right-of-way for access. Surveyors establish and stake the well location (Adams, 1985).

Usually the drilling is done by a drilling contractor. Once decision to drill the well is made by management, the drilling engineering group prepares a more detailed well design and writes bid specifications. The equipment and procedures that the operator will require, together with a well description, must be included in the bid specifications and drilling contract.

## **The drilling system**

The reigning drilling system at use in recent years is the rotary drilling system. It comprises the manpower and the hardware systems. The hardware systems make up the rig; they include rotary system, hoisting system, substructures, fluid circulating system, power system, blow-out prevention system, well monitoring system, light plant.

### **Drilling rigs**

A drilling rig is a machine which creates holes (usually called boreholes) or shafts in the ground. Drilling rigs can be massive structures housing equipment used to drill water wells, oil wells, or natural gas extraction wells, or they can be small enough to be moved manually by one person. They sample sub-surface mineral deposits, test rock, soil and groundwater physical properties, and also can be used to install sub-surface fabrications, such as underground utilities, instrumentation, tunnels or wells. Drilling rigs can be mobile equipment mounted on trucks, tracks or trailers, or more permanent land or marine-based structures (such as oil platforms, commonly called 'offshore oil rigs' even if they don't contain a drilling rig). The term "rig" therefore generally refers to the complex of equipment that is used to penetrate the surface of the Earth's crust.

Rig components are generally common to both offshore, swamp and onshore operations except that compensators are required in offshore environment.

According to Gow, (2005), there are five main types of rigs, which include;

- Land rigs which are used on dry lands and are moveable
- Jack up rig used to drill offshore and also moveable. It operates at a water depth of 120 metres.
- Fixed Platform rig, a permanent offshore structure and it is fixed.
- Submersible rig, the type that rests on the sea floor.
- Drill ship, a self-propelled floating offshore drilling unit that uses a subsea blow-out control system.

Offshore platforms could be classified as mobile platform or fixed platform. The criteria for selecting a platform type are (1) operations to be performed example, exploratory drilling, development drilling, storage or combination; (2) water depth.

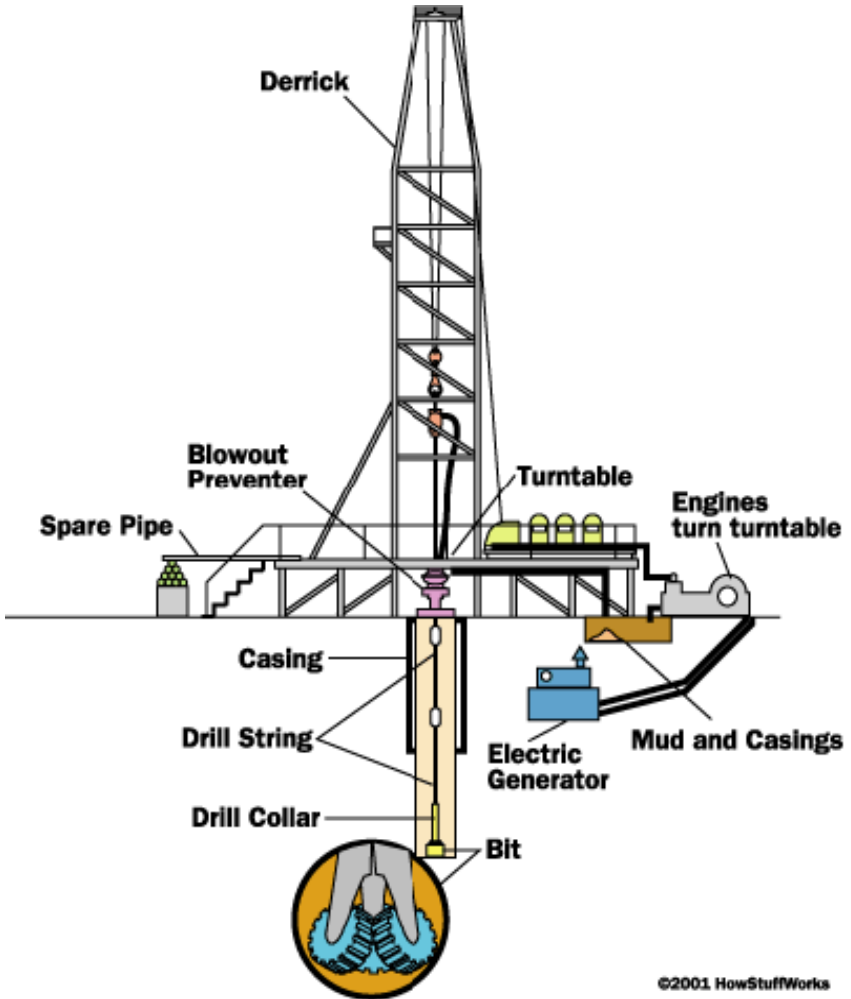


Fig 1: Anatomy of an oil rig  
Source: (HowStuffWorks, 2001)

