A method for valuing architecture-based business transformation and measuring the value of solutions architecture
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Chapter Four. Measuring the Value of Business Transformation

This chapter describes several approaches for measuring the value of business transformation and compares them to Real Options Analysis (ROA). It describes adaptations to the standard ROA theory, to make it suitable for valuing business transformation. The theory is illustrated by an example. The chapter closes with an overview of criteria that can be used for selecting business transformation scenarios, when using ROA.

4.1 Role of Enterprise Architecture

4.1.1 Managerial Instrument

The purpose of enterprise architecture is to help management understand the impact and ramifications of business change. As such, enterprise architecture is one of the instruments that management has available to manage the organisation. Enterprise architecture differs in two ways from other instruments:

1. Enterprise architecture is aimed to manage change, instead of managing existing operations
2. Enterprise architecture is content-oriented, instead of being process or financial oriented.

The goal of enterprise architecture is to deliver a blueprint of the new situation. The purpose of this blueprint is to increase the understanding of the new situation and to define an optimal transformation approach. By increasing the understanding of the new situation, management can check whether the new situation aligns with
and complies with the business strategy and the transformation objectives. By having a clear understanding of the target, future situation, defining a transformation scenario to go from the AS-IS to the target situation becomes easier.

### 4.1.2 Enterprise Blueprint

There are several enterprise architecture methodologies, among which Zachman (1987) and TOGAF (2004) are best known. The purpose of these methodologies is to structure the work of an enterprise architect. These methodologies provide tools, concepts and process models to create an enterprise blueprint. The blueprint describes the strategic direction of the organization and the main organizational goals. It describes objectives, principles, scope, requirements and the structure of the desired situation. A blueprint generally includes business, information and IT architecture. The business architecture describes the services, processes and structure of the business. The information architecture defines and structures the information requirements, flow and ownership for the organization. The IT architecture describes the information systems and the infrastructure.

Blueprints may include the description of several solution alternatives. The purpose of defining solution alternatives is to find the solution that balances business value, cost and risk.

### 4.2 Transformation Scenarios

Architectural blueprints are implemented using transformation scenarios. For instance, the enterprise architecture may have three main solution options: (1) buy and configure a standard package; (2) build a new solution from scratch; or (3) reuse and expand an existing system. The options may vary considerably with regard to the value for the business, the consequences for business processes, investment levels, risk profiles and implementation options. A solution option with the related investment and implementation choices is called a transformation scenario. To assess the value of the architecture-based business transformation, we will assess the value of the associated transformation scenarios and compare these to the value of the null-scenario. The null scenario is a continuation of the status quo: no change. The difference in value between the transformation scenario and the null-scenario provides us with an understanding of the value of the business transformation scenario.
4.3 **Architecture Valuation Methods**
To understand the value of a business transformation scenario based on an architectural blueprint, we will consider some methods for assessing the value transformation scenarios.

4.3.1 **Net Present Value Analysis**
A simple and often used approach of assessing the value of the transformation scenario is the Net Present Value (NPV) method. NPV calculates the current value of future cash flows.

\[
NPV = \sum_{i=0}^{n} \frac{C_i}{(1 + r)^i}
\]  

where:
- \( n = \text{Number of years} \)
- \( C_i = \text{Cash flow in year } i \)
- \( r = \text{Annual interest rate} \)

See Table 4-1 for an illustration of the use of NPV. Based on architectural blueprint the transformation of an enterprise has two possible scenarios. Scenario 1 is a big-bang approach and scenario 2 is a phased approach. The scenarios have the following expected cash flows over the five years (with an interest rate of 5%): 

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Expected Cash flow in Year</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1. Big-bang</td>
<td>Revenue</td>
<td>€0</td>
</tr>
<tr>
<td></td>
<td>Cost</td>
<td>€8</td>
</tr>
<tr>
<td></td>
<td>Cash Flow</td>
<td>€-8</td>
</tr>
<tr>
<td>2. Phased</td>
<td>Revenue</td>
<td>€0</td>
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<td></td>
<td>Cost</td>
<td>€3</td>
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<td></td>
<td>Cash Flow</td>
<td>€-3</td>
</tr>
</tbody>
</table>

*Table 4-1. Example Net Present Value (M€)*

Calculating an NPV is simple and straightforward. The optimal selection criterion is simple: choose the scenario that provides the highest net present value, i.e. in this example the big-bang scenario. To calculate the value of the big-bang scenario, we compared the value of the scenario to the null-scenario. In this case, the null-
scenario is “doing nothing” (NPV zero). Compared to the null scenario the architecture implementation provides a value of € 6.3 million.

