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ORIGINAL ARTICLE

Economic feasibility analysis for insourcing hydraulic maintenance services using the Monte Carlo method

Análise de viabilidade econômica para a primarização de serviços de manutenção hidráulica pelo método de Monte Carlo

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Abstract: Maintenance plays an indispensable role in the productive sector of an organization. The increasing use of high-precision operations in the steel industry means that hydraulic systems demand greater attention. This study proposes an evaluation framework for analyzing the economic feasibility of insourcing hydraulic maintenance services, seeking to present tools for assisting managers in decision-making and optimizing maintenance strategies. This paper presents a cash flow study, where the Net Present Value (NPV), the Internal Rate of Return (IRR), and the Profitability Index (PI) are calculated. Subsequently, the Monte Carlo method is applied to perform a sensitivity analysis for viewing the probabilities and output results. The main contribution of this study is to enable the evaluation of the results considering the economic feasibility of insourcing or outsourcing maintenance contracts through the proposed framework. In this case, the economic viability of insourcing presents a cost reduction in maintenance services. This approach suggested an industrial case study, where the use of the Monte Carlo and cash flow methods are useful tools for decision-making, contributing to the optimization of resources among industrial managers.

Keywords: Maintenance; Hydraulic systems; Insourcing; Monte Carlo.

Resumo: A manutenção representa um papel indispensável no sector produtivo de uma organização. A crescente utilização de funções operacionais com alto nível de precisão na indústria siderúrgica, faz dos sistemas hidráulicos um dos itens que requer um maior índice de atenção. O objetivo deste estudo é efetuar uma análise de viabilidade económica para primarização de serviços de manutenção hidráulica, se tornando uma ferramenta para auxiliar os gestores na tomada de decisões, almejando otimizar as estratégias de manutenção. Este artigo apresenta um estudo de fluxo de caixa, onde é calculado o Valor Presente Líquido (VPL), a Taxa Interna de Retorno (TIR) e o Índice de Lucratividade (PI). Posteriormente utiliza-se o método de Monte Carlo para efetuar uma análise de sensibilidade, permitindo assim visualizar as probabilidades e resultados de saída. A principal contribuição deste estudo se dá pela utilização do *framework* proposto, o qual permite uma visualização da análise dos resultados, considerando a viabilidade económica para primarização ou terceirização dos contratos de

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manutenção. Neste caso, a viabilidade econômica de primarização apresenta uma redução de custos nos serviços de manutenção. Esta abordagem propôs um estudo de um caso industrial, onde a utilização dos métodos de Monte Carlo e do fluxo de caixa se tornam ferramentas úteis para a tomada de decisão, contribuindo assim para a optimização dos recursos por parte dos gestores industriais.

Palavras-chave: Manutenção; Sistemas hidráulicos; Primarização; Monte Carlo.

1 Introduction

According to Bustamante (2019), decision-making can play a vital role in an organization's strategy for companies that want to become competitive in an increasingly globalized market. Decision-making concerning outsourcing or insourcing is one of the significant daily decisions that companies face.

In answer to several transformations that have occurred over the years, such as increased competition based on low costs, extensive globalization, and demand-driven networks, organizations are increasingly aware of the necessity to readjust their strategies, focusing on generating value for customers (Moro et al., 2021).

As per Singh et al. (2023), the steel industry often is exposed to the most challenging manufacturing conditions like corrosive environments, erosion, wear, and high temperatures. All these factors directly affect the assets' operating performance, leading to high maintenance costs and production losses.

In steel plants, there is ever more sophisticated equipment that is related to random failures. The maintenance strategy of an organization is directly related to its objectives and the nature of economic and non-economic functions in an integrated way (Shahin et al., 2018).

According to Saad & Murray (2022), maintenance means a conjunction of all technical, administrative, and management activities during an asset's life cycle, intending to maintain or restore it to a state that can perform the function required. Successful maintenance management systems deliver the proper maintenance to the appropriate asset at the right time. Since a company's operating budget is heavily affected by maintenance costs, maintenance control plays a crucial role in minimizing costs for the operating team members.

