SAND98-1537C
SAND--98-1537C
CONF-980917--

# A Simple Tool to Assess the Cost-Effectiveness of New Bit Technology

Thomas M. Bomber, Sandia National Laboratories
Bill J. Livesay, Livesay Consultants, and
Kenneth G. Pierce, Sandia National Laboratories

**Abstract:**

Cost or performance targets for new bit technologies can be established with the aid of a drilling cost model. In this paper we make simplifying assumptions in a detailed drilling cost model that reduce the comparison of two technologies to a linear function of relative cost and performance parameters. This simple model, or analysis tool, is not intended to provide absolute well cost but is intended to compare the relative costs of different methods or technologies to accomplish the same drilling task.

Comparing the simplified model to the detailed well cost model shows that the simple linear cost model provides a very efficient tool for screening certain new drilling methods, techniques, and technologies based on economic value. This tool can be used to divide the space defined by the set of parameters: bit cost, bit life, rate of penetration, and operational cost into two areas with a linear boundary. The set of all the operating points in one area will result in an economic advantage in drilling the well with the new technology, while any set of operating points in the other area indicates that any economic advantage is either questionable or does not exist. In addition, examining the model results can develop insights into the economics associated with bit performance, life, and cost. This paper includes development of the model, examples of employing the model to develop "should cost" or " should perform" goals for new bit technologies, a discussion of the economic insights in terms of bit cost and performance, and an illustration of the consequences when the basic assumptions are violated.

## Introduction

Under the sponsorship of the DOE Geothermal Division, the authors developed a very detailed geothermal well drilling cost model. The purpose of this model was to help understand the cost drivers in well drilling and to assess the potential of new technologies to improve the cost-effectiveness of drilling. While the model can make such assessments it requires a large quantity of detailed input data and many runs to define the total space of acceptable performance goals. A simplified approach to screen technologies for potential pay-off, before running the detailed model was desired. This led to the development of a simple linear economic tool for assessing the cost-effectiveness of some drill bit technologies. The objective was to develop a first-order linear relationship between the important bit parameters of cost, life, and rate of penetration. The tool could then be used to screen new bit technologies and also to set performance goals for new technologies to ensure cost-effectiveness. The resulting simple economic analysis tool is discussed in this paper.

# DISCLAIMER

# DISCLAIMER

Portions of this document may be illegible electronic image products. Images are produced from the best available original document.

**Tool Development**

The cost of a trouble-free drilling interval is given by:

$$C_I = C_D\, t + C_F$$

where: $C_I$ is the cost of the interval,
$C_D$ is the daily (or hourly) operating cost,
$t$ is the time needed to drill and complete the interval, and
$C_F$ are the fixed or non - time related costs.

The time can be divided into three general categories:

$$t = t_D + t_T + t_E$$

where: $t_D$ is the time drilling (turning to the right),
$t_T$ is the tripping and BHA time, and
$t_E$ is other time (principally end - of - interval activities).

The fixed costs are divided into two categories:

$$C_F = \sum C_{Ti}\, N_{Ti} + C_E$$

where: $C_{Ti}$ is the cost of the $i^{th}$ tool,
$N_{Ti}$ is the number of the $i^{th}$ tools consumed, and
$C_E$ is all other fixed costs (primarily end - of - interval costs).

Then the interval cost is given by:

$$C_I = C_D\,(t_D + t_T + t_E) + \sum C_{Ti}\, N_{Ti} + C_E$$

For new tools to be economically competitive, the interval cost with the new tools must be less than or equal to the cost with old tools:

$$C_{IN} \leq C_{IO}$$

$$C_D\,(t_{DN} + t_{TN} + t_{EN}) + \sum C_{TiN}\, N_{TiN} + C_{EN} \leq C_D\,(t_{DO} + t_{TO} + t_{EO}) + \sum C_{TiO}\, N_{TiO} + C_{EO}$$

The assumptions in this economic analysis of new bit technologies are:
i. The end-of-interval costs and times will not change with a new bit,
ii. The tool costs will not change,
iii. The daily cost will not change,
iv. Drilling time is significantly larger than the combined tripping and the bottom hole assembly (BHA) times ($t_D >> t_T$).

Under these conditions, the above equation becomes:

$$C_D\,(t_{DN} + t_{TN}) + C_{bN}\,N_{bN} \le C_D\,(t_{DO} + t_{TO}) + C_{bO}\,N_{bO}$$

The following relationships are used for the number of bits and the drilling time:

$$t_{DK} = \frac{L_I}{ROP_K}$$

$$N_{bK} = \frac{L_I}{ROP_K * t_{bK}}$$

where : $L_I$ is the length of the drilling interval and

$t_{bK}$ is the K type bit life in hours.

