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Economic feasibility analysis for co-generation of power by diesel generator at peak time: Monte Carlo simulation approach in a hospital

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ABSTRACT. The cost of electricity in hospitals represents a significant portion in its context of operating expenses. Therefore, it is important to constantly think about ways to reduce this cost without losing the quality and reliability required for hospital care activity. It is well known, that reducing electricity consumption has a direct impact on the effective management of hospital cash flow, so it is imperative to rationalize this resource. In this context, the objective of this paper focuses on analyzing the economic feasibility of purchasing and using a diesel generator to find the peak hour demand and verifying financial uncertainty by applying a Monte Carlo simulation approach to risk analysis. The target hospital of this research is located in southeastern of Brazil and it is part of a foundation that covers educational and assistance activities, serving the local population and thousands of patients during the year. Finally, the economic risk analysis applied through the Monte Carlo simulation found that the acquisition of the aforementioned diesel generator has a very high probability of viability. Therefore, it is verified that the investment is viable and attractive from the hospital's economic and operational point of view, while the Net Present Value remains positive, with the expected value of R$ 868,358.84, considering the risk and uncertainty analysis having an attractive internal returning rate of 78.76% per year.

Keywords: Monte Carlo simulation; economic risk analysis; diesel generator; net present value, health care.

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Introduction

Electricity expenditures in hospitals are significant within their context of operating costs; representing around 2.5% of total hospital costs (González, Calcedo, & Salgado, 2018). Therefore, it is important to think regularly about ways to reduce this value without losing the quality and reliability required for the activity. It is well known that reducing these costs has a direct impact on the effective management of hospital cash flow.

The target hospital for this research, located in the south of the state of Minas Gerais, Brazil, it is part of a foundation that covers educational and assistance activities, serving the local population and thousands of patients throughout the year. Thus, this work is understood as having an essential social character, aiming at reducing costs for the aforementioned organization to obtain better results. With this, this organization can improve the rationalization of its scarce and finite resources. Accordingly, the aim of this paper focuses on analyzing the economic viability of purchasing and using a diesel generator to meet the demand for peak hour and analyzes the financial risk for investors and lenders by applying a Monte Carlo Simulation approach to risk analysis. It is important to emphasize that, according to (Pimm, Cockerill, Taylor, & Bastianns, 2017; Zaroni, Maciel, Carvalho, & Oliveira Pamplona, 2019) electric generators are widely used as emergency power sources, preventing some installations from experiencing sudden power outages. They can also be used to reduce grid energy demand by providing electricity during peak periods. In other words, the proposed approach has already been corroborated by other studies.

It is also possible to see that the use of Monte Carlo Simulation in the economic viability analysis is wide, including several studies related to the use and production of energy, and there are recent examples in the literature with applications of this analysis for biorefinery related works (Wang, Ou, Brown, & Brown, 2014), electric vehicles (Gough, Dickerson, Rowley, & Walsh, 2017), ethanol production (Rezende & Richardson,

2015) and wind energy (Aquila, Oliveira Pamplona, Queiroz, Rotela Junior, & Fonseca, 2017b; Rocha et al., 2018). However, Urbanucci and Testi (2018) also demonstrate that this can be employed in the context of energy risk management.

Finally, the present work is divided as follows: materials and methods, where some essential concepts and mathematical formulas are presented; results and analyzes, in this part evidences and facts are presented, discussed and concluded.

Material and methods

Until now, Monte Carlo simulation techniques have rarely been used within the context of hospital infrastructure risk management. For the application of this technique, it was necessary some important definitions such as probability density for random input variables and confusing or uncertain design and prediction parameters that were conceived in this research. Regarding this technique, it is relevant to say that its objective is to analyze financial investment situations with excellence (Arnold & Yildiz, 2015).
Based on Yin (2015) it can be stated that this research is descriptive since a phenomenon was observed during a specific time and the nature of the study was quantitative using statistical techniques, as well as the aforementioned Monte Carlo simulation. Below, some essential concepts applied in this research will be presented sequentially. Figure 1 shows this structure briefly.

