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APPLICATION OF AN INTEGRATED MODEL FOR EVALUATION AND OPTIMIZATION OF BUSINESS PROJECTS PORTFOLIOS♣

Camila Costa Dutra[1], Maria Auxiliadora Cannarozzo Tinoco[2,♦], Rogério Feroldi Miorando[3]

ABSTRACT

This work presents an application of an integrated model for the evaluation and probabilistic optimization of projects portfolios, integrating economic, risk and social and environmental impacts analysis. The model uses the Monte Carlo simulation and linear programming techniques for treatment of uncertainties and optimization of projects portfolio. The integrated model was applied in a Brazilian company of electricity distributions. The portfolio of selected projects was related to the expansion of the supply of electricity in a town in the south of the country and the analysis horizon was set in ten years. The aim of the application was to maximize the return for the implementation of a substation and a transmission line in a set of projects, which are diverse in terms of costs, benefits and environmental and social impacts. As a result, the model generates: i) an analysis of each individual projects, from budget information (costs and benefits involved) and estimation of social and environmental impacts generated by the project and the risks (uncertainties) involved and ii) the optimum combination of projects that the company should prioritize to ensure the best financial return and lower social and environmental impacts, thus generating an optimal portfolio.

Keywords: Projects Portfolio, Economic Analysis, Risk Analysis, Analysis of Social and Environmental Impacts.

INTRODUCTION

Investments in projects have become an increasingly dominant part of the companies' budget in recent decades. Currently, it is difficult to find an organization that is not engaged in some sort of project activity (Maylor *et al*., 2006). Therefore, project management is an area of great interest both to business managers and to academics. Organizations usually have a large number of projects and should deal with budget, deadlines and resources limitations, besides the technical and financial feasibility issues. Thus, the use of methodologies for project

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[1]Departamento de Engenharia de Produção e Tranportes, Escola de Engenharia, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil. orcid.org/0000-0001-9315-5316
[2]Departamento de Engenharia de Produção e Tranportes, Escola de Engenharia, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil. orcid.org/0000-0002-2941-1693
[3]Departamento de Engenharia de Produção e Sistemas, Universidade Federal de Santa Catarina, Florianópolis, Brasil. orcid.org/0000-0002-2487-9430

♦Corresponding author: maria@producao.ufrgs.br

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portfolio management becomes mandatory for selection, prioritization and implementation of projects that ensure maximum return for the organization (Archer and Ghasemzadeh, 2007; Amaral and Araújo, 2009).

The evaluation of investments in new projects commonly involves a set of techniques that seeks to establish indicative parameters of its viability. These parameters are usually expressed in terms of the return period of the initial investment, the internal rate of return or net present value of cash flows. However, few approaches in investment analysis consider the risks that involve the project's cash flow. Although there are established and accepted risk management frameworks, project managers commonly understand that these are not effective to manage the projects uncertainties. Over the last two decades, most of the frameworks proposed to identify investment opportunities in projects failed to capture the dynamic nature of such investments, and few explicitly addressed the risks involved (Neumann, 1994; Wu and Ong, 2008; Pender, 2001).

Moreover, it is observed that the practice of project portfolio management has been dominated by approaches with emphasis on technical and financial analysis, with little or no attention to sustainable aspects, which considers not only financial and technical aspects, but also social and environmental values (Shen *et al*., 2010; Vandaele and Decouttere, 2013). The integration of project sustainable evaluation to the technical and financial analysis is difficult to be done, as they constitute heterogeneous dimensions with different units of measures, making it difficult to directly compare projects (Labuschagne *et al*., 2005; Fernandez-Sanchez and Rodríguez-López, 2010; Shen *et al*., 2010; Vandaele and Decouttere, 2013). However, the integration of these aspects in the analysis guarantees a more robust portfolio management and decision-making based on information from a closer to reality scenario (Labuschagne *et al*., 2005; Dobrovolskienè and Tamošiunienè, 2016; Siew, 2016; Neumüller *et al*., 2016).

