A Value-Oriented Framework for Return Evaluation of Industry 4.0 Projects

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Abstract. Organizations can transform their businesses and create more value by adopting Industry 4.0 initiatives. During evaluating these projects, the decision-maker must assess significant uncertainties (risks) resulting from socio-technical, economic, and financial factors. One of the main objectives of this study was to identify the necessary building blocks to develop a framework for project implementation in high-risk scenarios, as in the case of Industry 4.0. A multi-criteria framework divided into three stages was proposed, integrating knowledge from Front-End-Innovation (FEI), Innovation Decision Process (IDP), Traditional Project Evaluation Methods, and Real Options Valuation (ROV). The first step is to identify an investment opportunity. The second step is the definition of a business model. The third step is the simulation of different implementation strategies to give managerial flexibility to decision-makers to decide the best strategy to mitigate risks. A real case study was used to test the framework. According to the results, managers can use this framework to create different project implementation scenarios and determine the best strategy to mitigate risks. However, we must still understand whether uncertainties behave discretely, dynamically, or both, the interactions between elements, and how to calculate them to improve our model.

Keywords: Framework · ROV · FEI · IDP · Valuation

1 Introduction

In general, the adoption of advanced technologies in the context of the digitalization of operations in companies is associated with investments, most of the time significant. In this context, investment decisions are not straightforward. The investment decision process has three fundamental characteristics, irreversibility, volatility, and timing, Copeland et al. [1]. Investments in innovation and technology projects face three types of risks: (a) the risks surrounding business strategy, (b) the risks associated with technology, and (c) the risks associated with transformations Almeida et al. [2], Schneider and Imai. [3]. The existing capital budgeting methods, such as Net Present Value (NPV) and Discounted Cash Flow (DCF), do not provide decision-makers with sufficient management flexibility to choose the most appropriate implementation strategy when a significant risk occurs.

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This paper has three main parts to present an innovative approach to assessing high-level uncertainties scenarios of project valuation for Industry 4.0 initiatives. During the first part, we presented the conceptual background of the three-stage multicriteria framework. In part two, we demonstrate the framework's applicability and results in a real case study. Finally, at the end of the paper, we concluded by resuming the main results, presenting the limitation and proposal for future works.

2 The Framework

The main goals of this three-stage framework are to identify a preliminary opportunity and solution to be implemented, define the business model, perform the feasibility, and project planning, and lastly, provide a method for project valuation to analyze project implementation strategies based on the volatility scenarios [1–10]. Figure 1 below explains the framework:

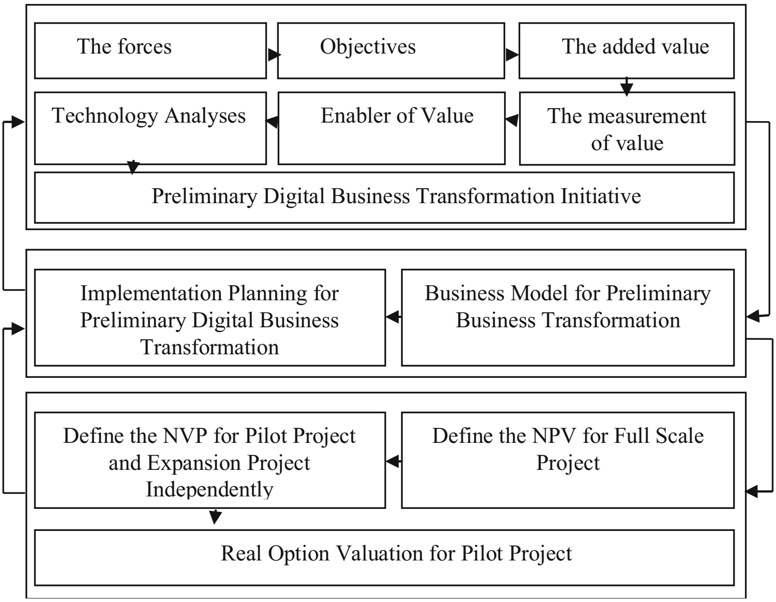

Fig. 1. The Three-Stages Framework.

2.1 The Real Options Solution Analysis

This stage implies identifying an opportunity and proposing the creation of a preliminary digital transformation opportunity. The steps were designed to identify the external and internal forces and evaluate the most appropriate digital business transformation opportunity to implement.