Mobile platforms are classified into three groups, (Gow, 2005):

- Self-elevating units which float on the seabed with legs in the lifted position while in transit, and is used in waters of approximately 60 - 300ft deep
- Drill ship unit, used in water depth greater than 300ft
- Column stabilized platforms, supported by either caisson with or without footings. They have two broad categories:
  - Submersible that operates while resting on the seabed
  - Semi-submersible that operates under floating conditions.

### **The Hoisting system**

The hoisting system hangs or suspends the drill string in the well. It allows one to lower the string in and out of the well and also allows the driller to adjust the weight applied to the bit.

Parts of the hoisting system are crown block, travelling block, drilling line and drilling line reel. The drill line connection is as follows:

Supply reel – spool around disc deadline – crown block – draw works

The line is turned a number of times between the crown block and travelling block to form a system of pulleys. Drillers use the Brake to set the block at any point and the block is pulled down by the force of gravity. These are achieved with the aid of the draw works.

### **The drill String**

The drill string consists of these:

- The Rotary Kelly: the rotary Kelly is the uppermost part of the drill string. The hexagonal shape of its external side facilitates the receiving and transmission of rotary motion gotten from the rotary table to the drill string.
- The Drill Pipe: this consists of several joints of about 9 metres in length of hollow steel pipe that screw together to form a long piece of tubular. The drill pipe permits the circulation of the drilling fluids through its hollow tube. Along with other components of the drill string, it acts as a shaft that transmits rotary motion from the rotary table to the rock bit.
- The Drill Collar: it also consists of some joints of about 9 metres in length of hollow steel tubular, but is relatively much heavier and of

- a bigger thickness than drill pipe. The drill collar is found between the drill pipe and the bit. It gives direction and weight to the drill bit.
- The Drill Bit: this is the cutting tool, it cuts through the earth to make wellbore. It is located below the drill collars. There are two main types of drill bit:
    - Drag bit, diamond bit used for deep wells and offshore drilling.
    - Rolling cutter bit that has tungsten carbide insert with milled tooth cutters and is used for relatively soft formations and shallow wells.
  - The Rotary Table: this is a heavy steel turn table. It rests on the derrick floor. The prime mover provides for the rotary motion that times the table which in turn, turns the bit through the aid of the drill string.

### **Drilling fluids**

Drilling fluids are fluids used to circulate out drill cuttings from the well. Drilling fluids cool and lubricate the bit, control and counter encountered subsurface pressure and also prevent fluid from entering the well. There are four basic types of drilling fluids viz: Air, Water, Oil and Mud (Gatlin, 1960).

#### **Drill Cost**

One basic aspect of drilling is costs evaluation. The cost estimate for any drilling project has to be established. This includes well drilling, tubing and casing, and wellhead costs (Mitchell, 1974).

Several formulae exist for drilling cost estimation. Lapeyrouse, (2002), gave the formula for the computation of drilling cost as shown below. Drilling cost per footage drilled represented as  $C_F$  is

$$C_F = \frac{[B + C_R (t + T)]}{F} \quad (1a)$$

and Total drilling cost,  $C_T$  is also given as:

$$C_T = C_F * TD \quad (1b)$$

where:

$C_F$  = drilling cost per foot, \$/ft

$B$  = bit cost, \$

$t$  = drilling time, hours

$C_R$  = rig cost per hour, \$/hr. This number must include all fixed daily cost not just only drilling contractor rate.

$T$  = round trip time, hour

$F$  = footage drill per bit, ft

$TD$  = total depth

Petrex International also applies this for cost per foot calculation:

$$CPF = \frac{[B + R (t + T)]}{F} \quad (2)$$

where:

CPF = cost per foot (\$ / foot)

$B$  = cost of the bit (\$)

$R$  = cost of the drilling operation (\$ / hour)

$T$  = rotating time (hours)

$t$  = round trip time (hours)

$F$  = footage drilled (feet)