Proper maintenance can not only extend the life of the equipment but also reduce the costs associated with industrial production. Every maintenance policy has strengths and weaknesses. Thus, some critical points require decision-making by the managers of organizations. In dealing with this, the Monte Carlo method simulation can help monitor the distribution of values, contributing to assertive decision-making (Foroozesh et al., 2022).

According to Dai et al. (2019), hydraulic systems are widely used in several industries due to a broad range of benefits, highlighting the control and transmission of energy. However, these systems are prone to several failures, which must be located and eliminated in time. Troubleshooting in hydraulic systems is a significant challenge in organizations. Through artificial intelligence, it is now possible to carry out diagnoses based on field signals, such as temperatures or pressures, for example (Torre et al., 2023).

Competitiveness results in continuous structural changes within industries, making them identify which activities should be performed internally or by outsourced companies. However, designating which maintenance activities should be insourced or outsourced may lead to decision-making with uncertainty, since maintenance can have a severe impact on the productive sector of an organization (Söderberg et al., 2017).

Considering this context, the main goal of this study is to propose an evaluation framework for analyzing the economic feasibility of insourcing hydraulic maintenance services, seeking to present tools for assisting managers in decision-making and optimizing maintenance strategies.

The research problem proposed for this study is: How to develop an economic feasibility analysis evaluation framework for insourcing hydraulic maintenance services using the Monte Carlo method?

The Monte Carlo method proves to be the most appropriate method for this type of analysis since, through cash flow projections, it’s possible to perform simulations, generating random numbers for expected revenues based on adopted premises. Thus, decision-makers can use this statistical tool to reach an appropriate decision for insourcing or outsourcing services.

This study presents a methodological approach with resourcefulness in actions related to hydraulic systems maintenance management, seeking strategies to assist managers in decision-making by applying the Monte Carlo simulation in a steel company.

2 Literature review

2.1 Hydraulic system maintenance

Asset optimization in an organization plays a fundamental role in achieving a large margin of profitability, aiming to reduce production costs. In this context, maintenance is constantly evolving, where predictive maintenance based on condition controls, has been surpassing the traditional maintenance methods, such as preventive and-or corrective maintenance, since it can reduce costs by extending component life, which in turn decreases service labor and unscheduled maintenance (Quatrini et al., 2020).

Hydraulic systems have several advantages, therefore if some abnormalities are not detected and eliminated in time, severe defects can occur, even leading to dangerous conditions for industrial players. Diagnosing hydraulic system failures is a great challenge, but with the advancement of artificial intelligence, it is now possible to carry out diagnoses based on field signals, such as vibrations, temperature, and pressure (Dai et al., 2019).

According to Li et al. (2021), hydraulic equipment downtime in an organization may result in costs associated with loss of production, reduced availability, and-or increased operational risks. Therefore, the maintenance management for these types of equipment needs adequate treatment, which leads organizations to frequently outsource these specialized services. Decision-making helps to base decisions in the desired level of service delivery at the lowest possible cost.

2.2 Maintenance service contracts

A maintenance contract depends on many variables like spare part availability, related costs to repair, purchase orders, etc. Regarding the acquisition of outsourcing maintenance contracts, decision-making methods are very important since, apart from associate maintenance costs, other items should be considered, like obsolete equipment, which can lead to production line stoppages. Furthermore, variable data like spare part availability, input purchases, and extra labor costs should all be considered (Bellani et al., 2020).

Outsourcing maintenance services are prevalent in many industrial sectors, including equipment maintenance. Usually, this issue becomes more prevalent when complex and expensive types of equipment are dominant, which calls for a specialized workforce. Outsourced contracts may provide partial or total coverage of maintenance actions, such as Preventive Maintenance (PM) and-or Corrective Maintenance (CM). Reaching targets of equipment availability related to outsourced maintenance should maximize the profit of the assets (Husniah et al., 2018).