2.2 Real Option Digital Business Transformation Model

At this stage, there are two significant steps necessary to decision-makers face: (a) deciding on the best business model to implement [6] and (b) planning the implementation for the business model [4]. To fulfill this stage, we must perform different tasks, such as (i) product-market fit, (ii) business model; (iii) prototype, (iv) identifying competitive scenario; (v); technology evaluation; (vi); (vii) problem-solution fit; (viii) proposed minimum viable product/solution; (xi) specify resources needed; (x) project description; (xi) market feasibility; (x) technical feasibility; (xi) organizational and managerial feasibility" [4].

2.3 The Real Option Solution Investment Valuation

At this stage, we use both financial approaches, the traditional methods of capital budgeting valuation and the Real Option Valuation (ROV) techniques. With the ROV methods [3, 9], we can assess at a specific time if the resulting form of ROV is higher than NPV, offering managerial flexibility to decision-makers to decide whether it is the best moment to invest.

2.4 Implementation Strategies

Strategy I. Analyze the full-scale project using the NPV method (Eq. 1) - if the market conditions are very favorable, the NPV is high, and the future cash flow volatility is low, the decision-maker can invest in the full-scale project immediately [10]. The time horizon for a full-scale project is usually five years. This procedure involves decreasing the present value of future cash flows from the present value of initial investment, as demonstrated in Eq. 1 and Fig. 2.

Equation 1: The NPV. Source: [10]

$$\mathrm{NPV}n = \mathrm{PV\ fcf} - \mathrm{PVinv} \tag{1}$$

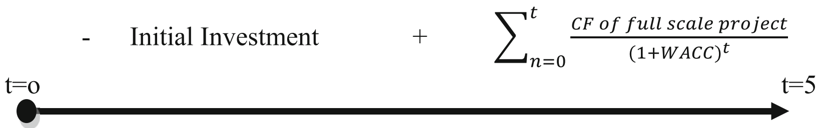

Fig. 2. The strategy I – NPV of full-scale project valuation

To know the volatility, Monte Carlos Simulation (MCS) was used to estimate the volatility of future cash flows. [10] describe the following procedures for estimation: (i) Calculate future cash flows for periods, (ii) Use Excel's INV.NORM. N function to generate random future cash flow scenarios for each year; (iii) Generate the Mean for each future cash flow scenario of the full-scale project; (iv) Estimate the PV for each future cash flow scenario; (v) Calculate the standard deviation of PV; (vi) Use Excel's

NORM.DISTR function returns the normal cumulative distribution for the specified mean and standard deviation; (vii) Calculate volatility through the standard deviation of the thousand simulations of normal distributions. As demonstrated in Fig. 3, If the NPV and volatility are high, we can perform strategy II by starting with a project pilot (t = o) to better understand the market conditions and the variables that influence the future cash flows, adjusting the knowledge during every six or twelve months (t = t), until deciding on the expansion (t = T + t).

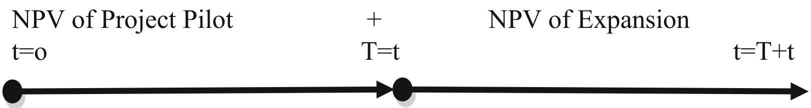

Fig. 3. Strategy II – NPVs independently Pilot + Expansion Project

To perform this strategy, according to [3], the decision-makers need to follow the procedure as follows: (i) Estimate the NPV for project pilot and expansion; (ii) Estimate the NPV for the expansion, which usually is positive, and compensate for the negative NPV from the pilot project; (iii) Finally, sum both NPVs. The results of NPV, in general, are lower than the strategy (1). However, the approach has the advantage of providing decision-makers with the necessary knowledge about the variables that influence future cash flows during the pilot project without waiting. Even though the future market condition does not demonstrate any improvement, they can abandon the pilot and full-scale project – selling or closing the pilot or full-scale project. If decision-makers decide to perform a pilot project, the time horizon (the difference between t = 0 and t = 1) of the project pilot must be defined.

