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An Alternative Method to Evaluate Complex Information Technology Projects

Sidney Chaves
Universidade de São Paulo, sidneychaves@usp.br

Cesar Alexandre de Souza
Universidade de São Paulo, calesou@usp.br

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Sidney Chaves
Universidade de São Paulo
sidneychaves@usp.br

Cesar Alexandre de Souza
Universidade de São Paulo
calesou@usp.br

Abstract

For most companies, it is a reality to face uncertainties when conducting complex projects focused on the implementation of Information Systems (IS) and, as a consequence, cost-benefit evaluation of this kind of projects has become a difficult task. In this context, Real Options Theory (ROT) has proved to be a viable alternative to provide methods to evaluate complex projects, not only in Information Technology but in many other economics and business areas. This paper intends to demonstrate how ROT can be applied to evaluate complex Information Technology projects, exploring a case study involving an implementation project of an Enterprise Resource Planning (ERP). In the case study, two distinct solutions for the implementation of an ERP were evaluated, demonstrating the applicability of ROT to such complex situations.

Keywords

Complexity, Information Technology, ERP, Evaluation Method, Real Options.

1. Introduction

For most companies, it is a reality to face uncertainties when conducting complex projects focused on the implementation of information systems, whether these systems are acquired in the market or internally developed. As a consequence, cost-benefit evaluation of this kind of projects has become a difficult task, mainly due to the fact that traditional economic evaluation methods do not lead to satisfactory results, because they do not take into account the uncertainties embedded in these projects (Wu et al., 2008; de Bakker et al., 2010; Baker et al., 2011).

In this context, Real Options Theory (ROT) has proved to be a viable alternative to provide methods to evaluate complex projects, not only in Information Technology (IT) but in many other economics and business areas (Trigeorgis, 1993; Luehrman, 1998; Copeland, 2001).

Given the above outlined context, we decided, as part of a broader research, to explore the potential of ROT to support cost-benefit analysis of complex projects, and carried out a study focused on the selection and application of a suited method to perform a cost-benefit evaluation of an Enterprise Resource Planning (ERP) implementation project. So, the objectives of this paper are: (1) to explore the potential of ROT to support cost-benefit analysis of complex projects and (2) effectively apply this method to a real complex project.

The achieved results of this study are being reported in this paper, which, besides this introduction, comprises four other sections. Section 2 includes the literature review, covering all relevant topics for the development of the study. Section 3 explores the object of the study and the method selected to make the evaluation, while Section 4 presents the case in which the chosen method was applied. Section 5 presents conclusion and final considerations.

2. Literatute Review

The literature review was focused, at first, on complexity and complex systems, and, afterward, on complex projects and their evaluation, both via traditional and ROT methods.

2.1 Complexity and Complex Systems

Academic literature defines and addresses complexity in many ways, depending upon a context. In the IS context, Sussman (1999), as an example, defines complexity as a systems' attribute composed by a group of related parts for which the degree and nature of the relationships are imperfectly known; as a result, the overall emergent behavior is difficult to predict, even when the behavior of the parts is readily predictable.

Hanseth (2007) sees complex systems in a similar manner, stating that a system is really complex only when it contains parts of different types. For Schneberger and McLean (2003), in turn, complexity is a function not only of the number of system parts or components, but also of the respective number of their interrelations. For these latter authors, as the combined parts of a whole and their interactions increase, the higher is the level of complexity.

For all these considerations, it becomes evident that the degree of complexity of a whole tends to be increased as the number of parts that make up this whole increases. Likewise, the more different types of parts compose a whole, the greater the degree of complexity, as the existence of different types tends to promote interactions of different natures rather than more uniform interactions, such as those that occur when all parts are of the same type or of few different types.

2.2 Complex Projects

In present days, we may say that project is a stable concept and that there is reasonable consensus about that. For example, the Project Management Institute (2008), states that "a project is a temporary endeavor undertaken to create a unique product, service or result".

Likewise, for the International Project Management Association (2006), project is "a time and cost constrained operation to realize a set of defined deliverables (the scope to fulfill the project's objectives) up to quality standards and requirements".

In the academic field, Gaddis (1959) is one of the pioneers that has proposed a definition for project: "a project is an organization unit dedicated to the attainment of a goal – generally the successful completion of a developmental product on time, within budget, and in conformance with predetermined performance specifications". Similarly, Shenhar (2001) states that a project is a temporary organization established with the aim of achieving a given goal.