2.3 Techniques of economic feasibility analysis

In the industrial environment, the study of relative measures of worth as profitability indices or rates of return, as well as net present value (NPV) and investment decision-making, has been a much-debated subject long since (Hazen & Magni, 2021).

The techniques of economic feasibility analysis have been employed to evaluate data from a given project through indicators, aiming to measure its profitability and the existing risk. Thus, it is necessary to draw up cash flows through calculations of economic indicators for decision-making (Oliveira et al., 2017).

Economic analysis includes management flexibility, uncertainty, and learning, which account for the cash flow arrangement, reflecting all cash inflows and outflows. Most decisions involve three significant factors: 1- If the investment is partly or wholly irreversible; 2- If there is uncertainty about the future return; 3- If the funding is flexible, including the possibility of being postponed, until more information is available about the main points which affect it (Benitez & Lima, 2019).

Cash flow is the most used method for decision-making by investors and has been employed in steel plants for a long time. It aims to measure the cash flows of a determined project to be implemented, predicting the gains in present value – PV (Kim et al., 2017).

For performing an economic viability analysis, it’s necessary to use some indicators intended to verify the financial return and the costs of the investments made. The best-known investment analysis criteria are the net present value – NPV, and the internal rate of return – IRR. The NPV is a technique widely used in investment analysis and is established as the sum of the estimated cash flows. NPV can be defined by the calculation formula given in Equation 1 (Colantoni et al., 2021).

$$\mathrm{NPV} = \sum_{n=1}^{T} \frac{CF_n}{(1+i)^n} - I_0 \tag{1}$$

Where:
NPV – Net Present Value
CF_n – Cash Flow for n period
I_0 – Initial Investment
I–- Discount rate
n–- Discount time
T–- Number of periods of the project implementation

The IRR refers to the concept of NPV. The IRR is defined by the maximum allowable relative level of expenses, which can be associated with a specific project. The calculation formula is given in Equation 2 (Sinenko & Savin, 2020).

$$CFO = \sum_{t=1}^{n} \frac{CF_t}{(1+IRR)^t} \tag{2}$$

Where:
n–- Number of project implementation periods
t–- Period
CFt–- Net flow of payments in period t
IRR–- internal rate of return (%)

The Profitability Ratio (PI) is calculated to verify if net cash prevails over investment costs. According to Sinenko & Savin (2020), the profitability index is defined by the calculation formula given in Equation 3.

$$PI = \sum_{t} \frac{CF_t}{(1+r)^t} / CF_0 \tag{3}$$

Where:
r–- Discount rate
CF_0–- Net flow of payments in a period t

The PI allows for the verification of project profitability, as:
PI > 1 viable project;
PI = 1 project break-even point; and
PI < 1 unfeasible project, since it does not cover the company's capital cost.

2.4 Monte Carlo method

The Monte Carlo simulation is a valuable tool for probability analysis. The simulation model, for example, can be applied to a financial model of an investment, where that model is analyzed many times (usually 100 to 100,000 times). In each iteration (simulated process flow), a generated random number is awarded for each parameter according to the predicted probability distribution (Rosłon et al., 2020).

Monte Carlo simulation can be applied to model uncertainties in the input and output values. Based on Monte Carlo simulations, decision-makers can determine, for example, the probability of an outcome being economically profitable or not profitable. However, the sensitivity analyses is simple when the variables can be ranked in order of impact on the uncertainty result, so decision-makers can prioritize which variables require better data collection to reduce uncertainties (Sjöstrand et al., 2019).