Joint Association Survey on drilling costs, (2003), developed the function that relates the average costs of oil and gas onshore wells drilled in the United States during the year 2003 with the listed depth intervals. Their table of figures shows that the average costs of completed oil and gas wells for the depth intervals from 1250 feet (380m) to 19999 feet (6100 m) can be described as an exponential function of depth, that is:  $\square_{\text{well}} = a \cdot \exp b_1 \cdot \text{depth} = a \cdot \exp (b_1 z)$  (3)

where  $a$  and  $b_1$  are fitted parameters. From their figures, a plot of  $\log_{10}(\text{well cost})$  vs. depth results in a straight line:

$$\log_{10} (\square_{\text{well}}) = \log_{10} (a) + b_2 z \quad (4)$$

Nguyen, (1996) gave a formula for the determination of the cost price per metre of hole drilled. The cost price is given by the formula:

$$P_m = \frac{P_b + P_h (T_r + T_t)}{m}$$

where:

$P_b$  = net cost of the bit

$P_h$  = rig rental price per hour

$T_t$  = tripping time

$T_r$  = rotating time

$m$  = number of meters drilled

### **The basic drilling operation**

During drilling, the rotary table rotates and drives the drilling bit by means of the drill string and the Kelly. The main control device is the brake lever. The driller controls and regulates the downward movement of the hook by putting on the brake. According to the principle of rotary drilling, bits are used at constant weight. The weight of everything that is suspended from the hook is constant and the driller knows this information by reading the weight on the hook when the bit is off bottom. The weight applied on the bit is the difference between the weight on the hook off bottom and on bottom. This is the difference that the driller reads on the weight indicator (commonly called Martin Decker). He must keep it constant by lowering the Kelly at the same speed as the rate of penetration of the bit. Rotary drilling uses a sharp, rotating drill bit to dig down through the Earth's crust. Much like a common hand held drill, the spinning of the drill bit allows for penetration of even the hardest rock. The basic rotary drilling system consists of four groups of components. The prime movers, hoisting equipment, rotating equipment, and circulating equipment all combine to make rotary drilling possible.

### **Prime movers**

The prime movers in a rotary drilling rig are those pieces of equipment that provide the power to the entire rig. Recently, while diesel engines still compose the majority of power sources on rotary rigs, other types of engines are also in use. Natural gas or gasoline engines are commonly used, as are natural gas or gasoline powered reciprocating turbines, which generate electricity on site. The resulting electricity is used to power the rig itself. Other rotary rigs may use electricity directly from power lines. Most rotary



rigs these days require 1,000 to 3,000 horsepower, while shallow drilling rigs may require as little as 500 horsepower. Rotary rigs designed to drill in excess of 20,000 feet below surface may require much more than 3,000 horsepower. The energy from these prime movers is used to power the rotary equipment, the hoisting equipment, and the circulating equipment, as well as incidental lighting, water, and compression requirements not associated directly with drilling (Gow, 2005)

### **Hoisting equipment**

The hoisting equipment on a rotary rig consists of the tools used to raise and lower whatever other equipment may go into or come out of the well. The most visible part of the hoisting equipment is the derrick, the tall tower-like structure that extends vertically from the well hole. This structure serves as a support for the cables (drilling lines) and pulleys (draw works) that serve to lower or raise the equipment in the well. For instance, in rotary drilling, the wells are dug with long strings of pipe (drillpipe) extending from the surface down to the drill bit. If a drill bit needs to be changed, either due to wear and tear or a change in the subsurface rock, the whole string of pipe must be raised to the surface. In deep wells, the combined weight of the drillpipe, drill bit, and drill collars (thicker drillpipe located just above the bit) may be in excess of thousands of pounds. The hoisting equipment is used to raise all of this equipment to the surface so that the drill bit may be replaced, at which point the entire chain of drillpipe is lowered back into the well.

### **Rotating equipment**

The rotating equipment on a rotary drilling rig consists of the components that actually serve to rotate the drill bit, which in turn digs the hole deeper and deeper into the ground. The rotating equipment consists of a number of different parts, all of which contribute to transferring power from the prime mover to the drill bit itself. The prime mover supplies power to the rotary, which is the device that turns the drillpipe, which in turn is attached to the drill bit. A component called the swivel, which is attached to the hoisting equipment, carries the entire weight of the drillstring, but allows it to rotate freely.

The drillpipe (which, when joined together, forms the drillstring) consists of 30ft sections of heavy steel pipe. The pipes are threaded so that they can interlock together. The drillpipe is a very heavy, strong pipe, but can be quite flexible when used in slant or horizontal drilling applications.

Below the drillpipe are drill collars, which are heavier, thicker, and stronger than normal drillpipe. The drill collars help to add weight to the drillstring, right above the bit, to ensure there is enough downward pressure to allow the bit to drill through hard rock. The number and nature of the drill collars on any particular rotary rig can be altered depending on the down hole conditions experienced while drilling.