Most companies in their project portfolio management still follow primarily strategic and cost/benefit oriented approaches to evaluate and optimize portfolio. In addition, studies that incorporate the assessment of environmental and social aspects in the analysis and projects selection do not present a comprehensive set of criteria (Labuschagne *et al*., 2005) and do not consider the uncertainty in estimates of future social and environmental impacts of projects (Epstein, 2008; Dobrovolskienè and Tamošiunienè, 2016).Therefore, there is a need for an approach that integrates economic analysis, risks and environmental and social impacts to the analysis and prioritization of the portfolio of business projects, especially in the context of companies that present a diversified portfolio of projects in terms of benefits, Investments, uncertainless and environmental and social impacts. Companies in the Brazilian electricity sector find themselves in this situation and most investment decisions are based on traditional economic analysis. This approach is considered deficient, since it does not consider the costs related to the risks involved and the impacts generated from the implementation and operation of the energy system. In this context, this paper presents an application of an integrated model for the evaluation and probabilistic optimization of projects portfolio of a Brazilian company of distributing electricity, integrating economic, risk and social and environmental impacts analysis. The model uses the Monte Carlo simulation and linear programming techniques for treatment of uncertainties and optimization of projects portfolio.

METHODOLOGY

The integrated model presented in this paper seeks to fill a gap in the literature for analyzes which integrate economic, social and environmental results for project portfolio selection. The main contributions of this model, compared to other models that evaluate project risks, such as Foo and Murugananthan (2000) and Schmitz *et al.* (2006), are: i) financially quantifying the risks and their impacts, while the literature models focus only on the risks criticality and the projects' success probability; ii) measure financially the social and environmental impacts involved in the projects; and iii) stochastically optimize the project portfolio based on their uncertainties and risks.

The application of the model was conducted in six steps, shown in Figure 1. The elements that are part of the model are shown with the application results in Appendix A (available at https://docs.google.com/document/d/1VsrxyWPLfBWAh07fu9CIWLi0dahe56TD4jY4-AxCV48/pub). The description of each step is presented below.

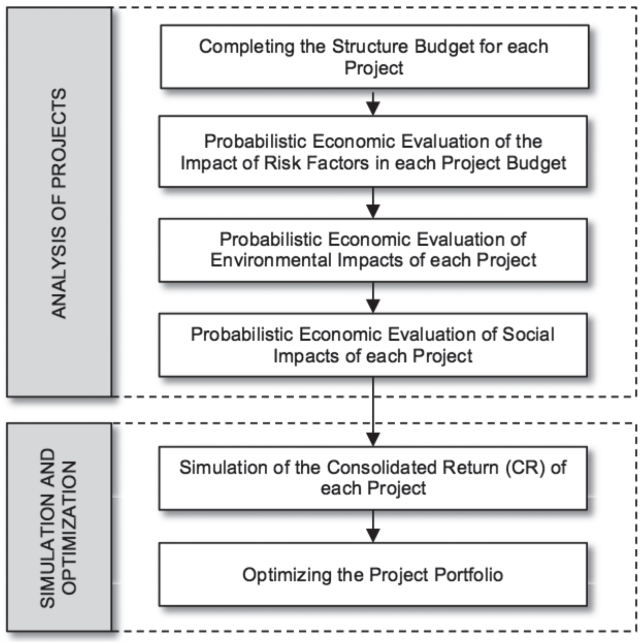

Figure 1. Model steps

Completing the structure budget for each project

The first stage of the model consisted of filling the budget structure for each of the projects that make up the portfolio. The budget involves meeting several criteria that represent the benefits and costs of the project. The choice of criteria was based on the studies developed by Dutra *et al*. (2014). The fulfillment of these criteria was conducted by consensus of several experts involved in the project analysis, which indicated the most likely present value (PV) for each criterion of benefits and costs of the project.

Probabilistic economic evaluation of the impact of risk factors in the budget

The selection of risk factors to be assessed was based on the study of Miorando *et al*. (2014), adjusting the context of enterprise project portfolio. The probabilistic economic evaluation of the impact of risk factors on the criteria of the budget was made based on the knowledge and experience of the analyst. First, the analyst assessed the likely effects of risk factor and its economic impact on the project budget. Then, the analyst assessed the possible impact of this variability, indicating the economic impact for the worst and best-case scenarios. The values for the best and worst case scenarios were estimated, predicting a confidence interval of 90% to the expected impact. Namely, a probability of 5% considers that the impact occurs below the expected value for the worst-case scenario. Similarly, it may be equally likely that the impact occur above the estimate for the best-case scenario.