The main disadvantage is that the approach does not give insight into the risks of a scenario. The NPV is a “single point static estimate” (Saha, 2004).

4.3.2 Decision Tree Analysis

Introduction

Decision Tree Analysis (DTA) provides an extension to the NPV method by allowing the possibility of several different outcomes of a scenario. Each outcome has an estimated probability, which allows for a weighted NPV calculation across the outcomes. We extend the example of Table 4-1, using Decision Tree Analysis.

In this example, the DTA analysis takes into account the possibility of overruns in year 0 and in year 1. The probability of overrun in year 0 is estimated to be 80% and the probability of overrun in year 1 is estimated to be 50%. This results in four possible outcomes; no overrun (with a probability of 10%), overrun only in year 0 (40%), overrun only in year 1 (10%) and overrun in both year 0 and year 1. For each of these four possibilities the NPV is calculated and the value of the scenario is the probability-weighted average of these four NPV’s. See Table 4-2 for the resulting value of the Big-bang Scenario example.
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<tbody>
<tr>
<td>No Overrun</td>
<td>€ 6.3</td>
<td>10%</td>
<td>€ 6.3</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>20%</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>50%</td>
<td>€ 8.0</td>
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<tr>
<td>Overrun 1st year</td>
<td>€ 2.3</td>
<td>40%</td>
<td>€ 0.9</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>80%</td>
<td>€ 4.0</td>
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<td>10%</td>
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<tr>
<td>Overrun 2nd year</td>
<td>€ 7.5</td>
<td>10%</td>
<td>€ 0.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>20%</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>50%</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
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<td>10%</td>
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<tr>
<td>Overrun 1st and 2nd year</td>
<td>€ 1.5</td>
<td>40%</td>
<td>€ 0.6</td>
<td>€ 12.0</td>
<td>€ 12.0</td>
<td>€ 12.0</td>
<td>80%</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>50%</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>10%</td>
<td>€ 8.0</td>
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</table>

**Value of Scenario**: € 1.2

**Table 4-2. Decision tree calculations for Big Bang Scenario example (M€)**

Similarly, we can calculate the DTA value of the phased scenario.

**Figure 4-2. Decision Tree for Phased Scenario Example (M€)**

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</thead>
<tbody>
<tr>
<td>No Overrun</td>
<td>€ 6.3</td>
<td>64%</td>
<td>€ 4.1</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>20%</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>50%</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>€ 8.0</td>
<td>10%</td>
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<tr>
<td>Overrun 1st year</td>
<td>€ 0.3</td>
<td>16%</td>
<td>€ 0.1</td>
<td>€ 5.0</td>
<td>€ 5.0</td>
<td>€ 5.0</td>
<td>40%</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>€ 4.0</td>
<td>80%</td>
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<tr>
<td>Overrun 2nd year</td>
<td>€ 0.4</td>
<td>16%</td>
<td>€ 0.1</td>
<td>€ 6.0</td>
<td>€ 6.0</td>
<td>€ 6.0</td>
<td>30%</td>
<td>€ 5.0</td>
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<td>70%</td>
<td>€ 5.0</td>
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<tr>
<td>Overrun 1st and 2nd year</td>
<td>€ 1.0</td>
<td>4%</td>
<td>€ 0.0</td>
<td>€ 6.0</td>
<td>€ 6.0</td>
<td>€ 6.0</td>
<td>50%</td>
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<td>30%</td>
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</table>

**Value of Scenario**: € 1.5

**Table 4-3. Decision tree calculations for Phased Scenario example (M€)**

Based on this analysis, we can compare the expected outcome for both scenarios using NPV and Decision Tree Analysis.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Valuation Method</th>
<th>NPV</th>
<th>DTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Bang</td>
<td>NPV</td>
<td>€ 6.3</td>
<td>€ 1.2</td>
</tr>
<tr>
<td>Phased</td>
<td>DTA</td>
<td>€ 2.3</td>
<td>€ 1.5</td>
</tr>
</tbody>
</table>

**Table 4-4. Expected business value of Big-Bang and Phased Scenario**
Compared to the NPV approach, the scenarios value calculations are more extensive; they include a probability estimation of the possible outcomes. For the Big-Bang scenario, it is estimated that there is a probability of 80% on cost overrun from 8 to 12 million for the first year and a probability of 50% for the second year. Consequently, the value of the scenario decreases sharply from 6.3 to 1.2 million. The value of scenario 2 also decreases, but less sharply, because of better risk control.