In summary, it is possible to adopt for *project* a definition that accepts as its characteristics: (1) to be a temporary effort, (2) have explicit and pre-defined objectives, (3) comprise a unique and finite set of activities, (4) require specific allocation of resources, and (5) generate exclusive products, services and results.

In view of this definition, several authors have addressed the theme of "complex projects". According to Kerzner and Belack (2010), complex projects are those that are extensive, absorb large investments, present a multiplicity of interactions with cultural implications, are subject to uncertainties, and have multiple stakeholders.

As for Remington and Pollack (2007), a complex project has critical size, timeframe, level of ambiguity, and interconnectedness. For these authors, complexity, as a rule, is the result of interrelationships and feedback between a large number of areas of uncertainty or ambiguity. When there are few areas of uncertainty in a project and little interconnection between them, complexity is usually low; however, complexity usually increases when the number of areas of uncertainty increases, especially if these areas are interdependent.

Given the above considerations, we can explicit a set of characteristics of complex projects:

- Having multiple distinct components and several stakeholders who interact with each other in multiple different ways;
- Present ambiguity and multiplicity of connections and sources of uncertainty;
- Absorb large volumes of investments;
- Are extensive and have a high number of distinct activities.

2.3 Evaluation of Complex Projects

Traditionally, cost-benefit analysis of projects, intended to determine the financial return provided by them, have been made by means of net present value or internal return rate methods (Saito et al., 2011).

The net present value method consists of the following steps: (1) determine the expected cash inflows and outflows over time, throughout the execution of the project, and (2) convert these cash flows into a resultant present value, using a return rate in line with the reality of the project. If the achieved present value is positive, it is worth to execute the project, otherwise, it is not worth (Luehrman, 1998; Wu & Liou 2011).

The internal return rate method, in turn, is a variant of the net present value and arises from the same cash inflows and outflows, with the difference that, instead of assuming an arbitrary return rate to calculate the present value, it deduces an internal rate that leads to equal inflows and outflows (Saito et al., 2011). The achieved rate is compared with an opportunity rate available to the project owner (from alternative investments) and, if it is higher, it is worth to execute the project.

However, several researchers, including, for example, Luehrman (1998), Trigeorgis (1993) and Copeland (2001), mention disadvantages associated to the use of those methods in the decision-making involving investments in complex projects. Those methods use forecasts of future cash flows and assume a passive posture that fails to dynamically respond to environments in constant change. Without recognizing that a proactive decision maker may undertake corrective actions in response to a changing environment, these methods are unsuitable for valuing projects under uncertainty (Wu et al., 2008; Baker et al., 2011).

De Bakker et al. (2010) support this vision, stating that those traditional methods do not produce accurate evaluations in situations where there is uncertainty, because they do not consider value that can be created through flexibility in decision making.

In contrast to those traditional methods, new ones based on ROT emerge as an alternative. According to Trigeorgis (1993), a project incorporates real options when it offers to its managers the opportunity to perform some future action (such as abandoning, postponing or changing investments or even modifying project scope) in response to uncertain events. Wu and Liou (2011) claim that methods based on real options are more suitable than traditional methods to evaluate large projects because they realistically value uncertainties.

Dewan et al. (2007) state that literature indicates that there is already a tradition in analyzing IT investments from the perspective of ROT, mentioning, as examples, studies of Benaroch and Kauffman (1999, 2000), Taudes et al. (2000), Benaroch (2002), Schwartz and Zozaya-Gorostiza (2003) and Fichman (2004). Wu et al. (2008) reinforce this point of view, stating that ROT, due to taking uncertainties into account, is the most viable alternative for evaluating investments required to implement ERPs.

2.4 Evaluation Using Real Options Approach

Several authors have addressed the issue of "viable options" when it comes to evaluating investments in projects of technological innovation and implementation of IT solutions and ERPs. Table 1 shows a summary of the options that some authors investigated on this subject.