According to Lee & Ahn (2020), the Monte Carlo method follows some steps, as shown in Figure 1:

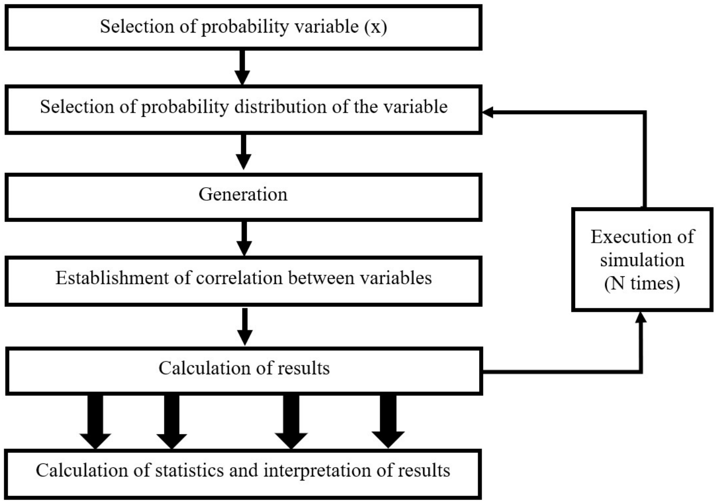

Figure 1. Procedure for the sequence of the Monte Carlo method simulation. Source: Adapted from Lee & Ahn (2020).

The Monte Carlo method is a computerized mathematical technique, which allows evaluators to monitor the existing risk via quantitative analysis and decision-making, since it demonstrates extreme possibilities for results. In this method, the decision-maker can visualize probabilities and output results to support decision-making (Al-Amin et al., 2018).

According to L'Ecuyer (2018), samples of random variables are used in the Monte Carlo method to build an experimental set related to reliability, aiming to calculate the statistical probability of the problem. In Monte Carlo, numerical integration is considered a problem in a function f(x) in the interval (a, b), according to Equation 4:

$$F = \int_a^b f(x)dx \tag{4}$$

Where:
F(x) - Function > 0
a and b - Interval of real numbers where the area will be calculated by the Equation 5, aiming to calculate the integral based on the averaging method, it can be said that:

$$F = (b-a)\frac{1}{N}\sum_{i=1}^{N} f\left(x_i\right) \tag{5}$$

where:
xi - Random numbers evenly distributed in the range a <xi < b
N - Number of sampled points

The application of the Monte Carlo simulation to support decision-making is not something new. However, its use is an approach for risk identification, intending to manage changes in an organization (Züst et al., 2021).

2.5 Insourcing or outsourcing services

Steel plants operate with high-cost equipment that affects capital expenditures (CAPEX) and operating expenditures (OPEX), where the operational reliability in the plant is fundamental for a continuous process that works 365 days a year (Kim et al., 2017).

Insourcing is a strategy to keep production activities within the company, while outsourcing is a strategy to outsource activities. Insourcing or outsourcing refers to a strategic decision that has been considered in most industrial sectors in recent decades. These issues have also generated interest from academia, which has led to the development of analytical models to help companies make the appropriate choice. Most studies on decision-making concerning insourcing or outsourcing have allowed many organizations to adopt both strategies in their businesses, known as dual sourcing (Kandil et al., 2022).

Outsourcing can be defined as a strategic decision to transfer organizational activities to a third party. Insourcing is a management decision towards replacing outsourcing and bringing the services back in-house. The outsourcing strategy is a widely researched topic, however, there are few studies on the results of insourcing strategies for outsourced services. Like similar outsourcing concepts, the insourcing process is a strategic decision to improve the organization's results. If the results of the outsourced company are satisfactory, it can be maintained. Otherwise, the organization can change the contractor or adopt an insourcing strategy (Damanpour et al., 2020).

2.6 Decision-making

In the last decades, decision-making has played a fundamental role in manager decision-making, which has evolved into a sophisticated approach, including expert judgments, cost-benefit analyses, and modeling methods in an environment with uncertain applications (Asuquo et al., 2019).

Decision-making is a process that identifies a problem and seeks to solve it. Several advantages can be had from decision-making, since it’s possible to analyze numerous variables present in a given problem that can facilitate a process overview, making the decision more objective and conscientious (Brandalise et al., 2019).