Use of DTA
Decision Tree Analysis provides a more differentiated picture of the value of transformation scenarios and provides more insight for decision-making. The weak point in creating a decision tree analysis is the estimation of the various probabilities. Estimation of a probability is subjective and influences the resulting value considerably. This weakness can be overcome to some extent by using sensitivity analysis. Sensitivity analysis gives some insight into the consequences of choosing specific probability values. Using Decisions Tree Analysis has its advantages compared to the Net Present Value method, but the method is difficult to handle in practice because of the required assessment of probabilities.

In addition, the DTA approach describes only a limited number of discrete points (in the example above four points per scenario). This limited number of points may also prove insufficient to get a good understanding of the risks involved. Extending the number of points, to for instance 10 or 15, only exacerbates the problem of determining the associated risk for each of these points.

The selection criterion that can be applied to the scenario can be more diverse than with the Net Present Value approach. One may choose the highest NPV or one may provide, for instance, a risk-based approach to avoid negative consequences as much as possible. In the above example, one would choose the Big-Bang scenario, when using the criterion of maximum expected value, but one may choose the Phased scenario, to avoid the large negative probability of large cost in the first year.

4.4 Using Real Options to Valuate Enterprise Architecture

4.4.1 Real Option Analysis Compared with NPV and DTA
Net Present Value calculates the expected cash flow of a scenario, by identifying estimations for revenue and for cost and subtracting the cost from the revenue. The value of the scenario is determined by calculating the interest-adjusted sum of the
cash flows. Decision Tree Analysis uses essentially the same approach, but instead of calculating one cash flow value, DTA calculates several cash flow values and calculates the associated probabilities. The DTA scenario value is equal to the probability-weighted average of the individual cash flows.

NPV and DTA calculate single-point estimates for revenue and for cost and, by subtracting them, for the cash flow. A single-point estimate is an estimate of one specific value. NPV calculates one revenue estimate, one cost estimate and, consequently, one cash flow estimated. DTA uses basically the same approach, but the one single estimate is replaced by multiple single-point estimates, each with its own probability.

**Real Options Analysis**

With Real Option Analysis (ROA), the single point estimate is replaced by a continuous range of possibilities described in a Probability Distribution. Hence, the single-point revenue estimate is replaced by a revenue probability distribution; the single-point cost estimate is replaced by a cost probability distribution and the cash flow probability distribution is calculated by merging the revenue and cost distributions in one overall distribution.

Because of the substitution of a single-point estimate by a probability distribution, Real Options Analysis accomplishes the same goal as DTA – which is incorporating possibility of multiple outcomes with associated probabilities. Compared to DTA, ROA has the following advantages:

1. ROA delivers a continuous spectrum of possible outcomes (instead of a limited number of discrete outcomes).

2. The probability of a specific outcome can be derived from the probability distribution (this removes a weak point of DTA; it is no longer necessary to estimate the discrete individual outcomes).

3. Since the Real Options Analysis provides more information than the NPV or DTA approach, additional criteria for Enterprise Architecture scenario selection become eligible.

Because of these advantages, the use of ROA provides a broader insight in to the risks, value and options of Enterprise Architecture. It allows, consequently, a more precise valuation of the options for management when implementing enterprise architecture.
Real Options Analysis is a field of research, which is derived from the financial options analysis. Therefore, we will first look at financial options analysis.

### 4.4.2 Financial Options Analysis

Option analysis calculates the value of financial options, based on the current value and volatility of the option. A definition: “An [financial] option is a right – not an obligation – of its owner to buy or sell the underlying asset at the predetermined prize on or before a predetermined date.” (Kodukula, et al., 2006).