Table 1 – Viable Real Options

Authors	Object of Investment	Options				
		Postpone	Pilot / Phasing	Implement on Single Phase	Change Scope	Abort
Benaroch and Kauffman (1999)	IS	X				
Schwartz and Zozaya-Gorostiza (2000 and 2003)	IT in general	X		X		X
Taudes *et al*. (2000)	ERP	X		X		
Benaroch (2001)	Technology	X	X		X	X
Wu *et al*. (2008)	ERP		X		X	X
Chen *et al*. (2009)	ERP		X			X
Saito *et al*. (2011)	Innovation	X		X		X
Wu and Liou (2011)	ERP	X		X		

In general, the options shown in Table 1 have the following meanings:

- Postpone: when the investment conditions appear to be uncertain, the decision to invest may be postponed to some future time; this option is useful as it provides the decision maker the opportunity to postpone the investment in cases where the right moment to do it is crucial to achieve higher returns;
- Pilot/phasing: the project can be implemented in phases or a reduced initial scope or pilot-project can be defined; at the end of each project phase or of the pilot, it is possible to evaluate the achieved results and decide to continue with the investment or not;
- Implement on single phase: unlike the previous option, it means to implement the investment at once;
- Change scope: during any one of the project phases, if the market environment seems to be positive and/or if the progress is beyond the expected, the project scope can be expanded, or vice versa, if things appear oppositely;

- Abort: if the expected market environment is unfavorable, the project can be aborted in order to avoid or reduce losses; the value of an investment that has the option to be aborted is higher than those without this option, especially when the market is volatile.

Besides the aspect of the viable options, it has to be considered the choice of the evaluation method. In order to evaluate projects by means of real options, there are two distinct methods known as basic or classic: the Binomial Tree method, also named Cox-Rubinstein, and the Black-Scholes method, both developed in the decade of 1970. Benaroch and Kauffman (1999) and Saito et al. (2011), to name just two groups of authors, present in their studies the concepts and the mathematical formulation that support these two methods, so we are not going to stress that formulation in this paper.

Based on these two classic methods, several authors have derived specific variants focused on particular applications of ROT. Some of these variants are listed in Table 2.

Table 2 - Methods for Evaluation of Complex IT Projects via ROT

Authors	Derived from	Description
Benaroch and Kauffman (1999)	Black-Scholes	Applies the standard Black-Scholes model and adds the possibility that the option to be considered may be exercised at any time during the project.
Benaroch (2001)	Cox-Rubinstein	Considers that a project is subject to multiple sources of risks and classifies them, associates risks with options, values each option and allows combined options.
Wu et al. (2008)	Cox-Rubinstein	Works with a set of combined options, but valuing each option individually.
Chen et al. (2009)	Cox-Rubinstein	Considers that a project is subject to multiple sources of risk, classifies risks into private and public, evaluates the relevance of each risk factor and sets a failure factor associated with private risks and a volatility coefficient associated with public risks; calculates the value of options based on the value of risks.
Saito et al. (2011)	Cox-Rubinstein	Incorporates the modeling of uncertainties through Monte Carlo simulation to the binomial tree and obtains volatility through the Markovitz's E-V rule.

3. The Study: Object and Selected Method

This section describes the object of the study –comprising the company and the project– that gave rise to this paper, and also points out the method selected to make the evaluation of the project under consideration.

3.1 Object of the Study

The research that gave rise to this paper is based on a case study involving a project evaluated through the application of ROT. We are acting as consultants for that project, so data collection was possible through our active participation in the project.

The project is an implementation of an ERP system, which is being conducted in a medium-sized, family-owned Brazilian company, engaged in the construction and commercialization of real estate developments. Data was collected during the second half of 2013.

The company, hereinafter referred to as RE-Dev, has incipient operational and management controls and makes low use of IT resources. Despite these aspects, RE-Dev is a profitable company and has experienced an accelerated business expansion over the past few years.

Amid this reality, RE-Dev was faced with the opportunity to admit as a partner an investment company, led by experienced professionals with proven managerial expertise. Once this new partner was admitted, a broad restructuring process began, including expand and enhance internal controls and raise the company level of computerization, both actions through the implementation of an ERP.

The ERP project was conceived during the first quarter of 2013 and was actually initiated in mid-April. The project first phase encompassed the identification of viable solutions in the market and was executed during the second quarter of 2013.

A working group was appointed to run the project and five solutions potentially able to meet RE-Dev needs were identified and subsequently evaluated. Once finished the evaluation, two solutions were selected as finalists and their owners and implementers were called to a further round of negotiations, at the end of which one of these solutions should be chosen.