The pilot project and expansion project are two dependent investments. Focusing on providing simplicity to perform strategy III, we must parametrize the inputs and outputs before using the ROV [3, 9]: (i) Establish the time horizon for the pilot project; (ii) Define the investment in the pilot project and the structure of futures cash flow; (iii) Define the investment in the expansion.; (iv) Determine the pilot project's investment amount and future cash flow structure.; (v) Estimate the volatility (σ) from the full-scale project obtained by MSC for the first strategy; (vi) Determine the risk-free rate. We used the weighted average cost of capital (WACC). This strategy allows decision-makers to decide anytime whether ROV differs from the NPV to exercise the option explained below [3, 9]. Option to defer - wait to proceed with a pilot or full-scale project until more favorable market conditions exist in any period where the option value is higher than the NPV for that period; If we consider using a pilot project strategy, we must have to perform two decisions: (i) When is the most appropriate period to launch a project pilot (t = o) and subsequently expansion?; (ii) When is the moment to expand from the project pilot into a full-scale project (t = 1)? Hence, despite its typically negative project returns, including the option to expand, usually, the consolidated NPV becomes positive [8]; Schneider et al., 2008 [2, 11]: Fig. 4 demonstrates the expansion options – to make further investments and increase the outcomes if conditions are favorable (t = 1; t = 2; t = 3; t = 4…t = n); (ii) Contraction options reduce the scale of a project's operation (t = 1; t = 2; t = 3; t = 4…t = n).

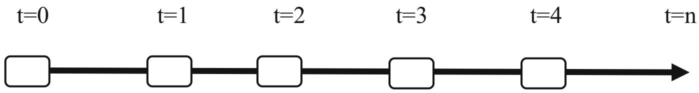

Fig. 4. Strategy III – Exercising the real option anytime.

It is worth explaining in more detail the use of the Black and Scholes Model (BSM) if there is a project divided into two stages, pilot project, and expansion, considering evaluation options in annual periods. We can solve the problem analytically with the BSM in these scenarios because of the model's simplicity. Considering a digital business transformation project can be a stochastic process described by a differential equation [3], we can simplify the utilization of the equation by performing the following procedures: (i) where measures the average growth of Vt (PCDT); (ii) σ its estimated volatility dW as a normally distributed random variable with mean 0 and standard deviation *dt (i.e., Brownian Motion) [3]:

$$dVt(PDBT) = \mu Vt(PDBT)dt + \sigma Vt(PDBT)dW \tag{2}$$

BSM is easy to apply even when the solution to the differential equation is mathematically complex. The formulas are independent since, in a risk-neutral world, the risk-free rate is used instead. To determine the Value of an option at t = 0, the following BSM can be applied [3]:

$$C(s.t) = SN(d1) - Ke^{(-rt)}N(d2) \tag{3}$$

While d1: $\frac{IN\left(\frac{S}{K}\right)+\left(r+\frac{\sigma 2}{2}\right)(t)}{\sigma\sqrt{T-t}}$

(d2): $d1 - \partial\sqrt{t}$; (S) is the NPV of the full-scale project; (K) Initial investment for the pilot project and full-scale project; (r)Risk-free rate; (t)Period of the Option years; (σ) volatility of digital transformation projects.

3 Case Study – Casa do Sono Digital

Caso do Sono is a Portuguese company that has been in business for five years and specializes in making and selling mattresses and sofas. Segmentation is a significant challenge. Companies are focusing on increasing their online business presence. The Company decided to start a new company called Casa do Sono Digital, and we used this framework to assess three different implementation strategies according to uncertainties.

The first strategy assessment consists of deciding in 2022 to invest in the five-year full-scale project (t = 5) without a pilot project. It comprises three fully integrated software, CRM, ERP, and Marketplace (application). The initial investments for 2022 and 2023 at −€250,000 and −€350,000, respectively. We are estimating €55.000 of sales per franchisee in 2023 on average. The revenue is from the 30% commission paid by manufacturers and partners. Thus, the operating cash flow for 2022 will be −€ 136.197,33 and for 2023 −€ 90.356,25. For 2024, 2025, and 2026, the operating cash flows will be positive as they incorporate new franchisees and an increase in the average sale of each franchisee, among other factors. This project has a time horizon of five years. The total investment required for the full-scale project is −€ 600.000,10 in 2022. The PV of future cash flow is € 1.387.124,56, providing a net present value of € 787.124,46 (Table 1). NPV is higher than 0, according to the traditional capital budgeting theory; this is a project to invest in.

Table 1. Strategy I, NPV for a full-scale project.