The impact of risk factors may have a negative or positive effect. When negative, this is associated with losses or adjustments not included in the project. When positive, it may be associated with new revenue opportunities or favorable situations that reduce the expected loss. As for the likely value to impact, it is usually indicated as zero, unless the effect of a given factor is inevitable and has not been considered during the filling of the budget.

Probabilistic economic evaluation of environmental impacts of each project

As well as in assessing the impact of risk factors, the probabilistic economic evaluation of environmental impacts was also performed based on the knowledge and experience of the analyst. The analyst economically assessed six environmental criteria: (i) material consumption; (ii) power consumption; (iii) natural resources consumption; (iv) waste generation; (v) emissions of gases and (vi) liquid emissions. The estimated economic impact for each environmental criterion was supported by a calculation script based on environmental indicators proposed in studies of Rossini *et al.* (2013) and Teles (2012). In this calculation script, data from company were necessary, linked to the materials consumption, amount of water and energy used in the project, as well as the amount of waste, emissions and wastewater generated by the project, among others. Similarly, some criteria also had an impact factor (multiplier factor) to consider the environmental impacts caused by the project, depending on the various alternatives considered (e.g., use of renewable, non-renewable or recycled materials, use of non-renewable, renewable of medium impact or low-impact energy, use of natural, ground or treated sewage water, etc.). In such cases, the analyst indicated the impact factor used in estimating the environmental criteria.

Other environmental criteria required cost values that could be obtained by searching the literature or could be estimated by experts, such as, for example, costs associated with the impact of CO_2 and of SO_x / SO_2 emissions. In order to consider the uncertainty in the measurement of environmental criteria, the analyst pointed estimates for the likely value of the environmental impact, the value for the worst and best-case scenarios. These last two values provide, as well as in assessing the impact of risk factors, a confidence interval of 90% for the true value of the environmental impact.

Probabilistic economic evaluation of social impacts of each project

The probabilistic economic evaluation of social impacts followed the same procedure performed for the evaluation of environmental impacts, supported by a calculation script based on studies of Rossini et al. (2013) and Teles (2012). However, the analyst assessed eight social criteria: (i) health and safety; (ii) employment generation; (iii) training and skills; (iv) noise pollution; (v) visual pollution; (vi) population migration; (vii) social development programs; and (viii) contract with local suppliers. In the script for calculating social criteria, data from the company were also needed, linked to investment in employee training, investment in health and safety practices, new job opportunities planned for in the project, among others.

Just as in the environmental evaluation, the analyst pointed estimates to the likely value of social impact for the value for the worst and best case scenarios, in order to consider the uncertainty in the estimation of impacts. Depending on the criteria analyzed, the estimates may generate positive or negative values, respectively representing social gains or losses generated by the project.

Simulation of the Consolidated Return (CR) of each project

Once the economic, social and environmental evaluation of each project was held, the Consolidated Return (CR) for each project was determined. CR represents the monetary balance of the Economic Return (ER), the Environmental Impact (EI) and Social Impact (SI) generated by the project. The Economic Return (ER) of each project was estimated through a stochastic simulation. The simulation was performed considering the estimates of the risk factors (worst-case scenario, probable value and best-case scenario) as a triangular probability distribution. Thus, each deterministic criteria value of the budget (benefits and costs) was added to the values of triangular distributions of economic risk factors belonging to these criteria. The process was performed using the Monte Carlo method (a broad class of computational algorithms that rely on repeated random sampling to obtain numerical results). By tallying the impact of the risk factors to the value of each criterion of the budget, the values of the risk-adjusted criteria were gotten, represented by probability distributions. The sum of these probability distributions, held by the simulation, generated risk-adjusted net present value (NPV) or net present worth (NPW) of the project, a probability distribution that represents the ER of the project.