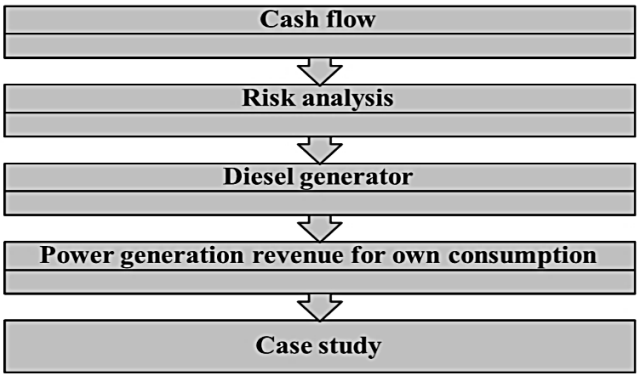

Figure 1. Presentation of the sequence of concepts and formulas used.

Cash flow

The basic idea of an investment project, according to Ross, Westerfield and Jordan (2008), is to create value for the owners of capital. Investment analysis is performed through the cash flow appreciation of the production systems to be described. For this, as a first step, disbursements or transfers are organized and scored. The outputs will then be used to construct cash flows that are the judicious organization of the inflows and outflows for each production system. Cash flow is divided into three parts (Ross et al., 2008), and the formula for calculating it is given by Equation (1).

$$CF = OCF - \Delta NWK - KE \quad (1)$$

where: CF = Cash Flow; OCF Based on cash flows, the project viability indicators presented below will be calculated.

Net Present Value (NPV) corresponds to the algebraic sum of cash flows in each period discounted at a discount rate, which is considered one of the easiest ways to understand, convince and top into practice (Arnold & Yildiz, 2015). NPV is calculated according to Equation 2 (Diana, Hidayat, Rafikasari, Ibrahim, & Farida, 2019).

$$NPV_0 = \sum_{\tau=1}^{T} \frac{CF_\tau}{(1+r)^\tau} \quad (2)$$

where: NPV_0 = Net Present Value at time 0; $CF\tau$ = Cash flow at time τ, Considering all inputs and outputs referring to the same; r = Discount rate; and T is the number of periods in the flow.

An investment project is considered financially viable when its NPV is positive. The advantages of NPV, according to Ross et al. (2008), is that this method informs if the investment will add value to the company considering the monetary value over time, besides the risk included in the rate of return (*r*).

Another widely used indicator is the Internal Rate of Return (IRR), which is the rate that makes the NPV equal to zero (Gitman, Juchau, & Flanagan, 2015). That is, the IRR is the value of the discount rate*r*that ensures the following equality is guaranteed (Equation 3).

$$0 = \sum_{\tau=1}^{T} \frac{CF_{\tau}}{(1+r)^{\tau}} \tag{3}$$

where: CFτ is the cash flow at time τ and *r* is the discount rate.

Thus, the IRR is compared to the rate of returning used in the project. If it is higher than the minimum attractiveness rate, the investment is approved. Despite the high acceptability of IRR for its ease of understanding, it presents serious problems, such as multiple responses when working with unconventional cash flows (which have more than one signal change), and induces imperfect decisions when analyzing mutually exclusive designs (Patrick & French, 2016).

Briefly, it can be stated that the Capital Asset Price Model (CAPM), describes, under equilibrium, the return on assets (Kisman & Shintabelle Restiyanita, 2015), whose formula is shown in Equation 4.

$$CAPM = R_f + \beta\left(R_m - R_f\right) \tag{4}$$

where: CAPM = Capital Asset Price Model; R_f = Risk-free Rate; R_m= Market return rate; β = Systemic risk. It is given by the formula: $\frac{COV(Rm;Ra)}{VAR(Rm)}$, where R_a = Return of the Asset in analysis, or alternatively: $R_a = \alpha + \beta R_m$.

According to Gitman et al. (2015), the beta coefficient is determined by identifying in the market organizations that can be classified as benchmarks, that is, organizations that perform similar activities that will serve as guides for the calculation of the index.

As the feasibility analysis proposed by this paper takes into consideration that the organization is installed on its own national ground, the most common is to consider the risk-free rate as Selic, which corresponds to the basic interest rate of the Brazilian economy, and the rate market returns as the return of the São Paulo Stock Exchange Index (Ibovespa).

Another important concept that will be employed in this article is the cost of capital (K_d) which is given by the weighted average interest rate of the long-term liabilities of the organization. Thus, considering the CAPM and the K_d, the Weighted Average Capital Cost (WACC) can be calculated using Equation 5 (Magni, 2015).

$$WACC = \frac{D}{D+E} K_d(1-T) + \frac{E}{D+E} K_e \tag{5}$$

where: D = Long Term Debts; E = Equity Capital; K_d = Cost of the Long Term Debt; K_e = Cost of the Equity Capital (CAPM); T = Income Tax.

