THE QUANTITATIVE EVALUATION OF RISKS AS A KEY SUCCESS FACTOR FOR INVESTMENT PROJECTS

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ABSTRACT

When estimating a new opportunity for an investment project, it is not sufficient to estimate only incoming and outgoing cash flows, the Project Manager or the Finance Manager must also find the way to tackle the associated risks. These risks can be related to any aspect of the project and have an impact on the costs (interest rate fluctuations, labor costs, environmental and social factors, ...) on the timing (performance, technology progress, ...) and on the revenues (macro and microeconomic markets).

The key to managing the risks is to identify them in advance and quantify their impact on the project so that an appropriate mitigation plan can be developed. This quantitative approach is based on the Monte Carlo method, by carrying out a stochastic analysis to calculate all possible future scenarios, each with its probability of occurrence. The probability of success of the investment is obtained through this probabilistic approach. In fact, it is possible to calculate the probability that the Net Present Value (NPV) is positive, to identify the most likely Return on Investment (ROI) value or the Value at Risk (VaR) of the investment. This information enables managers to make decisions with greater awareness and confidence in situations with uncertainty.

The method presented in the paper illustrates in a case study the evaluation of an investment for an offshore wind farm and demonstrates how a probabilistic forecast of cash flow is more realistic and complete than traditional single scenario analyzes.

Purpose of this paper

Large corporations in all industries are involved in a continuous stream of investments for internal growth, acquisitions, R&D and reorganization.

All kinds of investment projects entail risks and uncertainties that lead to underperformance, missed opportunities and excessive risk exposure, especially in the infrastructures, utilities & transportation sectors. However, most of the time these risks and uncertainties are not taken into consideration in the project evaluation, due to a lack of knowledge or suitable tools.

The purpose of this paper is to present a well proven approach to integrate and evaluate risks variables in an investment's profitability analysis. The methodology presented is either structured and comprehensive, because it gives the possibility to consider both financial and timing risks variables to calculate a complete set of financial parameters such as CFaR, VaR, DCF, probabilistic NPV, IRR, ROI. With such approach, any organisation should be able to perform a quantitative risk evaluation and therefore increases the level and quality of information provided to the decision makers.
The following figure represents a typical and simplified process for an investment valuation. The information flows between the Strategy & Investment Committee and the Project Team. At any stage of the process, there are various possible risks (or uncertainties) that arise (highlighted in red):

![Figure 1 Investment Evaluation Process](image)

The risks focus is changing along the investment lifecycle, but the objective of the analysis is to anticipate them as soon as possible. Actually, the capacity of an organization to manage its risks is directly related to the anticipation of the identification and the implementation of the control actions. The earlier the risks are treated, the lowest will be the cost of their treatment. This is the reason why the risk-based analysis of an investment should be initiated at the earliest stages of opportunities screening.

The following paragraphs are presenting the methodology and benefits of a risk-based investment evaluation, illustrated by a case study. This case study is providing the economic evaluation for the planning, construction, operation and decommissioning of an offshore wind farm having the following characteristics:

- 10 km offshore field, 15 m depth
- 60 ground based turbines, 5 MW each
- 30+ years plan (including decommissioning)
- 400 Mln$ initial investment

The case study has been developed using Riskturn [1], a sophisticated yet user friendly solution to perform risk-based investment evaluations.

**Design/methodology/approach**

The process is divided in five steps: four steps to define the assumptions and one step for the results analysis. This process is illustrated below, all the steps are common to any investment valuation, except for the step “Risk” that is dedicated to the definition of uncertainties variables:
Between the Input and the Results, there is the Monte Carlo simulation. The purpose of the Monte Carlo simulation is to combine various uncertainties variables (defined in the “Risk” step) in a high number of scenarios, in order to have a complete picture of future investment outcomes.

The Monte Carlo simulation is a well proven mathematical method of automated calculations [2]:
1. Random values are selected in each variable distribution.
2. The results of the model are calculated based on these random values and recorded.
3. The process is iteratively repeated a high number of times (10,000 times in the case study).
4. All results are represented on a statistical basis (values and associated frequencies).

A typical approach for a risk based investment evaluation starts with the model preparation, the results interpretation and ultimately the evaluation of possible improvements, through cost versus benefits analysis.

Model Preparation

Definition of the investment project

The first step is the definition of the main project characteristics, with all indications that will guarantee the traceability of the information (categorization of the projects, versioning of the different scenarios,…). For a long time, the stand-alone Excel spreadsheets have been considered as the only support for cash flow planning, but now cloud or server based software are becoming the standard for investment project evaluation, in order to facilitate data storage, perform benchmark analyses, and monitor any deviation from budget.

