Using Historical Well Data to Increase the Accuracy of Drilling AFEs
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Introduction

No company has an infinite supply of money, so it is important to know how much a project will cost before embarking on it. Underestimating project costs can cause budget shortfalls, often resulting in incremental requests for expenditures. Cost overestimation, though, is just as bad because the money allocated could have been spent on other projects. Therefore, it is important to get the cost estimation—and Authorization for Expenditures (AFEs)—as close to reality as possible the first time.

Fortunately, many of the wells being drilled today are not unlike wells that have been drilled in the past. Most companies have access to a wealth of historical information detailing the time previous wells have taken. If the candidate project will be performed in an environment like the historical well using a similar well program, the actual well data can be considered historical data for this well type. When a sufficient set of historical projects have been found, these data points become a sample upon which an estimate can be based.¹

Landmark’s Well Cost software is a great fit for this type of estimation, because it can be used to lay out the well program for a new drilling project, retrieve any historical data available, fit probabilistic distributions to this data, and then use the fit distributions to produce an estimate of both the time and the cost required to complete the project. Note that while the discussion here will be limited to a drilling project, the Well Cost software is equally applicable to completions or abandonment-type projects, as well as any other project for which time and cost estimates are required.

There are a series of steps that are typically used to produce an estimate based on historical data:

1. Define the Well Program
2. Account for Nonproductive Time
3. Retrieve Historical Data
4. Fit Probabilistic Distributions to the Historical Data
5. Define Applicable Costs
6. Simulate the Project and Make Adjustments

To describe each of these steps and how the Well Cost software is used to achieve them, consider the case of Landmark Consulting. They are doing work for a company drilling in South Texas. Ten wells have been drilled in an existing field and credible operations reporting data is available for each of these existing wells. Landmark needs to tell their customer what it will take, in terms of time and cost, to drill the eleventh well.

Step 1: Define the Well Program

The Well Program consists of the steps that are taken in order to complete the well project. Items like Rig In/Move Up and Drill Conductor Hole are high-level steps (phases) and normally have operations reporting data available from previous projects. Lower-level steps (activities)
such as Skid Rig and BHA Pick-Up may not be available in the historical data, so it is important to know up-front what level of detail exists so the program can be appropriately laid out. Analysis can be performed at either the phase or activity level. For this analysis, Landmark Consulting will only consider phases.

After setting up the design for phase level analysis, the events used in the design are defined. Up to three events can be used in a single design: the Start Event, the Completion Event, and/or the Abandon Event. The Well Cost software has a predefined list of events, but these names can be customized as desired. Landmark Consulting’s project will use only a Start Event (Original Drilling). Each event has associated with it a list of phases and activities, which are the items that need to be completed as part of that event. Before getting to this level of detail, the project must be fully defined by specifying both the trajectory (wellpath) and the casing.

The Engineer’s Desktop™ (EDT™) set of applications, of which the Well Cost software is a member, contains a number of engineering applications that can be used to define these design aspects. If such applications are used, their output data is immediately available for use by the Well Cost software. For this example design, the wellpath was defined by the COMPASS™ software and the casing design was laid out in the StressCheck™ application.

With the engineering design in place, the next step is to lay out the phases required by the project. As with the list of events, the phase list is completely customizable, allowing the user to define any activities that may need to be performed as part of the project. As each phase is defined, the casing is associated with it, thereby assigning it to a hole section (Figure 1).

![Figure 1: Selecting the casing for a phase](image)

Note that the phases can be entered manually, one at a time, or they can be added in bulk through the import facility (Figure 2). Since many well projects are similar and, thus, use the same sequence of phases, the software allows the user to configure the phase list, save it as a template, and then load that template into other designs, thereby simplifying the process of creating new designs.

![Figure 2: The full list of phases in the well program](image)
If an activity level analysis were being performed, the next step would be to lay out the sequence of operations required to complete each phase. Because our analysis will be confined to the phase level, we can stop here.

**Step 2: Account for Nonproductive Time**

Things go wrong in well projects: weather events occur, workers go on strike, and equipment fails or gets delayed. In order to properly produce a well program, the possibility of such events occurring must be taken into account. The Well Cost software allows the user to account for these risks and use historical data to predict how often they will occur and, if they do, how much time will be lost as a result.

As our example performs analysis at the phase level, both Planned Time and Unplanned Time (NPT) can be entered directly for a given phase. Both of these items can be entered either as a set deterministic time, as probabilistic distributions (Figure 3) based on expert data, or fit to historical data (see Step 3 for a further description of this).