Organizations are looking for ways to use their resources efficiently and effectively. Thus, items along the production chain are the main object of focus for decision-makers to gain a competitive advantage. The complexity of the decision-making process in an organization's performance relates to both the tactical and operational management strategy levels (Campos et al., 2021).

Decision-making complexity is not caused only by imperfections or uncertain information but by many factors that influence the choices. Sometimes several selection criteria are in conflict with each other, which can result in complex decision-making. Therefore, to obtain an ideal solution, decision-making methods can be used (Nurrohkayati & Vanany, 2021).

3 Methodological procedures

This study is based on a data survey from a third-party company that provides hydraulic maintenance services, aiming to analyze the economic feasibility of insourcing these maintenance services. Thus, this research is classified according to Table 1.

Table 1. Scientific research classification.

Types of research	
Applications	Applied
Objectives	Exploratory and Descriptive
Inquiry Mode	Quantitative
Methods	Modeling and Simulation

Source: Adapted from Kothari & Garg (2019).

The study is classified as applied research, with a descriptive and exploratory objective, since data surveys are associated with variables identified in literature. As for the inquiry mode, the study has been undertaken quantitatively since an economic feasibility analysis has been performed using the data collected. The method consists of modeling and simulation since it explores real situations that require clearly defined solutions.

The bibliographic analysis comprised a search in the Scopus database through combinations of the words - Monte Carlo, Cash Flow, and Insourcing or Outsourcing, from 2018 to 2022, selecting the most relevant articles according to the subject.

To perform the economic feasibility analysis for insourcing hydraulic maintenance services, Figure 2 shows the proposed framework with the following steps to consider.

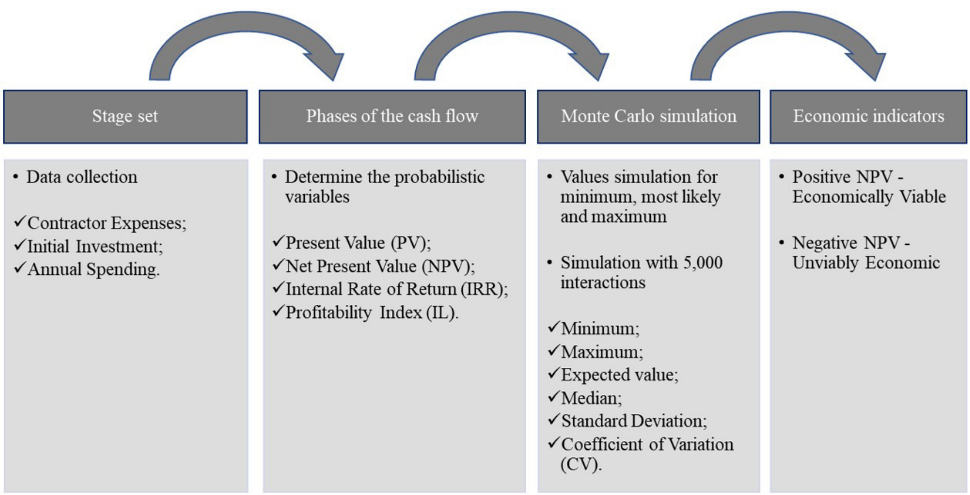

Figure 2. Proposed framework for analyzing the economic feasibility.
Source: Prepared by the authors (2023).

In the first step, data are projected from a third-party company considering the costs related to contractor expenses, the initial investment, and annual spending, using Microsoft Office Excel.

The second step employs the cash flow method, where the probabilistic variables PV, NPV, IRR, and IL, are determined.

The third step, which consists of a Monte Carlo simulation, determines the minimum, most probable, and maximum simulation values after 5000 iterations.

Finally, the NPV distribution graph is generated using statistical synthesis, a histogram, and the average and standard deviations.

In the fourth and final step, the economic feasibility analysis for insourcing hydraulic maintenance services is verified. If the results show a positive NPV, then the analysis is economically feasible. If not, the analysis is not economically feasible.