One of the evaluation's dimensions was price and commercial terms and its evaluation was carried out using the net present value method. Since, in principle, the expected benefits would be common to all candidate solutions, the calculation of the present value was limited to the investment for the acquisition and implementation and the costs to be incurred over the first five years of use of the ERP, this period estimated as the life cycle for the solution before a major upgrade or replacement.

As of in the first round, in the final round of negotiations, the original intent was to use the same method to comparatively evaluate the reviewed commercial proposals received for the two finalist solutions. It was exactly at that moment of the project that we saw the opportunity to make an alternative assessment and apply ROT.

3.2 Qualification of the Chosen Project

In order that ROT could be applied in its entirety, it was mandatory that the ERP implementation project at RE-Dev could be effectively qualified as a complex project, without which it would not be relevant to evaluate it from the perspective of ROT.

In this sense, it is worth noting that Schneberger and McLean (2003) argue that ERPs, due to integrate and manage enterprise business processes, especially in geographically distributed companies, may show themselves as extremely complex to be implemented and operated. Stefanou (2001), in turn, highlights that the intangible nature of costs and benefits of ERPs, which evolve over time, as well as the complexity of ERP implementation projects have been recognized both by researchers and professionals.

Stefanou (2001) also states that the implementation of an ERP is a complex and resource-intensive risky task. In this same line of reasoning, Hakkinen and Hilmola (2008) share the opinion that the implementation of an ERP typically consists of a complex and risky project, which involves multiple elements and must take into account numerous issues before and after the implementation of the system in order to be successful.

In any case, regardless of the reflections of these authors, the ERP implementation project at RE-Dev, when confronted with the basic attributes of complex projects highlighted in the last paragraph of topic 2.2 above, shows full compliance to all of them. Indeed, that project:

- Comprises an extensive list of activities, arranged in various distinct groups that present a multiplicity of inter-relationships one to the others, due the fact that the project scope includes the implementation of seven ERP' modules for something like 30 real estate developments;
- Has numerous stakeholders, represented by circa 30 site managers, each one of them responsible for one of the real estate developments, and by all partners –the old and the new ones–, who interact in not completely stable and regular ways;
- Presents a high level of uncertainties regarding the completion of all activities during the total expected time, due to both the natural difficulty to execute those activities and the extensive web of inter-relationships among them;
- Has a large amount of money budgeted to fulfill the required investment, when compared to other non-regular investments recently made by RE-Dev.

3.3 Strategy of the Finalists

The two finalist solutions selected by RE-Dev differ in terms of the implementation strategy proposed by their implementers. One of the finalists proposed a single phase to implement the ERP, except for the Payroll, which would be deployed subsequently. The other finalist intended to implement the ERP effectively in two phases, the first one comprising the main modules and the second one comprising Payroll, Fixed Assets and Management Reports.

The relevant information relating to each proposal is shown comparatively in Table 3.

3.4 Method Selected for the Evaluation of Finalists' Solutions

Among the methods mentioned in Table 2, the one that appeared to better adhere to the case reported in this paper is that of Chen et al. (2009), not only due the formulation itself but also for being suitable for the real options that proved viable for RE-Dev, namely, phasing and abort (see Table 1).

Given the conditions presented for RE-Dev, none of the other usual options was viable for the ERP implementation project. RE-Dev could neither postpone the investment (due to the new shareholders' agreement) nor change the scope or implement the ERP in a single phase (since the two finalists' proposals did not include these alternatives).

Table 3 - Key Information of the Finalists' Proposals

Topic	Finalist 1	Finalist 2
Implementation Strategy	All modules in a single phase, except Payroll.	In two phases; Payroll, Fixed Assets and Management Reports in the second phase.
Implementation Term	7 months for the first phase and 3 additional months for Payroll.	8 months for phase 1 and 4 additional months for phase 2.
Cost of Software License	30,000 in D0.	8 monthly installments of 14,000 from D1.
Cost of Implementation Services	6 monthly installments of 110,000, from D0, plus an installment of 100,000 in D8 for Payroll.	8 monthly installments of 53.000, plus an installment of 220,000 in D9.
Cost of Operation	9,500 per month from D7.	6,000 per month from D9.
Cost of Software Maintenance	6,000 per year, from D0 and every 12 months.	3,500 per month from D1.

Therefore, the comparative evaluation of the proposals was made in accordance with the steps proposed by Chen et al. (2009): (1) calculation of the failure factor and the volatility coefficient, and (2) real options valuation.