For this work, as the organization under analysis has long-term debt, the WACC will be used as the cash flow discount rate.

Risk analysis

In all economic engineering analyses, the risk inherent in the investment must be taken into account. When placing capital in profitable, but risky activity, it is essential to perform a sensitivity analysis, which indicates which range of risk (high) there is a need to refine your estimates, while for others (low), the first approximations are enough Arnold and Yildiz (2015).

This work uses the Monte Carlo simulation technique (MCS) and according to Arnold and Yildiz (2015) followed for the implementation of the technique are cash-flow construction; elaboration of a model with the main uncertainties related to the cash flow analysis variables, using probability distributions; determining the relationships between variables since most of the cases, random variables are dependent and perform the simulation. In the last step, several sampling processes are generated, considering the correlations between the variables. For each sample, the indicators of economic and financial analysis are calculated. This procedure should be repeated until the fluctuations in output distribution values are small.

The Risk R of the NPV project being negative can be represented by the Equation 6 (Arnold & Yildiz, 2015; Zaroni et al., 2019).

$$R_{NPV<0}(x_1, \dots, x_n, r) = \int_{-\infty}^{0} pdf(NPV)dNPV \quad (6)$$

where $R_{NPV<0}$ represents the accumulated probability of negative NPVs in the project; pdf (NPV) is the probability density function of the NPVs in the project, and Xi denotes the random variables of the project.

Diesel generator

The use of diesel generators has several advantages, such as low investments, mobility, and the possibility of combination with others energy sources, which can be a robust alternative for power generation (Ameen, Pasupuleti, & Khatib, 2015). Equation 7 is used to calculate the estimated fuel consumption of the diesel generator.

$$CD_G = a \times P_G + b \times P_{R-G} \quad (7)$$

where: CD_G = Fuel Consumption Estimated; P_G = Output Power of the Generator; $P_{R\text{-}G}$ = Nominal Power of the Generator; a and b = Consumption Rate of the Generator. This value may vary depending on the model and the manufacturer (Aquila, Rotela Junior, Oliveira Pamplona, & Queiroz, 2017a), being 0.246 and 0.08145 common, respectively (Ameen et al., 2015; Ismail, Moghavvemi, & Mahlia, 2013).

Another factor of the financial expense of the generator is its maintenance and operation cost, which can be calculated mathematically according to Equation 8 for 1500 rpm and 50 Hz generators (Museli, Notton, & Louche, 1999).

$$C_{O\&M} = \frac{[(0{,}242 + 0{,}3505.P_{R-G}) \times 15{,}2 + 120{,}8]}{600} \quad (8)$$

where: $C_{O\&M}$ = Maintenance and Operations Cost of the Generator (per/hour), calculated in US Dollar; $P_{R\text{-}G}$ = Nominal Power of the Generator.

The total operating cost of the generator is comprised of the sum of the hourly fuel costs and the hourly maintenance costs times its usage time. This relation is represented by Equation 9 below.

$$C_{Total} = \sum_{m=1}^{12} C_{M\wedge O} \times t_m + C_D \times \sum_{m=1}^{12} CD_G \times t_m \quad (9)$$

where: C_{Total} = Total Annual Cost of the Generator; C_D = Fuel Cost; t_m= Machine Operator time per month.

Power generation revenue for own consumption

The revenue from this project is given by the energy produced by the generator and the current price of kWh provided by the grid. Equation 10 and 11 show the monthly and annual revenue, respectively, with the use of the generator (Zaroni et al., 2019).

$$R_{(m)} = \begin{cases} E_r \times e_p se E_r < E_G \\ E_G \times e_p se E_r > E_G \end{cases} \quad (10)$$

$$R_{year} = \sum_{m=1}^{12} R_{(m)} \quad (11)$$

where: $R_{(m)}$ = Monthly Revenue by the Generator; R_{year}= Yearly Revenue by the Generator; E_r= Monthly Energy Demanded by the unit in analysis; E_G = Energy to be produced by the Generator; e_p= The Price per kWh of the net electricity price. Zaroni et al. (2019) further point out that the generator energy production follows Equation 12.

$$E_G = P_G \times t \times \eta \quad (12)$$

where: E_G = Energy Produced (kWh); P_G = Output Power of the Generator (kW); t = operation time of the generator by hours; η = generator efficiency.