#### The Black-Scholes Equation

Option analysis got an important impulse in the 1970s, when Fischer Black, Myron Scholes and Robert Merton published two articles on option pricing. (Black, et al., 1973; Merton, 1973). These articles constitute a breakthrough in financial option pricing. Their solution became known as the Black-Scholes equation. This equation calculates the future value of a financial (European*) call option based upon the current price and the volatility of the price. The formula is:

\[
C = N(d_1)S_0 - N(d_2)Ae^{-rT}
\]

where:

- **C** = Future value of the Call option
- **S_0** = Current value of the asset
- **A** = Strike price
- **r** = Interest rate
- **T** = Time to expiration (in years)
- 
  \[
  d_1 = \frac{\ln(S_0/A) + T(r + 0.5\sigma^2)}{\sigma\sqrt{T}}
  \]
- 
  \[
  d_2 = d_1 - \sigma\sqrt{T}
  \]
- **\sigma** = Volatility of the asset — Standard deviation over the period of a year
- **N(x)** = Value of the cumulative standard normal distribution

The most interesting point is that no future value needs to be estimated. The only actual input is the Current Value and the Standard Deviation of the asset. Although the approach was initially developed only for financial instruments, it was suggested by Myers (1977) that the approach would also be useful for non-financial, real assets.

*An European option is an option that can only be exercised at the end of its life, this in contrast to an American option, which can be exercised anytime during its life.*
4.4.3  Real Option Analysis

Real Options and Enterprise Architecture
“A real option is the right – not an obligation – to take action […] on an underlying non-financial asset” (Kodukula, et al., 2006). Applying real options analysis for enterprise architecture value assessment is interesting for several reasons. Pallab Saha writes about this: “[We view] enterprise architecture development as largely a process of decision making under uncertainty and incomplete knowledge. [. . . We] assume that portion of the value of enterprise architecture initiative is in the form of embedded options (real options), which provide architects with valuable flexibility to change plans, as uncertainties are resolved over time.” (Saha, 2004).

In other words, a real option is an opportunity to invest now for gaining future benefits. Architecture-based business transformation provides a framework for investment to improve business performance and gain future business benefits. Both the investment and the outcomes are subject to uncertainty and, consequently, option analysis is a viable approach of valuing the investments in enterprise architecture.

Adapting the Financial Options Approach
The Black-Scholes equation deals with one source of uncertainty, i.e. the future price of the asset. An enterprise architecture based transformation scenario has two sources of uncertainty; uncertainty about the required investments and uncertainty of the future revenue. The Black-Scholes approach will need to be adapted to include both sources of uncertainty.

Methods of Calculating Real Options
There are several calculation methods for calculating real options, among which using the Black-Scholes equation. The choice for using a specific calculation method depends on the information that is available and the validity of the method for a given application. An overview of calculation methods (see also Kodukula (2006)):
These methods deliver essentially the same results, but some methods are more suitable in certain situations than others. Considering the type of analysis that we need to do and the type of the available information, the best approach for us to calculate the value of enterprise architecture scenarios is using integrals in combination with Probability Density Functions, because this approach allows for easy manipulation of Probability Density Functions both in analytical and numerical form, using multiple sources of uncertainty. We also use Black-Scholes when applicable, in the case of one source of uncertainty.

### 4.4.4 Probability Distributions

**Probability Density Functions**

The Real Options Approach calculates the future value of an underlying asset using a probability distribution. The possibility that a specific future event happens does not have to be estimated by hand – as is the case with Decision Tree Analysis – but can be derived from the probability distribution.

Probability distributions are mathematically represented by a Probability Density Function or PDF. A PDF has two main characteristics:

\[
p(x) \geq 0 \quad \forall \ x \in \mathcal{R} \quad \quad (4-3)
\]

\[
\int_{-\infty}^{\infty} p(x) \, dx = 1 \quad \quad (4-4)
\]

Equation (4-3) denotes the fact that a probability cannot be negative, while (4-4) means that the cumulative probability of an experiment described by a probability density function must be 100%.
4.4.5 Calculating the Cash Flow Probability Density Function

The Probability Density Function for Revenue

The revenue structure of organizations consists generally of a large number of small identical, independent transactions, where each transaction adds a percentage to the revenue. For example, if an organization sells books, each book will have a revenue percentage, which adds to the overall revenue. This is true for many organizations, whether they sell books, computers, insurance contracts, furniture, software, learning courses, etc. The total revenue of many organizations is build-up of small revenues of numerous small individual transactions.