Under these assumptions, the condition for the new bit to be economically competitive becomes:

$$C_D \frac{L_I}{ROP_N} + C_{bN} \frac{L_I}{ROP_N * t_{bN}} \le C_D \frac{L_I}{ROP_O} + C_{bO} \frac{L_I}{ROP_O * t_{bO}}$$

$$\frac{1}{ROP_N}\left\{C_D + \frac{C_{bN}}{t_{bN}}\right\} \le \frac{1}{ROP_O}\left\{C_D + \frac{C_{bO}}{t_{bO}}\right\}$$

$$\frac{ROP_N}{ROP_O}\left\{C_D + \frac{C_{bO}}{t_{bO}}\right\} \ge C_D + \frac{C_{bN}}{t_{bN}}$$

$$C_D\left\{\frac{ROP_N}{ROP_O} - 1\right\} \ge \frac{C_{bN}}{t_{bN}} - \frac{ROP_N}{ROP_O}\frac{C_{bO}}{t_{bO}}$$

$$C_D\left\{\frac{ROP_N}{ROP_O} - 1\right\} \ge \frac{C_{bO}}{t_{bo}}\left\{\frac{C_{bN}/t_{bN}}{C_{bO}/t_{bO}} - \frac{ROP_N}{ROP_O}\right\}$$

$$\frac{ROP_N}{ROP_O}\left\{C_D + \frac{C_{bO}}{t_{bo}}\right\} \ge \frac{C_{bO}}{t_{bo}} * \frac{C_{bN}/t_{bN}}{C_{bO}/t_{bO}} + C_D$$

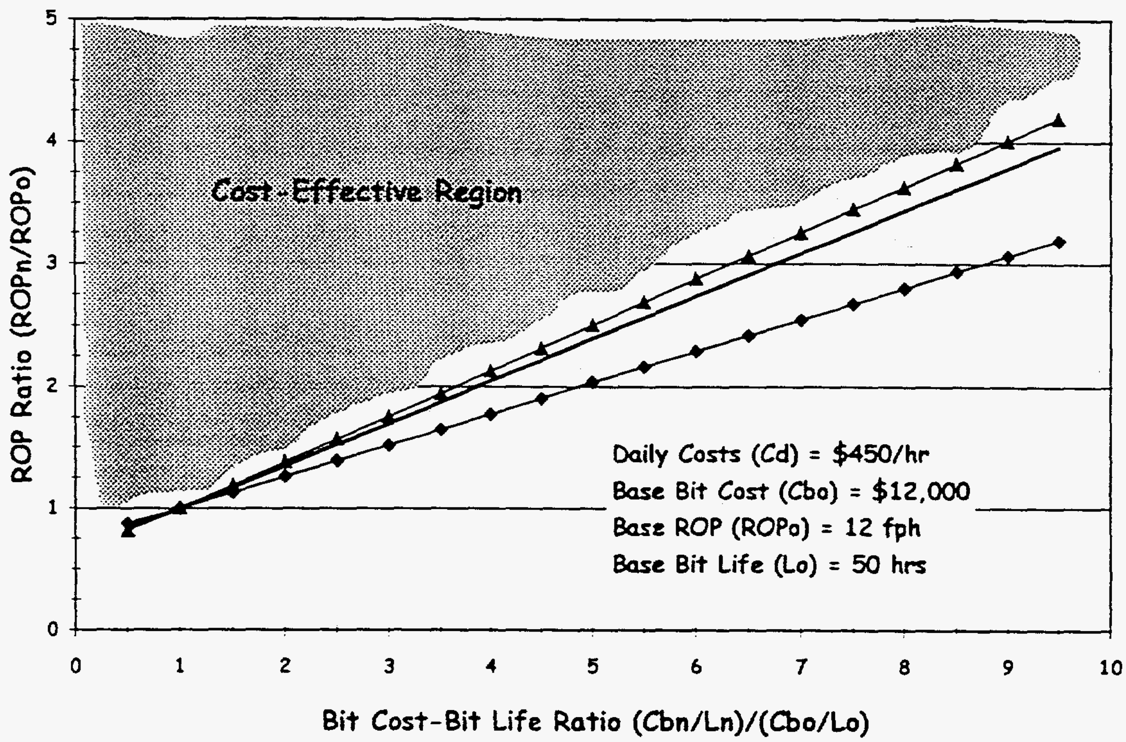
$$\frac{ROP_N}{ROP_O} \ge \frac{C_{bO}/t_{bO}}{C_D + C_{bO}/t_{bO}}\left\{\frac{C_{bN}/t_{bN}}{C_{bO}/t_{bO}}\right\} + \frac{C_D}{C_D + C_{bO}/t_{bO}}$$

This inequality is a linear relationship passing through the point (1,1) in the dimensionless variables $\{ROP_N/ROP_O\}$ and $\{[C_{bN}/t_{bN}]/[C_{bO}/t_{bO}]\}$. This line divides the operating space into two regions. The region above the line is a cost-effective region for the new technology and the region below the line represents a cost-ineffective region.