Timeline

When considering the economic value of a project, it is mandatory to integrate all project phases, from the earliest stages of scouting to the final decommissioning or sale of the asset. A typical project phasing can be concept, build, operate, and close.

Timeline of the investment is a key information for cash flow planning, since the future cash flows are discounted, any delay or anticipation of a cash flow will have an impact on the Net Present Value (NPV) of the investment. Most cash flow analyses do not consider possible delays; besides it is quite common to face delays in project execution. In this analysis, the potential delays or anticipation for each phase are taken into consideration as uncertainty variables on the duration of each phase. Hence, the phases are linked with a finish to start logic, in order to replicate any time variation on the entire plan. With such time variation capabilities, the cash flow model becomes more realistic, compared to the standard time-frozen models.

Cash Flow

The construction of the cash flow table must allow the maximum level of detail in the items. Often cash flow model suffers from a lack of detail and content in the inputs, because it is difficult to consolidate
on a single spreadsheet the information coming from different departments/disciplines. With a cloud software, any department/discipline can bring its contribution on a common cash flow model. Model construction and updates are considerably accelerated. The use of a shared solution brings other advantages in terms of model consistency and validation of the assumptions.

The previous paragraph emphasises the importance of the time variation in a discounted cash flow evaluation. This is the reason why, in this model, any possible risk on phases durations is modelled. Nonetheless, the impact of a phase duration must be reflected on the running costs (like daily rates, overheads, salaries, rentals…), in order to reflect the logic: longer duration means additional costs (during construction) or revenues (during operations). In Riskturn software, this critical aspect is provided by a “Time Base” function assigned to each cash flow item, that can be activated or not, according to the type of cash flow item. As an example, in the case study, engineering costs are time dependent (or Time Based), while number of piles for foundations are not time dependent.

The Effect of Time dependency is illustrated on the graph below, presenting the successive calculations applied on a cash flow item in the model:

In this illustration, a first cost item (black curve) is defined as a baseline. On this baseline, a risk is applied (red curve). Then, when the duration of the phase increases from 7 to 10, the same cost is redistributed over the extended duration, with the same overall amount (orange curve), if Non Time Based. However, if the cost is indicated Time Based, then it is spread over the extended duration, also proportionally increased (blue curve). At any moment, the initial distribution of the cost is respected in its proportions. Such feature guarantees the highest level of realism in the model.

Risks

The innovative part of the model is definitely the possibility to add any variable impacting the cash flow model. These variables are named “Risks”, but must be understood as uncertainties, either threats or opportunities for the investment project. Each uncertainty is characterized by a probability of occurrence and an impact variable either on financials or on time.

Practically, each risk is integrated in the model choosing the variable distribution to represent its impact with the best realism. Variables distributions can be continuous probability distributions, where there is a range of continuous outcomes values, or discrete distributions, where there are a limited number of discontinuous possible outcomes. Quantitative estimations are based on the most relevant information available such as lessons learned, databases, and expertise [3]. The following diagram illustrates the logical flow to select the most relevant variable:
The Sample or Percentile Distributions are based on statistical records. When no statistical records are available, the other distributions are called “simple” distributions, because they are built on 1 to 3 values (minimum, most likely, maximum), based on expertise and experience.

Once a risk variable has been defined, it is then assigned to one or more cash flow items (Financial risk) or one or more phase duration (Timing risk).

Typically risk-based cashflow model have around 40 risks variables (obviously it can vary a lot according to the project complexity). It is impossible to reflect all these uncertainties with a traditional “what if analyses”, and here comes the Monte Carlo simulation. The model is automatically recalculated 10000 times and a complete set of financial criteria are reported on a probabilistic basis.

**Results**

The probabilistic representation of the investment economics contains high value information for the decision makers, in terms of probability to reach a given target, in terms of outcomes variability, in terms of value at risk, in terms of confidence and in terms of sensitivity.

**NPV**

The Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. A positive net present value indicates that the projected earnings generated by a project or investment exceeds the anticipated costs.
Generally, an investment with a positive NPV will be a profitable one and one with a negative NPV will result in a net loss. This concept is the basis for the Net Present Value rule, which dictates that the only investments that should be made are those with positive NPV values.

Following the Monte Carlo simulation, 2 NPV graphs are available, the Relative Frequency diagram (on the top) and the Cumulative Frequency diagram of the same statistical distribution (on the bottom):

The passage from the Relative to the Cumulative distribution is given by cumulating the frequencies starting from the maximum objective (highest NPV value) to the minimum. This decreasing curve goes from P100 to P0, and provides the level of confidence on several NPV possible outcomes. For example, considering an NPV target of 30 Mln$, it’s rather improbable to reach that target (35% chance). However, it’s highly probable to have a positive NPV (77% chance to have a NPV=0).