Because of this revenue structure, it is possible to define the shape of the probability density functions of these organizations. Statisticians have demonstrated that the probability distribution of a sum, consisting of many small amounts, will be normally distributed. This proof is called the Central Limit Theorem (Weisstein, 2009). Based on this theorem we assume that the revenue for these types of organizations is normally distributed*.

Normal Distribution

The normal distribution is characterized by two parameters: the mean and the standard deviation. The probability density function for the Normal distribution is:

\[
p(x) = \frac{1}{\sigma \sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{4-5}
\]

where:

* \( x = \text{Value} \)
* \( \mu = \text{Mean} \)
* \( \sigma = \text{Standard deviation} \)

See Figure 4-3. Probability density function of an example Normal Distribution, with an expected value (\( \mu \) or the mean) of 4 and a standard deviation (\( \sigma \)) of 1.

---

* This approach may not be valid for organizations that make profit or create budgets in some other way. Especially governmental organizations and companies who sell a small number of large products (such as shipyards) may need another approach.
Probability functions either are graphically presented using the density function or by the cumulative probability function. The cumulative probability function is defined as:

\[ cn(u) = \int_{-\infty}^{u} p(x) \, dx \quad \text{(4-6)} \]

Where \( p(x) \) is the Probability Density Function.

Associated with a probability density function are three values, the Expected Value, the Mode and the Median. The Expected Value is the average outcome considering all experiments who obey to this distribution function. Is calculated by:
Where \( p(x) \) is the probability density function. The **Mode** is the most often occurring or the *most likely* outcome. It is calculated by solving the equation

\[
p'(x) = 0
\]  
(4-8)

Where \( p'(x) \) is the derivate \( \frac{d}{dx} p(x) \) of the probability density function. The **Median** is the value where the cumulative probability is 50%. It is calculated by solving the equation

\[
cn(x) = 0.5
\]  
(4-9)

Where \( cn(x) \) is the cumulative probability function.

For the normal distribution, the expected value, the mode and the median are the same and equal to \( \mu \) (in this example 4).

**Probability Density Function for Cost**

The *cost* of a project is the sum of the cost of the various activities that take place within a project. However, a main difference between the revenue and cost probability distributions is that the activities of a transformation program are *not independent* from each other; there are numerous interdependencys. Researchers in the field find that, consequently, the individual activities have a *multiplicative* (instead of an *additive*) effect on each other. Marasco (2004) states: “One could argue that all variance in the outcomes of software development projects is due to many small but multiplicative [...] effects.” The multiplicative effect leads to a type of probability distribution called the lognormal distribution. The *Multiplicative Central Limit Theorem* states that random factors that have multiplicative interactions, obey the lognormal distribution (Limpert, et al., 2001). Marasco writes: “Mathematically, the [probability] distribution [function of software development projects] results from phenomena that statistically obey the multiplicative central limit theorem.”

The probability density function of the lognormal distribution is:
\[ cp(x) = \begin{cases} 
\frac{e^{-(\ln(x-\lambda) - \mu)^2/(2\sigma^2)}}{(x - \lambda)\sigma\sqrt{2\pi}} & x > \lambda \\
0 & x \leq \lambda 
\end{cases} \] (4-10)

where:

- \( x \) = Cost of the Project
- \( \mu \) = Location parameter
- \( \sigma \) = Scale parameter
- \( \lambda \) = Threshold parameter

An example lognormal distribution, with \( \mu = 0.85, \sigma = 0.6 \) and \( \lambda = 0 \) is shown below:

[Figure 4-5. Probability density function of an example lognormal distribution]

The horizontal axis denotes the cost, while the vertical axis denotes the probability that this cost occurs.