Total investment	PV of all future cash flows	NPV full-scale project
−€ 600.000,10	€ 1.387.124,56	€ 787.124,46

Strategy II, we proposed splitting the full-scale project into two dependent phases. The first consists of performing a project pilot, and the second phase consists of the expansion project to mitigate the risks. With this approach, the company can learn more about the fourteen variables influencing future cash flow and adjust to mitigate the risks involved. The time horizon for the project pilot is two years (t = 1 and t = 2) and will happen in 2022 and 2023. After the period of the project pilot, the decision-maker can decide if the company will continue investing in the expansion in more three years project (t = 3, t = 4, and t = 5), 2024, 2025, and 2026. Otherwise, we will not continue the project and will make the (negative) payments for the pilot project to mitigate the risks. We simulated the NPVs separately for the two-year pilot and the expansion. The NPVs of the pilot project are generally negative. However, we incorporated the NPV of the expansion project into the NPV of the pilot project. We calculated the NPV of the project pilot for 2022 and 2023 years, discounting the initial investment of −€250.000. The NPV for the pilot project is −€ 448.490,34. We estimate that −€350.000 will need more investment to continue the project. The PV for 2024, 2025, and 2026 is € 1.568.594,04, which gives an NPV of € 1.218.594,04. Adding the negative NPV of the pilot project to the NPV of the expansion, we have a final NPV for strategy II of € 770.103,69 (Table 2).

Table 2. Strategy II. Project pilot and expansion summing the NPVs.

Total investment	PV of all future cash flows	NPV for project pilot
−€ 250.000	−€ 198.490,34	−€ 448.490,34
Total investment	PV of all future cash flows	NPV for project pilot
−€ 350.000	€1.568.594,04	€ 1.218.594,04
Total investment	PV of all future cash flows	NPV for project pilot
−€ 600.000	€1.370.103,69	€ 770.103,69

Strategy II using the BSM to confirm that the pilot project strategy was the most appropriate and that we were not undervaluing the financial results using the NPV method. We decided to use BSM instead of decision tree techniques because the option occurs minimum annually [3]. The time horizon for the option is valid and is the same as a pilot project, two years (t = 2). The PV of the pilot project is considered the Strike (S). To exercise the option of investing in the expansion, we must keep the initial investment in the project pilot (K), adding dividends (y). The dividends are investments needed to conduct a better market study, evaluate the necessary technologies, and understand the impact of the war in Ukraine and Covid-19. This Value is given by the sum of all operating expenses related to the maintenance of the pilot project while the option lasts. The risk-free rate (rf) is the WACC (10%) estimated in strategy I. After obtaining the ROV from the pilot project using BSM, we summed it up to the NPV of the expansion project. The results demonstrated that we were undervaluing the pilot project using the NPV method because the result of the option is € 29.927,64, different from the −€ 448.490,34 using the NPV approach. Resuming the Value of the option of using a pilot project strategy is a positive result in € 29.927,64 instead −€ 448.490,34. Adding the positive result of the pilot project using the ROV method of €29.927,64 with the positive NPV of the expansion project of €1,218,594.04, we have a result for strategy II of €1.248.521,68. (Table 3).

Table 3. Strategy II – Valuing the project pilot by BSM (Source: Own source)

Variables	Explanation	Results
S	The Present Value of future cash flows	€ 198.490,34
K	Investment required	€ 250.000,00
R	Risk-free rate (WACC)	10%
T	Period of the Option is valid	2 years
Σ	Volatility of future cash flows	~30%
Y	Costs to keep the Option valid (dividends)	5%
d1	$\frac{\text{IN}\left(\frac{S}{K}\right)+\left(r+\frac{\sigma^2}{2}\right)(T-t)}{\sigma\sqrt{T-t}}$	−0,069392923
d2	d1-$\sigma\sqrt{T}$	−0,493656992
ROV	C(S, t) = S ∗ N(d1) − Ke − r(T − t)N(d2)	€ 29.927,64
NPV	Investment - Present Value	−€ 448.490,34
The Real Option	The difference between NPV - ROV	€ 473.454,31
Pilot project with ROV	PV of all future cash flows	NPV for project pilot
−€ 250.000	−€ 198.490,34	€ 29.927,64
CAPEX Expansion project	PV of all future cash flows	NPV for expansion
−€ 350.000	€ 1.568.594,04	€ 1.218.594,04
Total investment	PV of all future cash flows	NPV for project pilot
−€ 600.000	€ 1.370.103,69	€ 1.248.521,68

4 Conclusion

Using this framework, we generated different project implementation strategies, considering return x risk by merging knowledge from the ROV, traditional project evaluation methods, FEI, and IDP knowledge. The limitation of this study is that more real-life case studies are needed to assess its applicability to other sizes and complexity of companies during the investment decision process. In future research, the researcher could utilize a Systems Dynamic approach to model innovation and technology investment decision processes rather than simply calculating volatility based on Brownian motions. In a dynamic system, artificial intelligence technologies such as reinforcement learning can improve investment decisions by automating the assessment of variables that influence the process. We also suggest incorporating other theories, such as the game theory, to simulate scenarios of genuine competition between investors.

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