Thanks to the risk based approach it is possible to measure the lowest negative values of the NPV distribution that represent the Value at Risk (VaR) of the investment. An organisation shall consider whether this VaR is acceptable, considering other investments in its portfolio. Considering a P95, the VaR is a loss of -38Mln$ in the case study.
Cumulative Discounted Cash Flow

Another result is the cumulative distribution represents the Discounted Cash Flows (DCF) over time, as illustrated below:

The values at the last period of the cumulative DCF curves coincide with the NPV of the project. This Cash Flow at Risk (CFaR) shows the effect of Timing Risk on the overall duration of the project lifecycle [4]. In this case the risk of delays in the Concept and Build phases are impacting significantly the NPV value, due to the Time Based (or time dependent) cost items. The longer is the phase duration, the higher are the costs, the lower is the final NPV of the project.

Many other financial criteria are available on a probabilistic basis: Return on Investment (ROI), The Internal Rate of Return (IRR), the Payback Time, the financing requirements, the time distribution of each single phase (to determine potential delays on phases end dates), and the probabilistic distribution of cost categories, such as CAPEX (Capital Expenditures) and OPEX (Operational Expenditures).

All these financial indicators bring significative information for the decision maker, when presented on a probabilistic basis, as listed below:

<table>
<thead>
<tr>
<th>Financial Criteria</th>
<th>Added value of the probabilistic approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Present Value (NPV)</td>
<td>✓ Probability to have a profitable investment</td>
</tr>
<tr>
<td>Discounted Cash Flow (DCF) over Time</td>
<td>✓ Calculation of the Value at Risk</td>
</tr>
<tr>
<td></td>
<td>✓ Measure of the impact of delays on the profitability</td>
</tr>
<tr>
<td></td>
<td>✓ Cash Flow at Risk (CFaR)</td>
</tr>
<tr>
<td>Internal Rate of Return (IRR)</td>
<td>✓ Probability to have an IRR that is greater than the discount rate</td>
</tr>
<tr>
<td></td>
<td>✓ Probability to reach a target IRR</td>
</tr>
<tr>
<td>Return on Investment (ROI)</td>
<td>✓ Benchmark of different ROI variations between different investments</td>
</tr>
<tr>
<td></td>
<td>✓ Probability to reach the average ROI of the investments portfolio</td>
</tr>
<tr>
<td>Payback Time</td>
<td>✓ Probability to recover the cost of the investment after a given period</td>
</tr>
<tr>
<td>Financing Requirements</td>
<td>✓ Amount and period of the lowest cash position during the investment lifecycle</td>
</tr>
<tr>
<td></td>
<td>✓ Definition of financing needs at different levels of confidence</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Financial Criteria</th>
<th>Added value of the probabilistic approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Distribution</td>
<td>✓ Probability to finish a phase at a given date (e.g., for incentives/penalties contractual schemes)</td>
</tr>
<tr>
<td></td>
<td>✓ Calculation of the overall time risk exposure at a given level of confidence</td>
</tr>
<tr>
<td>Cost Distribution</td>
<td>✓ Probability to overcome a given capacity for CAPEX</td>
</tr>
<tr>
<td></td>
<td>✓ Calculation of risk based contingencies for the investment at a given level of confidence</td>
</tr>
<tr>
<td></td>
<td>✓ Probability to reach a target of Operating Income</td>
</tr>
</tbody>
</table>

Table 1 Added Value of the Probabilistic Approach

Sensitivity Analysis

An ultimate indicator for investment decision making is the sensitivity analysis. This analysis is the study of how the uncertainty in the model output can be apportioned to the different risks in input.

Such Sensitivity graph is useful to understand which risks (both Financial and Timing) have the greatest impact on the NPV, thus what are the risk variables you need to manage to improve your project profitability.

The calculation of the correlation factor is based on the correlation of Pearson's product-momentum among NPV and each single risks’ impact, over all iterations performed during the Monte Carlo simulation. Correlation at 30% is considered weak, at 50% moderate, over 70% strong.

![Figure 8 Sensitivity Diagram](image-url)

In the case study, the “Long term wind regularity” is the main risk factor (a Financial risk in the model), followed by the “Reduction in the Feed In Tariff (FIT)” (Financial risk) and “Insufficient ground foundations” (Timing Risk).