[Figure 4-6. Cumulative probability function of an example lognormal distribution]
There are several differences between the normal distribution and the lognormal distribution. The lognormal distribution is not symmetric, but has a tail to the right. This tail represents a small probability of high cost overruns. Because of this, the expected value, the median and the mode all differ from each other. The value of the most likely value (the mode), the expected value and the median are respectively:

\[ e^{\mu - \sigma^2} + \lambda \quad \text{Most likely value – Mode (} =1.6) \]  
\[ e^{\mu + \frac{\sigma^2}{2}} + \lambda \quad \text{Expected Value (} =2.8) \]  
\[ e^{\mu} + \lambda \quad \text{Median (} =2.3) \]

We find that for the lognormal distribution the mode is an easy to understand measure, denoting the most likely outcome. We find too, that the expected value is difficult to calculate without statistical analysis.

**Convolution of Probability Density Functions**

The cash flow of a business transformation effort is equal to the revenue minus the cost. To calculate the cash flow, we will need to merge the revenue and cost distributions into one combined cash flow distribution. Probability distribution functions can be merged by a mathematical operation called convolution. Convolution takes two probability density functions as input, and delivers a third PDF, which is the combination of the two input functions.

The convolution of two functions is given by:

\[ h(u) = f \circ g = \int_{-\infty}^{\infty} f(x)g(u-x)dx \]  

where:

\[ h(u) = f \circ g = \text{The convoluted Probability Density Function} \]  
\[ f(x) \text{ and } g(x) = \text{Input Probability Density Functions} \]

Convolution has the following properties (Weisstein, 2007):

\[ f \circ g = g \circ f \quad \text{Commutativity} \]
The convolution of two normal distributions with parameters \((\mu_1, \sigma_1)\) and \((\mu_2, \sigma_2)\), provides again a normal distribution with parameters \(\mu_c\) and \(\sigma_c\) (Weisstein, 2007), where

\[
\mu_c = \mu_1 + \mu_2 \tag{4-18}
\]

and

\[
\sigma_c = \sqrt{\sigma_1^2 + \sigma_2^2} \tag{4-19}
\]

In the general case, the function centroids of the convoluted functions can be added together (Weisstein, 2007).

\[
\langle x(f \circ g) \rangle = \langle xf \rangle + \langle xg \rangle \tag{4-20}
\]

Where the function centroid \(\langle xf \rangle\) is defined as:

\[
\langle xf \rangle = \frac{\int xf(x)dx}{\int f(x)dx} \tag{4-21}
\]

Since \(\int_{-\infty}^{\infty} f(x)dx = 1\) for a probability density function (see(4-4)) and the expected value for PDF is equal to \(EV(f) = \int_{-\infty}^{\infty} xf(x)dx\), we can derive from this:

\[
EV(f \circ g) = EV(f) + EV(g) \tag{4-22}
\]

Where \(EV(x)\) is the expected value of probability density function \(x\). In other words, the expected value of a convoluted probability density function is equal to the sum of the expected values of the input functions.

**Cash Flow Probability Distribution Function**

Merging the revenue and the cost probability distribution functions will give us the probability distribution of the cash flow. First, we define cost as a negative cash flow. From (4-10) we can define the cost probability function with negative \(x\):

\[
(f \circ g) \circ h = f \circ (g \circ h) - \text{Associativity} \tag{4-16}
\]

\[
f \circ (g + h) = f \circ g + f \circ h - \text{Distributivity} \tag{4-17}
\]
The cash flow probability density function becomes – from (4-5), (4-14) and (4-23):

\[ c(x) = cp(-x) \quad (4-23) \]

The cash flow probability density function becomes – from (4-5), (4-14) and (4-23):

\[ cf(u) = \int_{-\infty}^{\infty} p(x) \cdot c(u - x) \, dx \quad (4-24) \]

The expression (4-24) describes the convolution of the revenue and cost probability density functions, and this is equal to the cash flow function. The convolution operator is not dependent on the type of distribution that is described by the input PDF's, i.e., it works both for normal, lognormal or any other probability distribution. In our case, \( p(x) \) has a normal distribution and \( c(x) \) has a lognormal distribution. Consequently, \( cf(u) \) describes the convolution of a normal and the lognormal probability density function. This result cannot be expressed analytically, because the convolution of a normal and a lognormal distribution cannot be expressed analytically, but the function \( cf(u) \) can be calculated using numerical methods. For the previous example, the resulting probability density function of the cash flow is:

\[ \text{Figure 4-7. Example Probability density function of the cost (left), revenue (right) and cash flow (middle).} \]