The drill bit is located at the bottom end of the drillstring, and is responsible for actually making contact with the subsurface layers, and drilling through them. The drill bit is responsible for breaking up and dislodging rock, sediment, and anything else that may be encountered while drilling. There are dozens of different drill bit types, each designed for different subsurface drilling conditions. Different rock layers experienced during drilling may require the use of different drill bits to achieve maximum drilling efficiency. It can be a long process to change bits, due to the fact that the whole drill string must be removed; but using the correct drill bit, or replacing a worn bit, can save a great deal of time during drilling. Drill bits are chosen given the underground formations expected to be encountered, the type of drilling used, whether or not directional drilling is needed, the expected temperatures underneath the Earth, and whether or not cores (for logging purposes) are required.

It is thus up to the drilling engineer to ensure that the correct bit is used at the correct time, to allow for maximum drilling efficiency, with minimum wear and tear on the valuable bit.

### **Circulating system**

The final component of rotary drilling consists of the circulating system. There are a number of main objectives of this system, including cooling and lubricating the drill bit, controlling well pressure, removing debris and cuttings, and coating the walls of the well with a mud type-cake. The circulating system consists of drilling fluid, which is circulated down through the well hole throughout the drilling process.

Typically, liquid drilling fluids are used. The most common liquid drilling fluid, known as 'mud', may contain clay, chemicals, weighting materials, water, oil, or gases. 'Air drilling' is the practice of using gases as the drilling fluid, rather than a liquid. Gases used include natural gas, air, or engine exhaust. The drilling fluid chosen must have a number of properties to allow it to accomplish its tasks. It must be light and thin enough to circulate

through the drill bit, cooling the bit as it drills as well as lubricating the moving parts. The fluid must be heavy enough to carry drill cuttings away from the bit and back to the surface, as well as control upward pressure that may be experienced in the well to prevent blowouts. The drilling fluid engineer ensures that the weight of the drilling fluid is greater than the upward pressure of escaping gas that may be encountered while drilling. In addition, the drilling fluid must be thick enough to coat the wellbore with a cake, which serves to temporarily seal the walls of the well until casing can be installed. The circulating system consists of a starting point, the mud pit, where the drilling fluid ingredients are stored. Mixing takes place at the mud mixing hopper, from which the fluid is forced through pumps up to the swivel and down all the way through the drill pipe, emerging through the drill bit itself. From there, the drilling fluid circulates through the bit, picking up debris and drill cuttings, to be circulated back up the well, traveling between the drill string and the walls of the well (also called the 'annular space'). Once reaching the surface, the drilling fluid is filtered to recover the reusable fluid. In addition to the fluid itself regulating downhole pressures encountered while drilling, a device known as the 'blowout preventer' is situated on the well casing below the deck of the rig. A blowout can occur when uncontrolled underground oil or gas pressure exerts more upward pressure than the drilling fluid itself can offset. The blowout preventer can consist of hydraulically powered devices that can seal off the well quickly and completely, preventing any potential for a well blowout should extreme downhole pressures be encountered. Pressure release systems are also installed to relieve the great pressure that can be experienced in a blowout situation.

### **Casing**

Once the borehole has been drilled to the depth planned for the current phase, the casing pipe is run into the well. Casing pipe is run in singly joint by joint. Once it is run in, normal circulation (i.e down the inside of the pipe) is used to pump cement into the annulus between the casing and the borehole wall.

### **The comprehensive drilling costs estimation formula**

The four formulae for drilling cost estimation given above were not comprehensive due to the following reasons:

- i. The drilling company usually spend more money than initially estimated.

- ii. settling the casualties that result due to unrest of different kinds
- iii. there is always a down time occurrence due to (ii) above and drilling program is altered consequently.

The reasons (i) to (iii) given above are as a result of non-inclusion of host community cost in the drilling cost estimation formulae to take care of any of the above and related problems if they occur. The host community cost is thus added to the existing drilling cost to obtain a comprehensive oil well drilling cost estimation formula as:

$$\text{Total Drilling Cost, } C_T = [D * C_F] + H_{CC} \quad (6)$$

which is further expressed as:

$$C_T = C_R (t_{mt} + D / \bar{R}_P) + C_B + C_A + C_C + C_M + H_{CC} \quad (7)$$

$C_F$  is the average drilling and completion cost per foot

$C_R$  = rig operating cost, \$/hr

$t_{mt}$  = maintenance and trip time, hr

$D$  = depth interval, ft

$C_B$  = bit cost, \$

$C_A$  = auxiliary equipment cost (turbodrill, etc), \$

$C_M$  = mud costs, \$

$C_C$  = completion costs (including cementing, etc), \$

$\bar{R}_P$  = average bottom penetration rate, ft/hr

$H_{CC}$  = host community costs, \$

The host community is the community in whose land the oil is discovered and on which the drilling process would take place. Host community costs comprise several costs that would be used to settle the host community, these costs are summarised below as:

- i Cost of acquiring the right/access to the land location.
- ii Cost of relocating the affected community to a different location if need be.

iii Cost of provision of basic amenities like pipe borne water, roads, churches, schools, markets, hospitals etc in order to lure their interest out of the acquired portion of their ancestral land.

iv Cost of acquiring land for the opening and construction of the access roads to the well site from the community roads to enable the operators transport heavy drilling equipment to the sites.

v Cost of settling crises and unrest by the host community to calm nerves wherever the need arises.

Costs of acquiring the land and resettlement or relocation of the host community people; costs of provision of basic amenities for the community; crisis management costs.

A Microsoft excel spreadsheet was developed using the comprehensive drilling cost estimation formulae for the estimation of drilling cost. Fig 2 is a sample of the Microsoft excel spreadsheet for drilling cost estimation.

<b>COMPREHENSIVE DRILLING COST ESTIMATION</b>	
ENTER RIG COST PER HOUR, Cr (\$/hr)	<input type="text"/>
ENTER MAINTENANCE AND TRIP TIME, tmt (hr)	<input type="text"/>
ENTER DEPTH, D (ft)	<input type="text"/>
ENTER BIT COST, Cb (\$)	<input type="text"/>
ENTER AUXILLARY EQUIPMENT COST, Ca (\$)	<input type="text"/>
ENTER MUD COSTS, Cm (\$)	<input type="text"/>
ENTER COMPLETION COSTS, Cc (\$)	<input type="text"/>
ENTER AVERAGE BOTTOM PENETRATION RATE, Rp (ft/hr)	<input type="text"/>
ENTER LAND ACQUISITION COSTS, Cwa (\$)	<input type="text"/>
ENTER HOST COMMUNITY RESETTLEMENT COST, Ccr (\$)	<input type="text"/>
ENTER BASIC AMENITIES PROVISION COSTS, Cap (\$)	<input type="text"/>
ENTER CRISIS MANAGEMENT COSTS (LOBBY), Ccm (\$)	<input type="text"/>
<b>RESULTS</b>	
AVERAGE DRILLING AND COMPLETION COST PER FOOT, Cf (\$/ft) =	<input type="text" value="0"/>
HOST COMMUNITY COSTS, Hcc (\$) =	<input type="text" value="0"/>
TOTAL DRILLING COST, TDC (\$) =	<input type="text" value="0"/>

**Fig 2: Microsoft Excel Spreadsheet for Drilling Cost Estimation**

## **Result**

The comprehensive drilling cost formulae given in equations (6) and (7) above are more reliable and effective for the implementation of drilling program as planned. The drilling program include the required number of crew which depends on the size and type of operation the equipment required, the cost of drilling the well and the time (period) it will take to complete the drilling of the entire depth of the well.

The application of the comprehensive formulae for estimating the cost of drilling oil well creates room for the smooth implementation of the drilling program due to the following facts:

i The company and up spending the amount estimated or even less when some of the anticipated problems from the host community may not arise throughout the period of drilling.

ii The down time is effectively prevented when the relationship between the host community and operating company remain cordial throughout the period of drilling and so no disturbances. The rig and other equipment are usually on lease arrangements in which the payment depend on the number of days it stayed.

iii The number of casualties are reduced to the bareless minimum when there is no frequent face off between the company and the host community as mentioned in (ii) above.

iv The host community benefits from the amenities provided by having their members gain employment in the school, churches, hospitals etc, and also benefiting in rural development through the roads, electricity, markets, pipe borne water.

v The planned duration of the drilling is reliable due to the facts given in (ii) and (iii) above.

## **Conclusion**

At the end of this study, it is shown that the comprehensive formulae shown in equations (6) and (7) for estimating drilling cost of oil well is reliable and provides detailed information needed to implement the designed drilling if adopted.

The following conclusion can also be drawn:

- i. The comprehensive formulae if adopted improve the relationship between the company and host community.
- ii. It helps to check the unforeseen circumstance that may arise during the drilling operation and also make provision for the solutions if in case they occur.
- iii. It provides more reliable information for the company to make and implement drilling budget.
- iv. It also brings about rural development and employment in return when the provisions in the formula are made.
- v. It saves cost, as well as man hours usually spent during drilling.

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## **NOMENCLATURE**

\$ =dollar

hr = hour

ft = foot/feet

m = metre

US = United States

vs = versus

z = well depth

$\square_{\text{well}}$  = well cost