Further, the economic value of the Environmental Impact (EI) and Social Impact (SI) of the project were estimated, from the same stochastic simulation. The simulation considered each estimative of the environmental and social criteria (worst-case scenario, probable value and best-case scenario) as triangular probability distributions. Thus, the values of Environmental Impact (EI) and Social Impact (SI) were obtained by adding the triangular probability distributions of the environmental and social criteria, respectively. Finally, the Consolidated Return (CR) of the project was determined, from the consolidation of the ER, the EI and SI of the project, according to Equation 1. The Consolidated Return (CR) is also represented in terms of probability distribution.

$$CR_i = ER_i \times F_{ER} + EI_i \times F_E + SI_i \times F_S \quad (1)$$

Where:
CR_i= Consolidated Return of the project i;
ER_i = Economic Return of the project i, given by the NPV of the project *i* adjusted to the risk;
F_{ER} = economic weighting coefficient;
EI_i = Environmental Impact of the project *i;*
F_E = environmental weighting coefficient;
SI_i = Social Impact of the project *i*;
F_S = social weighting coefficient.

The weighting coefficients F_{ER}, F_E e F_S could take values between 0 and 1, depending on the importance attributed by the analyst or by the company, to each of the economic, social and environmental aspects in the evaluation of projects.

Project portfolio optimization

The calculation of the optimal portfolio was performed seeking to maximize the Consolidated Return (CR) of the portfolio (Equation 2). The solution for the optimal portfolio was achieved with the use of linear programming. Besides the objective function that maximized the CR of the portfolio (Equation 2), the constraints identified by the analyst were also considered. These restrictions were arbitrage free and could control the availability of resources, deadlines of conclusions, mandatory project, etc. A solution that offered the highest value for the objective function and meets all restrictions would be identified as the optimal solution.

$$Max(CR) = \sum_{i=1}^{n} P_i(CR_i) \quad (2)$$

Where:

Pi = variable indicating project i status. It could take a value of 1 (project i was selected for the solution) and value of 0 (project i was not part of the solution).

During the simulation of the economic return risk adjusted for the projects, at each draw held by the Monte Carlo method, the model ran a new problem of linear programming to seek a new optimal solution. As a result, there was a histogram of the optimal solutions (charts of relative frequency) showing how often they occur while the values of ER, EI and SI vary for each project. The solution that was repeated more times would be the most robust one against the risk and variability of the environmental and social impacts. The generated histogram showed the combination of projects that optimizes the portfolio.

RESULTS

The application was performed in a Brazilian company distributing electricity. Before beginning the test, a meeting for presentation of the model took place, defining the portfolio of projects for implementation and time horizon of analysis. The portfolio of selected projects was related to the expansion of the supply of electricity in a town in the south of the country and the analysis horizon was set in ten years. The practical test was performed in six four-hour meetings with the participation of a team of eight decision makers from different areas of the company (management, financial, engineering, environmental, HR).

A set of six candidate projects was assessed, being three of substations (with different locations and powers) and three projects of transmission lines (with different capacity and configurations). The analysis sought to maximize the return for the execution of a substation and transmission line, selected among six candidate projects. The completion of the practical application in the scenario presented above is justified by the degree of uncertainty involved in the selection of projects, mainly related to technical difficulties and estimated growth of electricity demand over time. The set of selected projects is diverse in terms of costs, benefits and environmental and social impacts, which also complicates the selection step. It should be noticed that the values presented have been manipulated to maintain the confidentiality of the company analyzed.

Analysis of projects

The first stage consisted in the analysis of projects. To do this, the filling out of the budget structure and the probabilistic economic evaluation of the impact of risk factors in the budget, the environmental and social impacts of each project were conducted. An example of a project analysis (economic, social and environmental) is available in Appendix A (https://docs.google.com/document/d/1VsrxyWPLfBWAh07fu9CIWLi0dahe56TD4jY4-AxCV48/pub).

The second stage included the simulation and optimization of the company's portfolio of projects analyzed. From the analysis of the projects, a stochastic simulation was held, using the Monte Carlo method for 1000 iterations (that allows the design of accurate histograms), to obtain the Economic Return (ER), the Environmental Impact (EI), Social Impact (SI) and the Consolidated Return (CR) of each project, calculated according to Equation 1. The company analyzed considering the importance of sustainable aspects to its strategic positioning, defined an economic weighting coefficient (F_{ER}) equal to 0.5, environmental (F_E) equal to 0.3 and a coefficient of social impact (F_S) of 0.2.