This figure shows \( cf(x) \) (yellow, middle), which is the convolution of

1. The revenue distribution (blue, right); a normal distribution with the expected value \( \mu \) is 4 and the standard deviation \( \sigma \) is 1, and
2. The cost distribution (red, left); a negative lognormal distribution with \( \mu = 0.85, \sigma = 0.6 \) and \( \lambda = 0 \).

\[ \text{Figure 4-7. Example Probability density function of the cost (left), revenue (right) and cash flow (middle).} \]
The probability distribution function $cf(x)$ describes the combined revenue/cost probability for the project. From this probability function, we can derive the expected value of the project, which is:

$$\int_{-\infty}^{\infty} x \cdot cf(x) \, dx = 1.22 \quad (4-25)$$

This value is equal to the expected value of the revenue (4), minus the expected value of the cost (2.8). We can also derive the most likely value of this distribution. The most likely value is calculated by solving the equation:

$$cf'(x) = 0 \quad (4-26)$$

Were $cf'(x)$ is the derivate of $cf(x)$ to $x$. This value is equal to 1.9.

### 4.5 Selecting a Preferred Scenario

#### 4.5.1 Potential Selection Criteria

When using the Net Present Value or the Decision Tree Analysis to analyze the value of scenarios, the evident selection criterion is the maximization of value, i.e. the scenario with the highest expected value will be chosen. Because of the fact that Real Options Analysis provides more information than the Net Present Value or Decision Tree Analysis approach, other selection criteria for business transformation scenarios become possible. An overview of the possible scenario selection criteria when using ROA:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Description</th>
<th>Rationale</th>
<th>Relation to PDF</th>
<th>Decision criterion</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximization of likely value (most often occurring) value</td>
<td>Use of most likely value is easy to explain and to understand.</td>
<td>The most likely value is the value where $cf'(x) = 0$.</td>
<td>The scenario with the highest likely value will be chosen.</td>
<td>The scenario with the highest likely value may not have the highest expected value.</td>
<td></td>
</tr>
</tbody>
</table>
### Table 4-6. Selection criteria for business transformation scenarios

As is demonstrated in Table 4-6, the available options to assess the value for enterprise architecture business transformation scenarios are more varied when using the Real Options Approach, compared to the Net Present Value or the Decision Tree Analysis. In the following paragraphs, we will describe these transformation scenario selection criteria in more detail.

### 4.5.2 Maximization of Expected and Likely Value

Maximization of value is, clearly, the main objective of starting a business transformation program. Obviously, maximization of *Expected Value* is therefore a meaningful strategy to pursue. However, determining the expected value of a business transformation program is not straightforward. The analysis described in the paragraph *Relationship of the Probability Density Function to the Planned Cost (page 55)* suggests that it is difficult for managers to calculate the *Expected Cost* of a business transformation program and use the *Most Likely Cost* instead. Consequently, managers tend to calculate with the *Likely Value* instead of the *Expected Value* of a transformation program. When using Real Options Analysis, both the *Most Likely* and the *Expected Cost* of a business transformation program are calculated and this gives a better understanding of the results of the transformation.

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Description</th>
<th>Rationale</th>
<th>Relation to PDF</th>
<th>Decision criterion</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximization of expected value</td>
<td>Maximization of the expected (average) value</td>
<td>Expected value gives a more realistic picture than highest likely value.</td>
<td>The expected value is calculated by $\int_{-\infty}^{\infty} x \cdot f(x) dx$.</td>
<td>The scenario with the highest expected value will be chosen.</td>
<td>The scenario with the highest expected value, may not be the scenario with the lowest risk.</td>
</tr>
<tr>
<td>Minimization of loss</td>
<td>Decrease the risk of negative results</td>
<td>To minimize transformation risk.</td>
<td>The probability for a result below a specific threshold risk $T$ is given by $\int_{-\infty}^{T} f(x) dx$.</td>
<td>The scenario that minimizes the probability of a result below a specific threshold will be chosen.</td>
<td>This scenario may not provide the maximum business value.</td>
</tr>
<tr>
<td>Maximization of option value</td>
<td>Optimization of the option value.</td>
<td>To incorporate the value of future uncertainty.</td>
<td>The option value is given by $\int_{-\infty}^{T} x \cdot f(x) dx$.</td>
<td>The scenario with the highest option value will be chosen.</td>
<td>Option value incorporates the value of the uncertainty in future cash flows.</td>
</tr>
</tbody>
</table>
4.5.3 Minimization of Loss

