Exercise set 04

PROBLEM 1:

An oil reservoir has been discovered in the Barents Sea, 310 km from Hammerfest. Seismic data and a few exploration wells have been drilled that provide enough information to perform an initial reserve estimation and economic valuation.

The company is currently in the business identification phase (leading to DG0) and it will decide if:

1) To go forward with the development
2) To drill some more appraisal wells and get more information about the extension of the reservoir. The cost of the appraisal well campaign is 80 million USD. The campaign could have two outcomes:
    a. If the appraisal wells give a positive indication of hydrocarbons, It will confirm the upper value of the rock volume.
    b. If the appraisal wells give a negative indication of hydrocarbons, the maximum rock volume must be reduced to 0.9 E10 bbl.

- To help the company to take the decision, you have to perform a probabilistic estimation of the value of the project (NPV). Use your results to decide if it worth or not if to perform the appraisal campaign. You are considering employing a probability tree together with the Monte Carlo or Latin-Hypercube sampling methods.

- Evaluate the effect of the oil price has on your results (varying in the range 30-50 USD/bbl)

- Discretize the cumulative probability distribution of the NPV in three values, P90, P10 and P50 and determine the probability associated to each value.

Additional information

For estimating the economic value of the project, you must use the following simplified expression (in million USD)

$$NPV = P_o \cdot F_D \cdot N_{pu} - C$$

Where:

- P_o is the price per barrel of oil [USD/bbl].
- C is the initial cost of the development, mainly representing facilities and wells [in million USD]. There is a uniform uncertainty of ±40% in this number. Given by the equation:

$$C = N_{pu} \cdot 3.24 + 2002$$

- F_D is a discounting factor [-], representing that reserves are recovered and discounted gradually within a period of time, instead of at time zero. This value will depend on the production profile, but for you analysis, assume it varies uniformly between 0.4-0.6.
- N_{pu} is the ultimate cumulative oil production [in Million stb] (or total recoverable reserves). Only oil is recovered from this field (due to lack of gas transport infrastructure).

The ultimate cumulative oil production is $N_{pu} = N \cdot F_R$, where

- F_R is the ultimate recovery factor [-]. Assume this value can vary uniformly between 0.2-0.4 (the reservoir has very low pressure).
- N is the initial oil in place [stb] , estimated by the expression

$$N = \frac{V_R \cdot \phi \cdot S_o \cdot N_{tg}}{B_o}$$

Where:

- V_R Rock volume [bbl]
- ϕ porosity [-]
- S_o oil saturation [-]
- N_{tg} Net to gross [-]
- B_o Oil formation volume factor [bbl/stb]

Values are provided in the excel sheet attached.

In tree analysis, we usually make a discrete approximation by setting up nonoverlapping (mutually exclusive) ranges that encompass all possible values (collectively exhaustive), by finding the probabilities that the values fall in these ranges, and by then choosing a value to represent that range. (This is the approximation.) By doing this, we have converted a continuous variable to a discrete variable and a probability density function to a probability mass function.

Given a continuous probability distribution such as the one shown in Figure 2–14, how does one perform this approximation? One widely used technique is to select the number of outcomes and the values of the probabilities you want and then draw a horizontal line at these probabilities. In Figure 2–15, we have chosen the number of outcomes to be three. We have also chosen the probabilities .25 for the lower range (line at .25), .5 for the