In addition to revenue, flow is affected by taxes and fees charged on the energy tariff. If the generator is used for its own generation, it will no longer bear the taxes proportional to the purchase of electricity from the grid, so they are considered an additional saving or cash inflow to the project. For this work, we considered as proportional taxes COFINS (acronym in Portuguese for Contribution to Social Security Financing) and PIS/PASEP (acronym in Portuguese for Social Integration Programs/Civil Servants Asset Development Program), which are incorporated into the energy tariff in varying percentages according to the utility's revenues, and the income tax (IR), charged on profit before taxes.

Case study

The present study was developed in partnership with a Brazilian regional hospital, aiming at economically evaluating the installation of a diesel generator to supply the hospital demand at peak hours. In this hospital, the emergency response network is recognized and classified as a multipurpose, for providing comprehensive care, equity, and efficiency of management and care. It currently serves 16 micro regions in the state of Minas Gerais, corresponding to 191 municipalities with an estimated population of 3,500,000 inhabitants. Its service demand has been growing in recent years without the proportional growth of the hospital's capacity.

Results and discussion

As can be seen in Table 1, considering an average of the two years under review, the hospital's capital structure is 94.58% third-party capital, while long-term assets are funded by 5.43% equity, having a debt/equity ratio of 26.29. In this way, we can see a financial situation that does not allow the acquisition of new financing, even for investments, as the costs of bankruptcy may increase even more.

Table 1. Balance Sheet of the hospital under analysis.

	Health activity				
Assets	2018	2017	Liabilities	2018	2017
Current assets			Currente liabilities		
Cash and cash equivalents	10,880,133	3,992,222	Loans and financing	6,509,069	12,332,059
Tables and mobiliarios values	163,220	1,908,479	Providers	11,343,405	9,496,608
Monthly payments receivable	-	-	Social obligations and holiday provisions	6,511,867	6,518,700
Agreements receivable	19,964	6,530	Taxes and contributions to collect	555,592	553,290
Hospital care to receive	18,867,397	21,561,728	Other obligations	545,210	486,130
Agreements to receive with restriction	4,852,634	4,260,728	Project resources running with constraint	6,652,624	6,167,414
Stocks	2,191,874	1,528,208	Total current liabilities	32,117,767	35,554,201
Other credits	409,551	3,902	Noncurrent liabilities		
Prepaid expenses	2,298	3,902	Loans and financing	46,243,198	25,368,951
Total current assets	38,907,071	33,660,827	Providers	-	152,507
Noncurrent asset			Other obligations	-	-
Long term achievable			Provision for legal claims	2,824,589	1,960,174
Prepaid ecpenses	-	-	Total noncurrent liabilities	49,067,787	27,481,632
Agreements to receive	419	419	Free equity		
Judicial deposits	9,259	101,806	Social heritage	5,494,141	5,494,141
Immobilized	51,390,502	50,552,788	Revaluation reserve	11,800,670	11,912,536
(-) Accumulated ecpenses	(15,892,661)	(990,610)	Accumulated deficit	(22,730,429)	9,059,086
Intangible	2,733,715	2,272,894	Total equity	(5,435,618)	(8,347,591)
(-) Accumulated amortizations	(1,398,369)	(990,610)	Total liabilities	75,749,936	71,383,424
Total noncurrent assets	36,842,865	37,722,597			
Total assets	75,749,936	71,383,424			

Source: Own Elaboration.

Thus, it was decided to calculate the rate of return, considering only the equity invested in the acquisition of the diesel generator. Table 2 presents the criteria for calculating the organization's CAPM and WACC.

According to the criteria presented, the return rate applied for the specification of the economic and financial viability analysis indicators was the CAPM, which presented a value of 5.99% a year.

Table 2. Parameters to calculate the Rate of Return.

Variable	Parameter	Variable	Parameter
Rf (5 years)	9.75%	IPCA	5.06%
Rm (Ibovespa - 5 years)	15.43%	CAPM	12.22%
β (Health sector Companies)	0.44	CAPM Real	5.99%
K_d	6.26%	WACC	6.25%
Third-party Capital	94.58%	WACC Real	1.32%
Equity	5.43%		

Source: Own Elaboration.