Minimization of risk means that the probability of negative outcomes is minimized. For instance, if management decides that the minimum revenue of a business transformation project should be €1 million, we can calculate the probability that the revenue is below this threshold value. In our example, the probability of having an outcome that is less than one million is equal to \( \int_{-\infty}^{1} cf(x) \, dx \). See the figure below for the cumulative probability function of \( cf(x) \).

![Cumulative probability function of cf(x)](image)

From Figure 4-8 can be derived that the probability that the outcome is less than 1 is 38.5%. Hence, although the expected value of the business transformation in this example could be acceptable (which is 1.22 – see (4-25)), the probability of 38.5% of having an outcome less than €1, may lead to a decision not to execute this business transformation scenario.

4.5.4 Maximization of Option Value

Financial value of Management Flexibility

During the execution of an enterprise architecture implementation program, the knowledge of the program management – about the expected outcomes, the feasibility of the results, the costs, the expected revenues, etc. – increases. When running the program, intermediate results become available and these results will be used to improve the probability of a positive outcome of the program. For instance, management may abandon projects, start new ones, increase or decrease the scope of projects, outsource the development of projects to a third party, etc.
This flexibility has its own financial value, because it allows management to use opportunities, which are not apparent at the start of the program. This additional value created by the flexibility of the management during the execution of the implementation of the enterprise architecture is not calculated by either NPV or DTA, but it can be calculated when using ROA. It is called the *Option Value*. The option value describes financially the freedom of choice that management has during the implementation of an Enterprise Architecture implementation program.

Kodukula and Papudesu state: “Whereas [DTA] is a deterministic model, ROA accounts for the change in the underlying asset value due to uncertainty over the life of a project. [...] There can be a range of possible outcomes of the life of a project, with the uncertainty increasing as a function of time. As a result, the range of the asset value would take the shape of a curve, called the ‘cone of uncertainty’. ROA accounts for this whole range of uncertainty using stochastic processes and calculates a ‘composite’ option value for a project, considering only those outcomes that are favorable [...] and ignoring those that are not. [...] This assumes that the decision-makers will always take the value-maximizing decision at each point in the project lifecycle.” (Kodukula, et al., 2006 pp. 56-57). The ‘cone of uncertainty’ that Kodukula describes is the cash flow probability distribution, which is described by the probability density function of Figure 4-7.

**Calculation of the Option Value**

Mathematically, the option value is determined by calculating the *partial, positive expected value* of the probability density function. In the example of § 4.4.5, this value becomes:

\[
\int_{0}^{\infty} x \cdot cf(x)dx = 1.59
\]  

(4-27)

Note that this Option Value is larger than the Expected Value of 1.22 (see ( 4-25 )). The difference between the option value and the expected value illustrates the freedom and flexibility that management has to steer the investment in the desired direction. Kodukula and Papudesu comment on this: “Real Options Analysis is most valuable when [...] management has significant flexibility to change the course of the project in a favorable direction and is willing to exercise the options.” In our example, the flexibility that management has to improve the outcome of the investment is equal to 1.59 − 1.22 = 0.37.
4.6 **Applicability of this ROA model**

In the approach and examples of this chapter, we have chosen a normal distribution for describing the benefits and a lognormal distribution for the costs. These choices for specific distribution types, depends upon the underlying characteristics of the business, which determine the probabilities distributions for revenue and cost.

However, the ROA calculation model itself is independent of the underlying distribution types. The model is applicable in any situation, as long as the revenue and costs can be described in terms of probability density functions. This is because the convolution expression (4-24) is valid for any probability density function, regardless of type. Thus, when the method is applied to calculate the value of a business transformation initiative, any suitable continuous probability density function can be selected to describe the revenue and cost distributions.

Consequently, the approach described in this chapter can be characterized as a general ROA calculation method for determining the financial value of architecture-based business transformation and it is applicable for all circumstances where the benefits and the costs of an investment can be described in terms of probability density functions.