4. Evaluation of the Project

In this section, all steps and details of the evaluation of the ERP implementation project are presented and discussed.

4.1 Calculation of the Failure Factor and the Volatility Coefficient

The rules and formulas that Chen et al. (2009) define for obtaining the failure factor and the volatility coefficient are not complicated but require further exploration of risks, which did not qualify as an actual requirement in this case. As this study was a comparative evaluation between two solutions aiming to identify the winning one, and the values of the failure factor and the volatility coefficient should be employed in the calculation of the options for both candidate solutions, we adopted a simplification at this point.

This simplification consists in using several different values for the failure factor and the volatility coefficient, all ranging in a extent reasonably close to the actual values that can be calculated, and verify whether these different figures lead to different winners. If all adopted combinations lead to the same winning solution, it can be concluded that it is not necessary to accurately calculate the failure factors and the volatility coefficient, allowing the use of approximate values.

Based on this reasoning, we adopted for the failure factor and the volatility coefficient the combinations listed in Table 4.

Table 4 - Combinations of Failure Factor and Volatility Coefficient

Failure Factor (F)	Volatility Coefficients (σ)			
0.4	0.2	0.3	0.4	0.5
0.5	0.2	0.3	0.4	0.5
0.6	0.2	0.3	0.4	0.5

4.2 Real Options Valuation

The method proposed by Chen et al. (2009) is based on the original formulation of the Cox-Rubinstein method, leading to the development of two binary trees:

- The first tree advances over time and projects the present value of the estimated net returns based on increases and decreases derived from the volatility coefficient; the calculation formula is:

$$R_{t+1}^{w} = wR_t \ ,$$

where: R_t – estimated net return on date t;

R_{t+1}^{w} – estimated net return on date (t+1), plus or minus w;

w – increase or decrease factor, obtained by:

– for increases: $w = i = e^{\sigma\sqrt{\tau}}$,

– for decreases: $w = d = 1/i$,

where: e – neperian constant;

σ – volatility coefficient;

τ – time range of tree stages (in this case, set to 1 month).

- The second tree reaches back in time, from the last period reached by the first tree, and obtains the value of the option for the periods in which there is investment by the formula:

$$O_{t-1} = max[0; (1 - F)\, R_t - I_t] \ ,$$

where: O_{t-1} – value of the option on date (t–1);

I_t – investment on date t;

F – failure factor.

- In periods where there is no investment, the formula is:

$$O_{t-1} = \left(pO_t^i + (1-p)O_t^d\right)/(1+j) \ ,$$

where: O_{t-1} – value of the option on date (t–1);

O_t^i – value of the option on date t with increase;

O_t^d – value of the option on date t with decrease;

j – interest rate in periods equivalents to τ (in this case, 1 month);

p – probability of increase in the value of the option calculated by:

$p = (1 + j - d) / (i - d)$

The starting values for the two trees are:

R_0 = present value of estimated net return, discounted at interest rate j;

$O_T^w = R_T^w$, where T is the last period of the first tree and w is equal to a or d.

4.3 Assessment Results

The calculations for assessing the finalist solutions were based on the values indicated in Table 5, partly extracted from the information shown in Table 3.

Table 5 - Values Used for the Assessment of the Finalist Solutions

Variable	Meaning	Finalist 1	Finalist 2
R_0	Present value of the estimated net return (benefits minus costs), arbitrated and equal for both finalists; this value includes costs of operation and software maintenance	1,000.00	1,000.00
j	Monthly interest rate, obtained from the annual rate J = 12%	0.95%	0.95%
F	Initial failure factor chosen from the values in Table 4	0.4	0.4
σ	Initial volatility coefficient chosen from the values in Table 4	0.4	0.4
I_0	Cost of software licensing and implementation services in the first phase, brought to present value by the monthly interest rate j	703.99	513.82
I	Additional value of implementation services	100.00 in period 8	220.00 in period 9

Note: to obtain R_0 we adopted a time horizon of five years for the lifetime of the ERP and considered that the costs of software operation and maintenance of the finalist solutions are equivalent, since the present values for both were quite approximate.

From the values indicated in Table 5 we obtained the binary trees for the finalists' solutions, presented in Tables 6 and 7.