The simulation results generated graphics of ER, EI, SI and CR. In Figure 2, it is observed that the average CR in ten years for project P1 is U$ 8,284,757.64 and, in addition, there is a probability of approximately 100% of the project having a positive ER (ER > 0). This result indicates that although the project could generate a negative environmental impact (U$ -7,451,342.89), the economic (U$ 19,749,654.87) and social benefits (U$ 3,226,665.35) would offset this impact. The same analysis can be performed for each project of the company's portfolio.

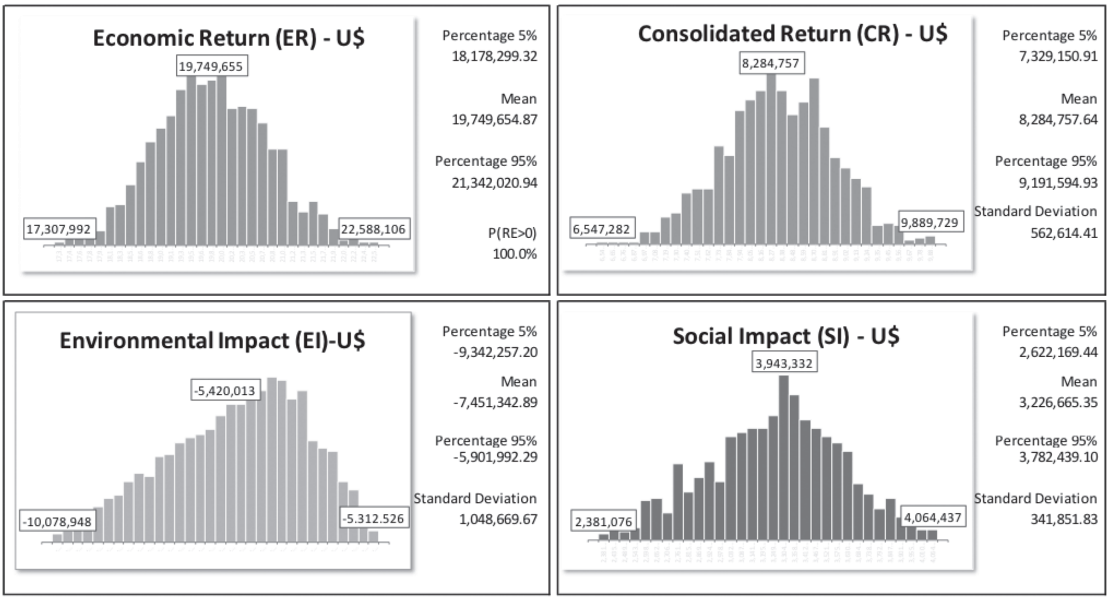

Figure 2. Results of the Simulation for Project 1

It can be noticed that the results of the CR for each project do not represent the actual return of the company with these projects because the social and environmental impacts are values that do not enter the cash flow of the company. However, the CR is indicative of the contribution of each project to sustainability.

The calculation of the optimal portfolio was performed seeking to maximize the Consolidated Return (CR) of the portfolio, from Equation 3. For each scenario generated in the Monte Carlo simulation, the model executed a linear programming problem to find the optimal solution.

$$Max(CR) = \sum_{i=1}^{6} P_i(ER_i \times 0{,}5 + EI_i \times 0{,}3 + SI_i \times 0{,}2) \tag{3}$$

Besides the objective function, the analyst considered, in linear programming, the constraints presented below (Equations 4 and 5).

$$P_1 + P_2 + P_3 = 1 \tag{4}$$

$$P_4 + P_5 + P_6 = 1 \tag{5}$$

The first constraint indicates that only one project, among projects P1, P2 and P3 (associated with new substations) can be performed. Likewise, the second constraint indicates that only one project among options P4, P5 and P6 (associated with transmission lines) is to be performed. The result of the optimization of the portfolio is represented by the histogram in Figure 3, which shows the combination of projects that optimizes the portfolio.