![Figure 3: Planned and unplanned time entered using probabilistic distributions](image)

Figure 3: Planned and unplanned time entered using probabilistic distributions
If the analysis were done at the activity level, multiple levels of risks could be defined to specify what could go wrong as each activity is executed, as well as what would need to be done as a result (Figure 4). In our well program, there is a 10% chance that, when the surface casing is run, a tight hole will be encountered. When this occurs, there is a 90% chance that it is a minor event that is easily rectified with a washdown, but there is also a 10% chance that it is a major event resulting in an additional sequence of activities that must be performed.

The Well Cost software makes it easy to define each of these risk levels as well as any actions that must be taken as a result.

![Risk layout for the Run Casing activity](image)

*Figure 4: Risk layout for the Run Casing activity*
Step 3: Retrieve Historical Data

If historical data is available for similar wells, then the next step is to use that data to fit probabilistic distributions that can be used to predict how long the new project will take. The Well Cost software provides the capability to use historical operations data entered in the OpenWells® operations reporting system for this distribution fitting. All the user must do is select the appropriate wells from the Offset Well selector (Figure 5).

After the wells have been selected, a query will be run on the database to automatically retrieve the historical data values for each phase for both Planned and Unplanned time (Figure 6).

Figure 5: Wells selected in the Offset Well Selector

Figure 6: Historical data retrieved from the offset wells
If a phase is not present in one on more of the wells, the data is left blank. Note that historical data not present in the EDM™ database can also be accessed. The User button presents a dialog where other wells can be created. The historical information can then either be entered manually for these wells or retrieved from another database using an appropriate query.

The Unplanned Time associated with a phase is determined by totaling all activities within that phase that have an Unplanned Time code. By default, activities with a code of U or D are considered unplanned, but this coding can be customized.

After all historical information is present in the spreadsheet, the next step is to analyze the information for accuracy, because the estimate will only be as good as the data on which it is based. For instance, in the Move In / Rig Up phase, one well had the rig moved from an offsite location (requiring additional time), while the other wells only moved the rig between adjacent pads. Fitting a distribution to these data points may result in an estimate that is too large, because the offsite move resulted in an inordinately large amount of time. These are the types of items that must be considered when looking at this historical data.

Adjusting for varying depths is another thing to consider when looking at the historical data. In this example, we have already turned this option on, so any value shown in red represents a value that has been modified to take into account the differing depths of the offset wells.

Other adjustments can be made manually to the data through the Use column (Figure 7). To see this column, activate the Show Use Columns option. Selections in this column allow you to decide whether to use the data point as is, replace it with another value that is entered directly, or decide not to use it as a data point (note that any data point not used will be displayed in gray).

Using the Well Cost software to automatically retrieve historical data helps ensure that it is free from entry errors so that the correct data is used. With the added ability to analyze, turn off, or adjust values, the software ensures a more reliable estimate.
Step 4: Fit Probabilistic Distributions to the Historical Data

After analyzing the data values and making any required adjustments, the next step is to fit probabilistic distributions to that data. Doing so will allow the user to set up a simulation run where each phase is “executed” in turn with its completion time being drawn from the fitted distribution. Ordinarily, such fitting is done through trial and error or through the use of third-party applications, which represent another source of expense (purchasing the application, training, etc.) The Well Cost software simplifies this process by automatically fitting probabilistic distributions to the data. The distribution fit is selected based on ranking criteria that considers the mean, standard deviation, skewness, and kurtosis. After the distributions are fit, the selections are displayed along with their key parameters.

The results of the fitting are then used as the distributions for the Planned and Unplanned Time of each Phase (Figure 8).

![Figure 8: The Drill Surface Hole phase configuration has been updated based on the distributions fit to the historical data.](image)

The Well Cost software makes it simple to link the well program to historical data and then fit distributions to that data. The user is free to make changes to the distributions fit by the software, and this process is simplified by the Query button available for each time characteristic. Discussion of this functionality, though, is beyond the scope of this white paper.

Step 5: Define Applicable Costs

The previous steps were necessary to produce an estimate of the time required to complete the project. This estimate though, has nothing to do with the costs incurred, which must now be considered. As part of the project, equipment must be rented, contractors paid, and downhole items purchased (e.g., casing, liners, tubing). Such items must be detailed if a realistic estimate of the project is to be given. The Well Cost software makes doing so easy by providing a
tree-based structure of cost categories that are organized by Class, Code, and Subcode. A default configuration is provided, but it is configurable to match the user’s financial accounting system.