The shadowed columns in the second trees in Tables 6 and 7 correspond to the periods in which the future investments occur. In those periods, the calculations were made using the formulas that consider future investments, unlike the formulas used to calculate other columns' values.

The value of R_0 was arbitrated in order to enable the start of calculations. After completing the first round of calculations, R_0 was replaced, in each solution, by the value that made net returns equal costs. Explaining in detail, for Finalist 1, whose calculations indicated an estimated net return with option of 1,285.59 versus a total investment of 796.71, both at present value (see Table 6), R_0 was reduced until the estimated net return with option turned equal to total investment. This occurred when R_0 equaled 644.00, indicating that this was the minimum net return to be generated by the solution of Finalist 1 to make the project viable, that is, provide a net return at least equal to the required investment.

Table 6 - Binary Trees for the Solution of Finalist 1

J (annual interest rate) =	0.1200	τ =	1.0000	i =	1.4918	p =	0.5474
j (monthly interest rate) =	0.0095	σ =	0.4000	d =	0.6703	F =	0.4000

Initial net return at present value =	1,000.00

Period -->	Present Value	0	1	2	3	4	5	6	7	8
Definite Investiment (DI) =	-703.99	-145.00	-115.00	-115.00	-115.00	-115.00	-115.00			
Flexible Investiment (XI) =	-92.72		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-100.00
Total Investiment (DI + XI) =	-796.71									

Tree 1	0	1	2	3	4	5	6	7	8
Estimated Net Returns =	1,000.00	1,491.82	2,225.54	3,320.12	4,953.03	7,389.06	11,023.18	16,444.65	24,532.53
		670.32	1,000.00	1,491.82	2,225.54	3,320.12	4,953.03	7,389.06	11,023.18
			449.33	670.32	1,000.00	1,491.82	2,225.54	3,320.12	4,953.03
				301.19	449.33	670.32	1,000.00	1,491.82	2,225.54
					201.90	301.19	449.33	670.32	1,000.00
						135.34	201.90	301.19	449.33
							90.72	135.34	201.90
								60.81	90.72
									40.76

Tree 2	0	1	2	3	4	5	6	7	8
Estimated Net Returns with Option =	1,285.59	1,758.75	2,396.01	3,253.40	4,406.57	5,957.45	8,043.12	10,847.87	14,619.52
		740.32	1,024.93	1,409.32	1,926.97	2,623.33	3,559.97	4,819.71	6,513.91
			411.63	581.55	812.82	1,125.21	1,545.56	2,111.09	2,871.82
				214.77	314.04	452.06	640.43	894.02	1,235.32
					99.21	153.70	233.73	347.16	500.00
						35.40	60.14	101.44	169.60
							6.22	11.46	21.14
								-	-
									-

Table 7 - Binary Trees for the Solution of Finalist 2

J (annual interest rate) =	0,1200	τ =	1,0000	i =	1,4918	p =	0,5474
j (monthly interest rate) =	0,0095	σ =	0,4000	d =	0,6703	F =	0,4000

Initial net return at present value =	1.000,00

Período -->	Present Value	0	1	2	3	4	5	6	7	8	9
Definite Investiment (DI) =	-513,82		-67,00	-67,00	-67,00	-67,00	-67,00	-67,00	-67,00	-67,00	
Flexible Investiment (XI) =	-202,07		0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-220,00
Total Investiment (DI + XI) =	-715,89										

Tree 1	0	1	2	3	4	5	6	7	8	9
Estimated Net Returns =	1.000,00	1.491,82	2.225,54	3.320,12	4.953,03	7.389,06	11.023,18	16.444,65	24.532,53	36.598,23
		670,32	1.000,00	1.491,82	2.225,54	3.320,12	4.953,03	7.389,06	11.023,18	16.444,65
			449,33	670,32	1.000,00	1.491,82	2.225,54	3.320,12	4.953,03	7.389,06
				301,19	449,33	670,32	1.000,00	1.491,82	2.225,54	3.320,12
					201,90	301,19	449,33	670,32	1.000,00	1.491,82
						135,34	201,90	301,19	449,33	670,32
							90,72	135,34	201,90	301,19
								60,81	90,72	135,34
									40,76	60,81
										27,32