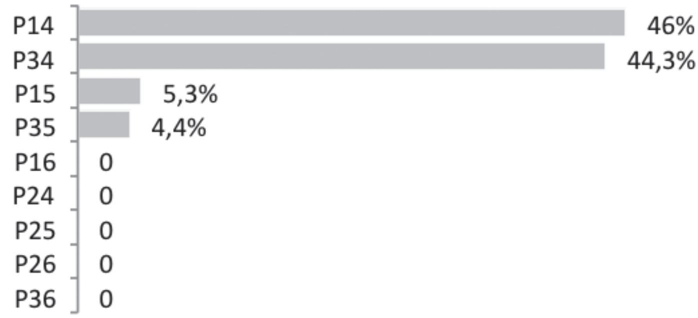

Figure 3. Optimized portfolio

Analyzing Figure 3, it may be observed that the most frequent solution (46%) indicates the execution of projects P1 and P4 that would optimize the project portfolio of the company analyzed. For this optimal combination, results from ER, EI, SI and CR are shown in Figure 4.

In Figure 4 it may be observed that the average Consolidated Return (CR) of the optimized portfolio for the analyzed company is U$ 9,920,291.94 in ten years, with a standard deviation of U$ 916,074.35. Although projects P1 and P4, optimize the company's portfolio with a negative environmental impact of U$ -11,521,176.39 (generated mainly by the materials consumption), social benefits (job creation) of U$ 5,233,331.96 and the economic return (U$ 24,659,956.93) monetarily compensate the environmental damage. Besides, it is observed that the ER of the optimized portfolio presents 100% of probability of being positive P (ER > 0). From the results obtained, it can be concluded that the analyzed company must prioritize projects P1 and P4, as they optimize the portfolio and minimize the risk.

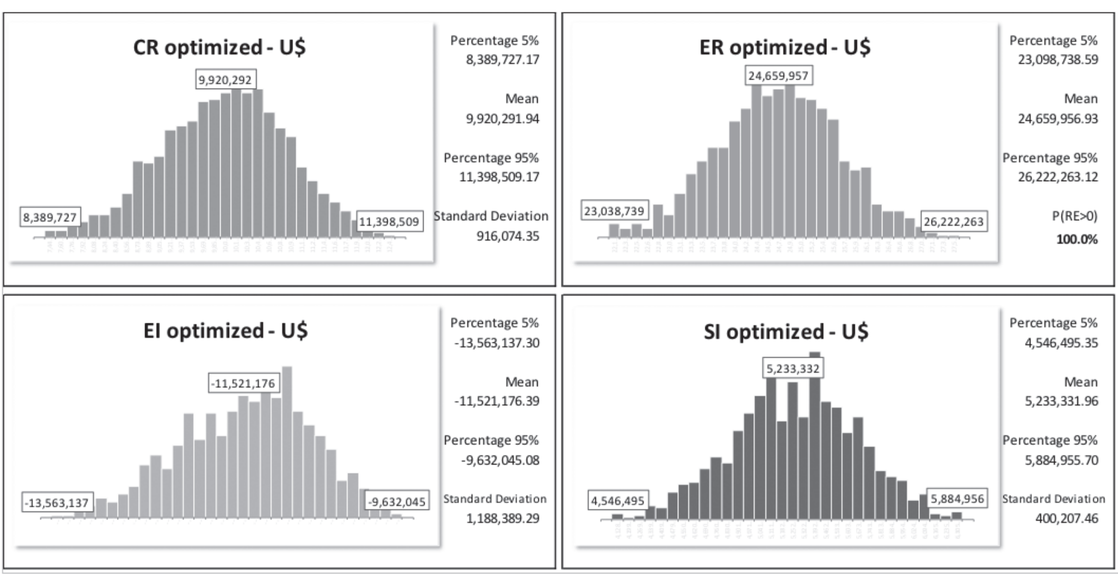

Figure 4. Results of the optimized portfolio (combination of Projects P1 and P4)

ANALYSIS OF RESULTS

With the completion of the practical test, it was possible to observe some important features that emerged from the interaction between the presented methodology and the analysts as discussed next. The use of monetary values to quantify project risks, their social and environmental impacts, provided a thorough review of the cash flow of each project, favoring the identification and correction of potential flaws in their completion. The inclusion of environmental and social aspects in the decision-making process provided a better alignment of the company's portfolio with its strategies. The evaluation of environmental and social impacts was facilitated by the calculation scripts included in the model, helping analysts in completing estimates. However, to estimate the costs involved in the calculation of some criteria, it was necessary to employ specialists in the environmental area and social responsibility, demanding greater amount of time to complete the project analysis form.