The Sensitivity analysis is a very useful indicator, however only a Monte Carlo simulation can provide it.

Costs versus Benefits Analysis

Considering the above Sensitivity analysis, among the three main risk factors, two are considered exogenous (“Long term wind regularity” and “Reduction in the Feed In Tariff”), with a limited capability to manage them, and one endogenous (“Insufficient ground foundations”), with greater capability to manage it. Therefore, it has been decided to perform a cost versus benefits analysis, where the possibility to perform additional ground investigations (the cost) is combined with the reduction of the associated risk (the benefits). The objective is to measure how these new inputs are affecting positively or negatively the overall investment project. It has been considered that an additional ground investigation would cost 1 Mln$, and at the same time it would reduce the probability of occurrence of the risk “Insufficient ground foundations” from 50 to 10%.
A new scenario (called “With ground investigation”) is created making a copy of the base case and changing only the parameters of that single risk. Then a new Monte Carlo simulation is run and the results of the two scenarios can be compared on any financial indicator, always on a probabilistic basis. The following figure shows the NPV Cumulative distributions of the two scenarios, overlaid on a single graph:

![Figure 9 Scenario Comparison](image)

The new estimates with additional ground investigation show that profitability of the investment has become nearly certain (88% probability). It’s very likely (70% probability) to obtain a NPV between 10 and 60 Mln $, with a roughly even chance (50% probability) to reach the NPV target of 30 Mln $.

This case study demonstrated that the benefits of the additional ground investigations are exceeding their costs, at nearly any level of confidence. Therefore, it is reasonable to recommend this action to increase the probability to have a profitable investment.

**Findings and value**

In addition to the single investment initiative evaluation, the risk based approach is also highly valuable when consolidated at a portfolio level. Actually, the probabilistic approach allows any organization to determine its Efficient Frontier among different development strategies. The following figure shows the different level of information provided by the Deterministic and the Probabilistic approaches for project portfolio management:
The Probabilistic approach is adding a second dimension in the portfolio management, that is the risk indicator for each portfolio scenario. This risk dimension is based on the Value at Risk (VaR) that represents a low probability (P98) - high impact situation for any portfolio. On that basis two different information are provided:

- Risk Acceptability: according to the risk appetite of given organisation (300 Mln$ Loss in the above figure), the probabilistic approach highlights which portfolio scenarios are in the tolerance range, and which are not and should be excluded from the strategic planning.
- Efficient Frontier: the portfolio scenarios that are giving the best perspectives in terms of high value (vertical axis) or low risk (horizontal axis) are defining the Efficient Frontier. This is a solid methodology to select the best strategies for medium and long-term business planning.

Practical implications

The probabilistic approach is providing a lot more information compared to traditional investment evaluation, and especially it helps decision makers to get a quantitative and accurate answers to all these common questions:

- Is there any room for improving accuracy and quality of the financial plans?
- How do we tackle uncertainties in price, quantities, demand,...?
- Are the assumptions shared within the team in a clear and effective way?
- Did we address enough scenarios for our investment valuation?
- Do we have quantitative elements to be challenged on our risk analysis?

All these questions can be clearly answered through the risk-based approach presented in this paper.

Originality/value of paper

The probabilistic evaluation of a cash flow planning is still a rare activity, limited to academic research and barely applied in the industry [5], because considered as an intricate one. For that reason, most of the organizations are stuck to deterministic investment valuation and planning, struggling to anticipate their risks in an efficient way. The venue of innovative and intuitive solutions for risk computation, such as Riskturn, are bringing the risk modelling techniques to non-expert users. Thanks to these new capabilities, this paper explores all the benefits of a risk-based approach in investment valuation.
Conclusions

Being able to plan in advance the business decisions and to evaluate all possible outcomes of different scenarios is more and more a key capability for C-level in every industry.

The classic approach, quite often based on spreadsheets, that identifies best, worst and “I hope so” versions is not reflecting the level of accuracy, reliability and high-standards of communication required by today’s data-driven economy.

The probabilistic approach provides the accuracy and completeness in investment valuation and capital budgeting, providing pertinent information and increasing confidence in decision making.

![Forecasting Techniques](image)

**Figure 11** Forecasting Techniques

The risk-based approach is boosting EPM (Enterprise Performance Management) with risk adjusted modeling, introducing sophisticated features like Monte Carlo Methods still assuring a greater communication among the project players (Controllers, Engineers, Project Managers,...) and the top management.

**Keywords (no more than 5):**
- VaR
- VAN
- Monte-Carlo
- Capital Budgeting
- Valutazione Rischi

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