**Tool Validation**

The detailed cost model was used to validate the simple economic tool. Figure 1 shows the data from the simple linear model compared to results from the more detailed cost model. The solid line in the middle is the prediction using the simple economic tool and the two lines surrounding the prediction are the results of the detailed cost model. The nominal values used for the calculations are shown on the chart. The daily cost is $10,800

**Figure 1: Tool Validation**




dollars per day. The nominal rate of penetration used in the detail model is 12 feet per hour. The drilling interval used in the calculation was from 2500 ft to 6500 ft. The upper bound from the detailed model was obtained by varying the new bit life and ROP while holding the new bit cost constant. The lower bound was obtained by varying the new bit cost and ROP while holding the new bit life constant. Based on this comparison for trouble free drilling, the simple economic tool gives very reasonable estimates. The important assumptions on which the simple model is based are true for this comparison. These assumptions are: the

*i ) daily costs are essentially unchanged for the new bit technology*,

*ii) tripping time is much less that the actual drilling time*, and

*iii) special tools and BHA cost are the same for the new technology and the baseline*.

The spread of the lines are the result of second order effects; therefore, the boundary between the cost-effective and cost-ineffective regions is not a sharp line but a *wide border*.

## Setting Technology Objectives

This simple economic tool provides a relationship between the bit cost, the bit life, and bit performance, i.e. rate of penetration. The developer of new bit technology now has a way to trade-off bit life and performance or bit performance and cost to achieve a cost-effective design. Figure 2 is an example of how the tool can be used in this manner. In

**Figure 2: Setting Goals**
**ROPn versus Cbn/Ln**

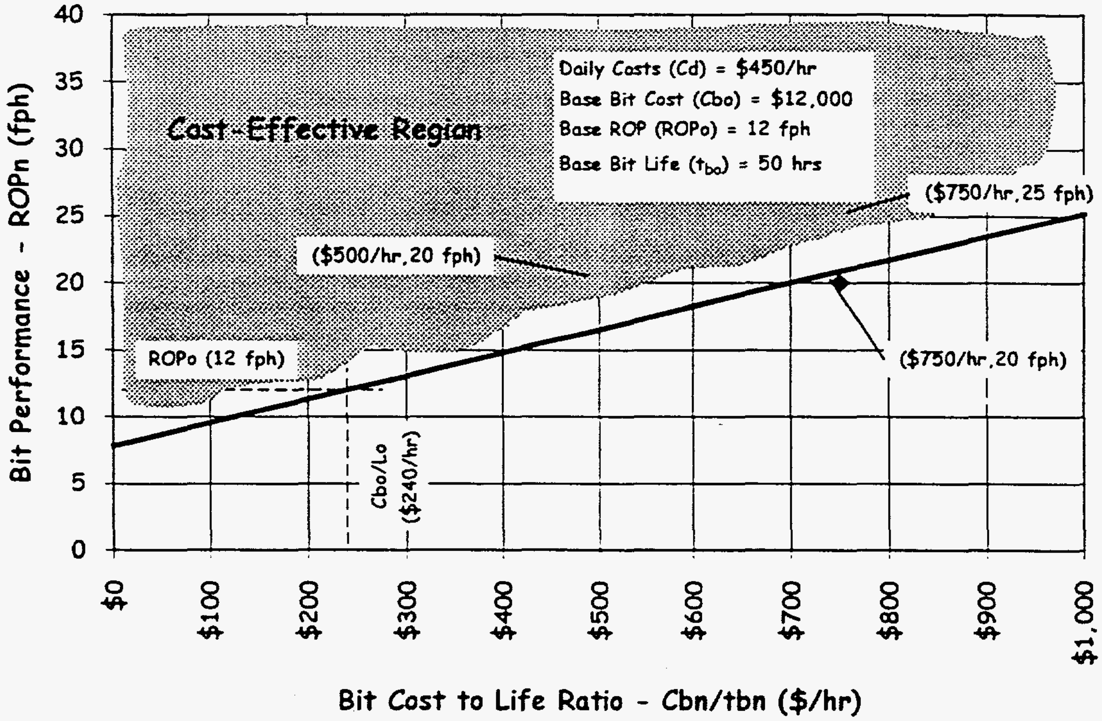



Figure 2 the rate of penetration for the new technology is plotted versus the ratio of new bit cost and life.