Figure 2–14

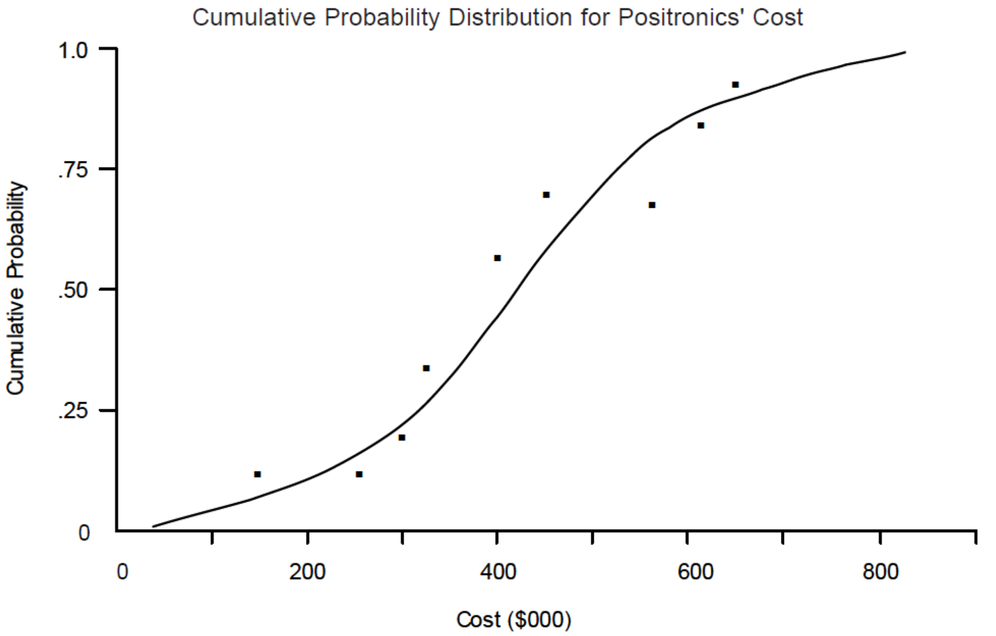
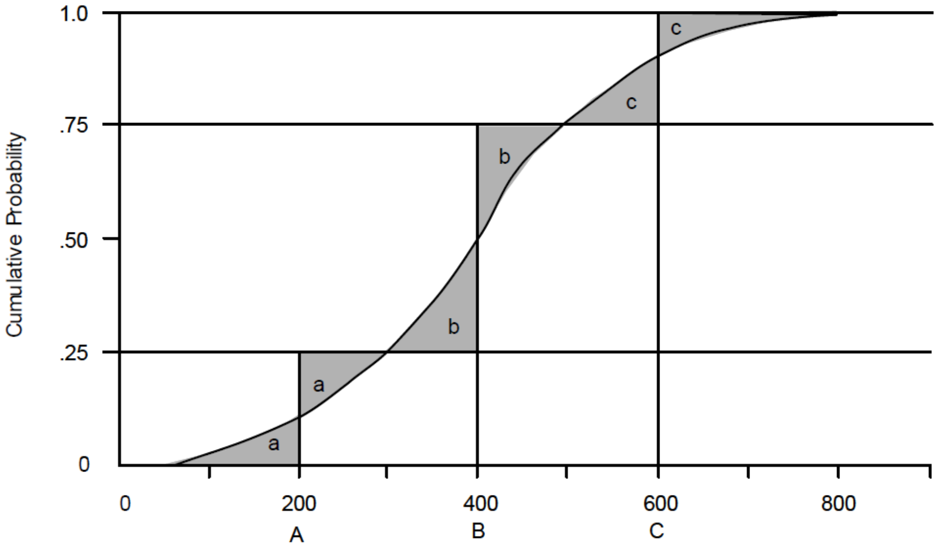


Figure 2–15

Approximation of Discrete Probability Distribution for Positronics' Cost



middle range (line at .25 + .50 = .75), and .25 for the top range (line at .25 + .5 + .25 = 1).

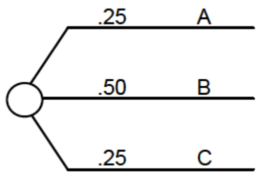
Next, we draw a vertical line at A, choosing point A so that the shaded area to the left of the vertical line is equal to the shaded area to the right. (The eye is surprisingly good at doing this.) These two areas are marked by the letter "a." Then we pick a point, B, at which to draw a vertical line with the shaded area to the right being equal to the shaded area to the left. Finally, we pick the third point, C, at which to draw the vertical line balancing the two shaded areas.

The procedure sounds much more complicated than it is in practice. The result is that we now have approximated the continuous probability distribution; the discrete probability distribution is shown in tree form in Figure 2–16. The actual values are A = 200, B = 400, and C = 600. These values are used for Positronics' cost in this chapter. In general, the values for A, B, and C will not come out evenly spaced.

The reason the procedure works is that we divided the continuous probability distribution into ranges with associated probability when we drew the horizontal lines. In Figure 2–17, we see that the first range was from negative infinity to x and had probability .25. The second range was from x to y and had a probability of .5. The third range was from y to infinity and had a probability of .25. (For this example, x = 300 and y = 500, corresponding to the ranges in Figure 2–4.) Picking point A in such a way that the shaded areas are equal is a visual way of finding the expected value, given that you are in the lowest range. (Proving that the expected value makes the shaded areas equal is a nice exercise in calculus in problem 2.15.) Choosing the expected value to represent the range is a natural approximation and is commonly used. There are, however, other possible choices.

Figure 2–16

Discrete Probability Distribution in Tree Form



<u>PROBLEM 2:</u> Wave statistics for the Aasta Hansteen area.

You have been invited onboard the R/V Gunnerus, a ship that belongs to NTNU that will carry several research activities on a trip to the Norwegian Sea. The vessel will be visiting the area where the Aasta Hansteen field will be located (67° Latitude and 7°Longitude). Equinor sponsors your stay and place on the ship. The ship is equipped with a buoy that measures wave elevation every 0.5 s.