In addition, an important learning acquired by analysts about the details of the projects and the awareness of the difficulties and threats concerning their economic, environmental and social returns was observed. The process of identifying the risks involved and the quantification of impacts in monetary values generated discussions that explored the details of the project and revealed many opportunities and threats that were previously not considered.

Similarly, while filling the structure of risk evaluation structure, the values that quantify the impact of risk factors often refer to the cost of the solutions to the contingencies related. Thus, the reasoning used in the analysis also helps in the development of contingency plans for preventing the occurrence of the analyzed risks.

As mentioned earlier, most companies in electricity sector still follow primarily strategic and cost/benefit oriented approaches in their internal project portfolio management. The integration of approaches constitutes an alternative to select projects and define optimal portfolio for sustainable development in business contexts characterized by uncertainties. The financial language used in the used model is easily understood and has a concrete meaning for both management and technical staff.

The integrated project portfolio evaluation and optimization approach used in the case study was adequate for the company studied and could be reapplied in large companies with a diversified portfolio of projects involving high investments and uncertainties that could generate environmental and social impacts. However, in less complex business environments it would not be appropriate to use this approach, since the use of techniques such as Monte Carlo simulation and linear programming would make the decision-making process very complex unnecessarily,

Our results confirms studies in literature (e.g., Dobrovolskienè and Tamošiunienè, 2016; Siew, 2016; Neumüller *et al*., 2016) regard to the integration of sustainability aspects to the return and risk criteria in the structure of the project portfolio analysis. The researchers used integrated approach in context of construction and automotive companies.

CONCLUSIONS

This research paper aimed to carry out the practical application of an integrated model for probabilistic evaluation and optimization of project portfolio, which allows the economic impact evaluation of the risks and factors of social and environmental aspects involved in projects, using the simple and understandable unit of measure commonly used by companies, the currency. The use of the monetary unit enables direct comparison in homogeneous bases of different project alternatives. The result of the consolidated return of the optimal portfolio, represented as a probability distribution, allows decision makers to easily evaluate the risk level of the portfolio without the need for specific knowledge or dependence on an expert's statistical area.

The model applied allows driving the economic, social, environmental and risks analysis, integrated to the portfolio analysis, a feature still deficient in literature. Additionally, it considered Monte Carlo simulation and linear mathematical programming for the definition of the optimal portfolio, which is its major contribution to the evaluation and optimization of projects. The use of linear programming enables the inclusion of a large amount of information simultaneously to maximize the consolidated return, incorporating restrictions hardly identified when performed only upon ranking projects.

With the completion of the practical test, it was possible to observe some important features that emerged from the interaction between the presented methodology and the analysts. The use of monetary values to quantify project risks, their social and environmental impacts, provided a thorough review of the cash flow of each project, favoring the identification and correction of potential flaws in their completion. The inclusion of environmental and social aspects in the decision-making process provided a better alignment of the company's portfolio with its strategies. However, to estimate the costs involved in the calculation of some criteria, it was necessary to employ specialists in the environmental area and social responsibility, demanding greater amount of time to complete the project analysis form.

In addition, an important learning acquired by analysts about the details of the projects and the awareness of the difficulties and threats to stop their economic, environmental and social returns was observed. The process of identifying the risks involved and the quantification of impacts in monetary values has generated discussions that explored the details of the project and identified many opportunities and threats that were previously not considered.

Similarly, while filling the structure of risk evaluation structure, the values that quantify the impact of risk factors often refer to the cost of the solutions to the contingencies related. Thus, the reasoning used in the analysis also helps in the development of contingency plans for the occurrence of the analyzed risks.

This practical work considered a small number of projects; therefore, it is important to perform other applications of the model in companies with a larger number of them in the portfolio. The development of a software for the operationalization of the model facilitate their use as a management tool for the evaluation and optimization of projects portfolio in companies. The analysis carried out in this test considered as time horizon of ten years. It is suggested for future work other applications considering the life cycle of projects and products generated and the inclusion of risk mitigation alternatives in the analysis.

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