Rig Rental is a typical cost incurred by drilling projects and is normally given as a day rate (Figure 9).

![Figure 9: Set-up of rig – Rental cost using a day rate.](image)

A number of different cost types are supported: day rate (as shown above), fixed rate, single payment per phase, casing, depth-based, and risk. When coupled with the formula field which allows for the use of algebraic and other such functions, almost any type of cost calculation can be written.

If the cost varies or the exact amount is not known, a probabilistic distribution can be entered or fit to a data set so that the software can vary the cost amount based on a “draw” from the defined distribution.

Costs can also be limited to a set of individual phases or a range of phases, allowing the user to accrue the cost at the appropriate point in the project.

The Well Cost software simplifies entering and analyzing project costs by providing a customizable, tiered approach. The Cost Sheet shows you exactly how the costs are allocated, making it easy to see if any adjustments need to be made.
Step 6: Simulate the Project and Make Adjustments

Now that the details of the well program and costs have been specified, the next step is to run the Monte Carlo simulation. Doing so will cause the simulator to run through the well program a specified number of times (10,000 iterations by default), generating both the completion time and the total cost of the project.

The results of the runs are sorted from smallest to largest, allowing for the computation of the P-values (P10, P50, and P90 by default but any three can be selected).

After the simulation completes, standard plots and reports are available to aid in the analysis of the results (Figure 10).

![Figure 10: Some of the plots available to help analyze the results. Shown here are the Time vs. Depth chart, the Phase Times histogram, the Well Schematic, and the Offset Wells (Time vs. Depth) chart that compares the results of the simulation with the historical data retrieved from the offset wells.](image-url)
After completing an analysis of the results, it may be necessary to make changes to the input data (phase layout, offset wells data, costs) before re-running the simulation. When satisfactory results have been produced, an AFE Report can be generated that can then be routed to management for project approval (Figure 11).

![Figure 11: An AFE Report generated for the estimate. The total cost is broken down per event for each cost-item type.](image)

The cost data can also be pushed back into the EDM database to populate the OpenWells Cost Estimate and AFE Report. Similarly, the activity detail can also be used to populate the Planned Operations section of the OpenWells Well Planning Report.

**Benefits**

The Well Cost software uniquely solves the problem of estimating complex drilling projects. Generic software products like spreadsheets are commonly used, but because these were not designed for this purpose, additional work is required to achieve the same estimate accuracy. For instance, if reports and plots are desired from these applications, they must be created using a set of standard reporting and plotting tools. The Well Cost software, however, automatically generates commonly used plots (X-Y, histograms, schematics, and pie charts) and reports that help the user analyze the results and obtain any approvals required for the project.

The Well Cost software was also designed with risk-based analysis in mind. As the list of activities required to complete the project is entered, the user can also list the things that could go wrong, as well as the additional steps that must be taken if they do. This allows the Monte Carlo simulation to produce a range of possible output results allowing the user to see the technical limit, the likely outcome, and the pessimistic outcome to enable estimating with more confidence. Generic tools can be used to produce similar estimates, but doing so requires the addition of a third-party Monte Carlo add-in, which requires additional work to learn how to use and set up to work with the specific data.
Another advantage the Well Cost software has over generic applications is providing a common environment for project estimation that is customizable and deployable throughout the entire organization. This eliminates each engineer having their own set of spreadsheets with nonstandard event, phase, and activity codes, as well as employing their own unique way of producing an estimate, making organizational roll-ups difficult.

Finally, the Well Cost software is built with collaboration in mind. Applications like COMPASS™, CasingSeat™, and StressCheck™ can be used to create the engineering aspects of the design, and then the Well Cost is automatically populated with the information for use in the costing process. OpenWells® users will also have access to existing operations reporting data for use as historical data on which a new estimate can be based. After entering the activity and cost information into the Well Cost software and running the simulation, the resulting information can be made available for further use and analysis in the EDT™ suite.

Conclusion
As demonstrated in the Landmark Consulting example, producing an accurate estimate of a new drilling project is a complicated process that can be aided with the use of historical data. The Well Cost software makes it easy to define the steps and the risks associated with a drilling project, access the available historical information to fit distributions to that data, enter the appropriate project costs, and then produce an estimate of the time, cost, and uncertainty associated with the project. Doing so will help produce a correct estimate the first time, thereby avoiding the need for incremental AFEs or having surplus funds at the end of the project.

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