Part 3.1. To show your gratitude to Equinor, you intend to process the wave elevation data that has been gathered for a period of 2047.5 s during the trip (See the excel data attached). The tasks are as follow:

- Perform an FFT of the data provided. Do this in excel and follow the instructions in the document "Frequency Domain Using Excel" written by Larry Klingenberg, from San Francisco State University. Please note that the procedure provided by Prof. Klingenberg already calculates the amplitude (wave elevation, in m), **NOT** the spectral energy.
  Plot the wave spectrum (amplitude in m vs frequency), provide the periods with the highest amplitude on a table and report the peak spectral period (the period with the highest amplitude). Is it possible to reconstruct the original wave elevation data with this plot?
- When an offshore structure is impacted by a wave with certain dominant amplitude and frequency, it will exhibit a displacement and movement that depends on the characteristics of the structure (support mechanism, weight, flexibility, damping, etc.). A technique typically used to predict movement is to use a response amplitude operator (RAO), computed from laboratory tests or numerical models. The RAO gives the ratio between movement and wave amplitude for a fixed frequency (assuming that there is always a linear relationship between them at a fixed frequency). A plot of the Heave RAO is shown below. **Compute the expected heave motion when a wave with the maximum amplitude found earlier impacts a: FPSO, Spar, Semi-Sub.**

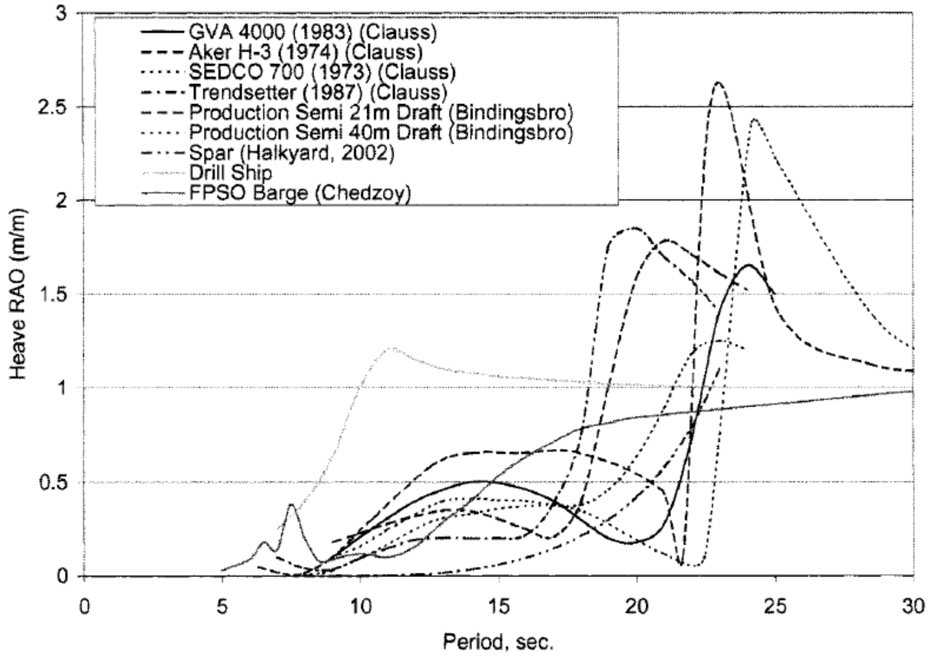


Figure 7.3 Example heave RAOs of various floaters

- If one assumes the wave elevation displays a normal distribution and the wave height displays a Raleigh distribution, the significant wave height H_s can be expressed as $H_s = 4 \cdot \sigma_\zeta$, where σ_ζ is the standard deviation of the wave elevation data. Using this assumption, **compute the significant wave height of the data gathered earlier on the R/V Gunnerus.**

PROBLEM 3: Routing configuration of subsea wells in the troll field.

The Troll field has 5 subsea wells (grouped in two templates, 3 wells in Template A and 2 wells in Template B) that have the possibility to flow to separator 1 or separator 2 on the platform.

Make a sketch of the system considering the following:
- There are only two flowlines to the platform from both templates. The x-over valve for pigging is located in template B.
- There are 4 flowlines to the platform (2 from each template). Both templates have x-over valves for pigging.

Include routing valves and specify what is located on the template, and what is located topside.

Separator 1 and 2 have maximum capacities of water handling and gas handling (provided in the excel file attached). The current routing of wells is bottlenecking the separators thus requiring that production of some wells is choked.

Your task is to determine all possible routing combinations for the 5 wells and compute the total gas production rate and water production rate in both separators. Propose a routing strategy that allows honoring the separator constraints and provides a similar oil production through both separators.