In this example, the baseline bit is assumed to have 50 hour life and a cost of $12,000. The daily cost is assumed to be $450. Now suppose the new bit technology is estimated to operate at (750,20). Fig. 2 shows the realization of this technology is apparently not quite cost effective. However, the bit designers have many options to improve this situation. For example, they can work on performance and increase ROP to 25. The new point (750,25) represents a cost-effective bit. There are other paths to cost-effectiveness. For example, the designer could work on increasing the life of the bit by 50 percent to move to the point (500,20). Another way to get to this point is to reduce the cost by one third. It is also possible to get there by any combination of bit life increase and cost decrease that result in reducing the cost to life ratio by 33 percent. This gives the designers and technologist considerable flexibility in how to achieve cost-effectiveness.

Another important use of the model is as a screening tool for assessing the potential cost-effectiveness of many technologies. The candidates can be quickly located on the chart and their potential cost-effectiveness can be determined. The subset of cost-effective bits can then be subjected to more detailed analysis.

**Some Insights Obtained with the Tool**

Referring to Figure 1 again, consider the cost-effective region for new bits which drill slower than the baseline bit (i.e. ROP ratios of less than one). For the example shown the y axis intercept is around 0.5 which means if the new technology bit drills at less than half the ROP of the baseline bit, it will cost more to drill with that bit than the baseline bit even if the new bit is free! This tool shows the dominance of performance (i.e. ROP) in assessing cost-effectiveness. In fact, for off-shore drilling with its very high daily charges, the slope of the boundary line is decreased dramatically. The slope is proportional to the reciprocal of the daily cost and the y axis intercept approaches one as the daily cost increases. In the extreme case with boundary line essentially horizontal, any bit which will increase the ROP will be cost effective at almost any cost to life ratio, but no combination of cost-to-life ratio cam make up for a bit with decreased ROP.

**Limitations of the Tool**

One of the limitations of the tool is that it provides no quantitative assessment of the savings to be obtained from a cost-effective bit. Generally speaking, the greater the perpendicular distance of the operating point of the bit from the line, the greater the cost savings, but this is a qualitative statement. Therefore, it is necessary to use a detailed cost model like the one used to validated the simple tool to assess the quantitative savings of the bits which have passed the cost-effective screening test with the simple tool. Again the value of the tool is in setting goals and screening technologies. Assessing actual savings must be done with the more detailed drilling cost models. Another limitation of this tool is that the analysis assumes trouble-free drilling. The percent savings in drilling cost resulting from the use of a cost-effective bit can be substantially eroded in a well prone to drilling problems.

The final limitation results from the assumptions made in order to develop the simple tool. It is important that none of these assumptions are violated to make a correct assessment. For example, in an analysis involving a "large coring" bit, the following results were obtained. In this example, the base case was an ROP of 12ft/hour, a bit cost of $18,000, and a bit life of 50 hours. The "large coring" bit was assumed to have a life of 75hrs and a cost of $4,200. Calculations with the simple tool would indicate the coring bit ROP need only to be greater than 8 ft/hour to be cost effective. However, the same comparison in the detailed drilling cost model indicated an ROP of 18 ft/hour was required to be less costly than the baseline bit. The problem is the basic assumptions of the simple model were violated in this case. In the first place, the tripping time for the coring bit was not much less than the drilling time, because it was assumed the tripping speed for the large diameter coring drill pipe would be the same as the running speed for casing of the same diameter. Secondly, the daily charge for drilling with the "large coring" bit was greater than the daily cost in the baseline case, because of the addition of a top drive, automatic pipe handling equipment, and a more expensive drill string for the coring bit.

## Summary

The simple model is useful in sorting multiple technologies and in setting goals for new bit technologies to achieve cost-effectiveness, when the simplifying assumptions are met. The tool also provides insight into the important parameters in the cost-effectiveness of new bits. The limitations are

1. The tool does not provide quantitative assessment of the saving achieved with cost effective bits, and
2. Care must be taken to insure that all the assumptions used in deriving the simple tool are met before applying the tool, or very misleading results can be obtained.

**Note: Work performed at Sandia National Laboratories is supported by the U.S. Department of Energy under contract DE-AC04-94AL8500.**

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.