Investments

For this work was considered the purchase of a model SWY400 generator, 60 Hz, and 505 kVA of power. This model was chosen due to the availability of technical assistance in the region and to supply the hospital's energy demand. The estimated cost of acquisition of this generator with freight and installation components is R$ 180,000.00 (Real is the Brazilian currency and represented by R$), which R$ 155,000.00 per generator and R$ 25,000.00 for components required to installation. Since mid-2015, a dollar is equivalent to values ranging from 3 to 4 reais most of the time. During the period of this study, one dollar was equivalent to 3.84 reais.

It is worth to mention that there is already a generator on-site and all the necessary installation and legal releases; however, the current generator is out of date and is not able to supply the demand. Also, it will be necessary to purchase components to connect to the generator ramp during peak hours, a value already included in the budget presented above.

Revenues

The regional hospital is classified in the Brazilian tariff category A4 Green, paying differentiated value at peak hours, between 5:00 p.m. and 8:00 p.m. Considering the demand and historical average rates can be outlined the annual revenue with energy was estimated at R$ 345,124.90, based on the average of the past three years. Besides, proportional taxes should be considered as input to the project flow, as the hospital will also stop paying the amount related to these taxes, being R$ 3,363.95 from PIS / PASEP and R$ 15,343.85 from COFINS, the related percentage taxes are outlined in Table 3. Because the object of this study is a philanthropic institution, income tax does not apply, as all results achieved must be reinvested to improve the services offered to the population.

Table 3. Model parameters.

Diesel Generator	Unit of measurement	Value	References
η	%	90	(Zaroni et al., 2019)
a	L/KW	0.246	(Ismail et al., 2013; Ameen et al., 2015)
b	L/KW	0.08145	(Ismail et al., 2013; Ameen et al., 2015)
$P_{R\text{-}G}$	KW	404	Manufacturer
Shelf Life	Years	10	Manufacturer
Diesel price	R$/L	3.708	(Agencia Nacional do Petróleo, Gás Natural e Biocombustíveis [ANP/GNB], 2019)
Generator price	R$/und	180,000.00	Manufacturer
Taxes			
COFINS	%	4.45	
PIS/PASEP	%	0.97	
T	%	-	
Others coefficients			
t	Hours	792	
e_p	R$/kWh	1.5433	
Real/dollar conversion	R$/$	3.84	

Source: Own elaboration.

Operational Costs

In addition to observe the project revenue, it is necessary to define operating costs. The generator has two cost sources, the cost of fuel and equipment maintenance and operation.

Fuel consumption is modeled by Equation 4, and considering the average cost of diesel in the Brazilian region of R$ 3.708, the annual fuel cost is R$ 184.311.40. The maintenance cost for this generator is already given by Formula VIII, which transformed to reais comes to an estimate of R$ 11,540.78.

Cash flow and economic valuation

The project's deterministic cash flow was projected for a 10-yeartime horizon (2019-2029) and an actual CAPM of 5.99% a year. For this project the NPV calculated is R$ 867,041.92 and an IRR of 78.76%, with the Project's Value at Risk (VaR) at 5% of R$ 595,071.70, thus proving to be viable from the deterministic view. Table 3 outlines some parameters used in the construction of cash flow.

Sensitivity analysis and Monte Carlo simulation

To analyze how sensitive a specific NPV calculation is, several scenario simulation hypotheses were used, in addition to the sensitivity analysis itself, to further examine the risks of the results obtained by applying the financial mathematics and finance tools. Crystall Ball Software® (release 11.1.2.2) was used for this purpose. This analysis is necessary because from this it is possible to distinguish two scenarios, the probability of the investment to be viable or to be unviable, that is, to try to answer the question 'What if?'.

By making the sensitivity analysis, one can infer which variables are responsible for the alleged fragility of NPV, that is, which factors are responsible for drastic changes in NPV, thus having the potential to make the investment unfeasible. Figure 2 presents the sensitivity analysis.

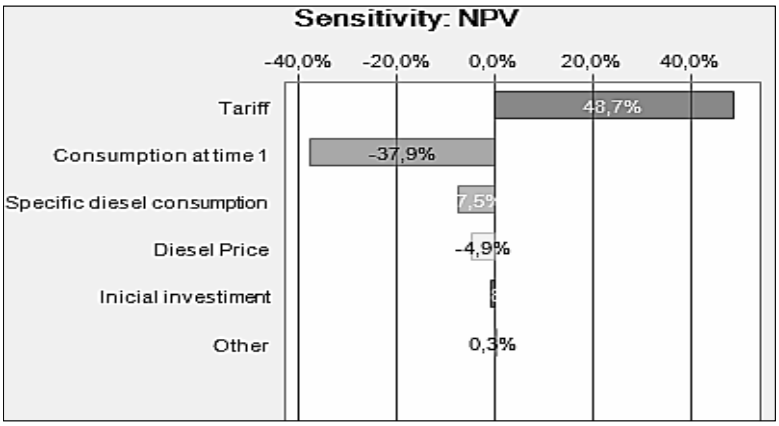

Figure 2. Sensitivity analysis.