Tree 2	0	1	2	3	4	5	6	7	8	9
Estimated Net Returns with Option =	1.337,43	1.856,08	2.558,93	3.507,82	4.785,95	6.505,63	8.818,64	11.929,43	16.112,97	21.738,94
		738,23	1.044,97	1.464,99	2.035,62	2.806,51	3.844,71	5.241,36	7.120,01	9.646,79
			382,73	558,92	805,60	1.145,98	1.609,77	2.236,21	3.079,22	4.213,43
				177,67	272,30	410,84	609,10	885,91	1.263,57	1.772,07
					66,96	110,46	179,69	287,08	447,75	675,09
						15,75	29,05	53,57	98,79	182,19
							-	-	-	-
								-	-	-
									-	-
										-

Similarly, this method was applied for Finalist 2 and the minimum value obtained for R_0 was 588.00, indicating an advantage for Finalist 2, since it requires a lower net return under the same conditions of failure and volatility.

Complementing calculations, we obtained the minimum net returns for all other combinations indicated in Table 4, achieving the values shown in Table 8.

Table 8 - Minimum Required Net Returns

Failure Factor (F)	Volatility Coefficient (σ)	Finalist 1	Finalist 2
0,4	0.2	646.00	601.00
	0.3	646.00	597.00
	0.4	644.00	588.00
	0.5	640.00	573.00
0,5	0.2	775.00	721.00
	0.3	775.00	716.00
	0.4	773.00	705.00
	0.5	768.00	688.00
0,6	0.2	969.00	901.00
	0.3	969.00	895.00
	0.4	966.00	881.00
	0.5	960.00	860.00

By analyzing Table 8, it can be seen that the selected method is very sensitive to variations in the failure factor but not with respect to the volatility coefficient. Independently of this finding, the minimum net return required by the solution of Finalist 2 showed to be always lower than the corresponding one required from the other solution.

Therefore, we concluded that Finalist 2 presented the most advantageous proposal for RE-Dev, because it was the solution requiring the lower net return (whatever be this value), when compared on equal conditions against Finalist 1's solution.

5. Conclusion and Final Considerations

5.1 Conclusion

We conducted this study intending to show how, by using ROT, alternative solutions available for the completion of a complex project could be compared, in order to support the decision of choosing the financially most convenient alternative.

To this end, we firstly presented a definition of "complex project" to then fit into this definition a project that served as a case to demonstrate the applicability of ROT. The adopted definition was supported by Complexity Theory and the concepts disseminated by it, particularly regarding the qualification of complex projects.

The complex project chosen referred to the implementation of an ERP for RE-Dev, a real estate development company that had to comparatively evaluate two alternative commercial proposals for the implementation of the ERP.

Once proved that the chosen project complied with the condition of being complex, we applied to it the evaluation method developed by Chen et al. (2009), based on real options and derived from the Cox-Rubinstein model. The application of this method was conducted with some convenient simplifications, appropriated to the situation in question, because instead of really evaluating the two available solutions, the goal was just to make a comparison between them and identify the most favorable one for RE-Dev.

The comparative evaluation of the alternative solutions led to the recommendation to accept the proposal submitted by the Finalist 2, which proved to be the most favorable in all explored scenarios.

It is important to note that, if the main goal of the study was not to compare competing alternatives but evaluate one single alternative in order to find its net return, the failure factor should be carefully estimated, because of the high sensitivity that the method presents regarding variations in this factor.

5.2 Achievement of Objectives

As previously stated, we conducted this study with the following objectives: (1) to explore the potential of ROT to support cost-benefit analysis of complex projects and (2) effectively apply this method to a real complex project.

Both objectives were fully achieved, via the choice of a ROT model and its application to select the most convenient alternative for RE-Dev to conduct the ERP implementation project, exposing, through the study, the applicability of ROT to evaluate complex IT projects.

5.3 Extensions and Limitations

ROT has been increasingly used in the most diverse situations involving the evaluation and management of complex projects. In this context, this study constitutes a further demonstration of common aspects shared by Complexity and Real Options theories and how these theories can be applied together to solve actual day-to-day problems in business organizations.

Therefore, it can be stated that this study offers an additional perspective to academic researchers and project managers involved in the search for solutions to problems inherent to complex projects, and that this perspective can be explored in further studies that require the comparative evaluation of distinct solutions.

With regard to the issue of limitations, it is important to note that this study presents the same limitations inherent to case studies in general, namely, the inability to generalize the findings and derive general models, and the possibility of biases deriving from the fact that the researches acted as active participants in the project.

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