The evidence of which variable has a significant impact on the NPV. It is the line with the highest angular coefficient. This is visible in the energy tariff, being the variable with the most significant impact on the project, consequently with the highest angular coefficient. After that, decreasing the impact, we have the energy consumption, price, and diesel consumption, and finally, maintenance cost and initial investment (generator price). These analyzes are supported by Monte Carlo simulation.

Therefore, for the variables with the most significant impact on the project, the inherent probability distributions were analyzed and defined. Thus, the probability distributions were defined, as shown in Table 4.

Table 4. Probability distributions.

Type	Distribution	Parameter
Specific diesel consumption (parameter α)	Triangular	Min: 0.22; Mode: 0.25; Max: 0.27
Diesel price	Lognormal	Location: 2.94; Mean: 3.70; σ: 0.10
Initial investment	Triangular	Min: 150000; Mode: 180000; Max: 210000
Energy tariff	Triangular	Min: 1.39; Mode: 1.54; Max: 1.70
Monthly Energy Consumption	Normal	Mean: 18635.29; σ: 2083.55

Source: Own elaboration.

As it seen, it was necessary to enter the behavior of variables through distributions to use Monte Carlo simulation. Choosing 10,000 iterations the result shows, within the estimated parameters, that there is a 100% chance of the project being viable, as shown Figure 3.

The average NPV was R$868,358.84 with a standard deviation of R$166,146.47. The maximum NPV calculated was R$1,442,991.63, while the minimum was R$217,230.03, confirming the feasibility of the project.

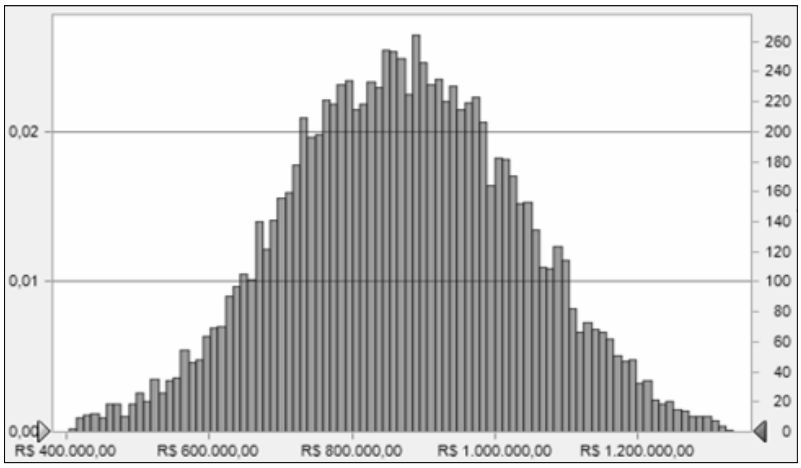

Figure 3. Histogram of Net Present Value for the analyzed project.

Conclusion

The objective of this paper was to analyze the economic and financial viability of purchasing and using a diesel generator to meet the demand for peak-hour energy from the regional hospital by applying a Monte Carlo Simulation approach to risk analysis. Considering the hospital's financial situation, it was decided to use the cost of equity in this project according to the results evidenced during this research. The actual CAPM of the hospital presented a value of 5.99% a year. Therefore, it is verified that the acquisition of this new generator has a positive NPV of R$868,358.84 with an IRR of 78.76%.

The economic risk analysis carried out through the Monte Carlo simulation verified that the acquisition of this diesel generator has a very high probability of viability. It is soon found that the investment is viable and attractive to the Brazilian hospital economy and operational point of view, while NPV remains positive in the face of risk and uncertainty analysis and has an internal rate of return above the organization's CAPM. Moreover, it is concluded that this type of analysis is possible and feasible in the hospital, and its operationalization results in significant savings. These positive and promising results that can be converted into improvements in other areas of the hospital unit, promoting better care to the population and, hence, increased patient safety.

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