4 Results and discussion

After analyzing the hydraulic maintenance service contract, it became apparent that it had been in place for seven years. The contractor would be responsible for the operational performance of the hydraulic systems, ensuring 100% reliability of the assets to the production line. However, Figure 3 shows the data collection with the production losses due to corrective maintenance of the hydraulic systems of the production line under analysis over seven years.

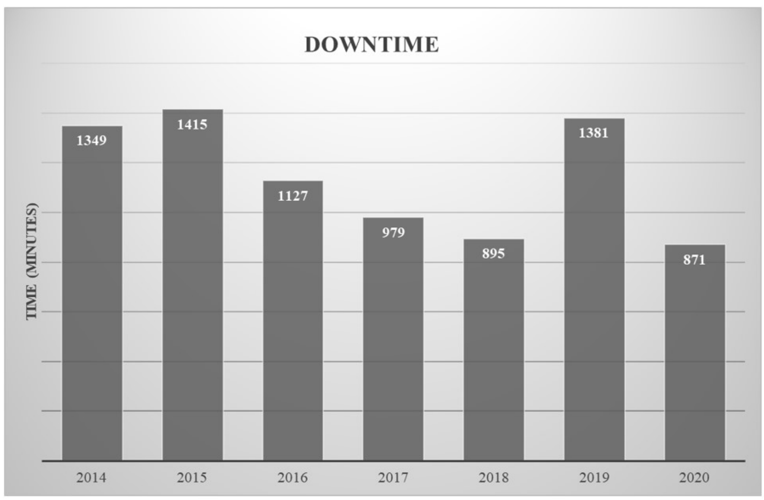

Figure 3. Downtime analysis due to corrective maintenance on hydraulic Systems.
Source: Prepared by the authors (2023).

A penalty was stipulated as being 1% off the unachieved targets, coming from corrective maintenance in existing hydraulic systems on the production line. In this context and assuming that the cost of downtime hours is R$171,000.00, we then have the values of contract penalties over seven years, shown in Table 2.

Table 2. Contract penalties.

Years	Production Losses	Penalties	Contract Penalties
1	R$ 3,844,650.00	1%	R$ 38,446.50
2	R$ 4,032,750.00	1%	R$ 40,327.50
3	R$ 3,211,950.00	1%	R$ 32,119.50
4	R$ 2,790,150.00	1%	R$ 27,901.50
5	R$ 2,550,750.00	1%	R$ 25,507.50
6	R$ 3,935,850.00	1%	R$ 39,358.50
7	R$ 2,482,350.00	1%	R$ 24,823.50

Source: Prepared by the authors (2023).

The outsourced contract expense is R$615,000.00 per year. So, service expenditures over seven years, including penalties, are shown in Table 3.

Table 3. Expenses with the outsourced company.

Years	Value
1	R$ 576,553.50
2	R$ 574,672.50
3	R$ 582,880.50
4	R$ 587,098.50
5	R$ 589,492.50
6	R$ 575,641.50
7	R$ 590,176.50

Source: Prepared by the authors (2023).

In this context, we have an average of R$582,359.36 in expenses with the outsourced company per year. To check the economic viability of insourcing with the existing contract, first, we estimated the value of investments correlated according to Table 4, which includes the indispensable inputs, as well as the certification and the necessary tooling.

Table 4. Initial investment.

Initial investment	
Description	**Value**
Office equipment	
Microcomputer / Accessories and Network	R$ 18,000.00
Air conditioner devices.	R$ 4,400.00
Printer/Fax	R$ 600.00
Water dispenser / 20 L bottle	R$ 850.00
Cordless type phone	R$ 720.00
Office tables	R$ 5,391.36
Table chairs	R$ 2,695.68
Drawer	R$ 2,062.20
Tool rack	R$ 2,000.00
Subtotal	R$ 36,719.24
Tools and maintenance equipment	
Flashlight	R$ 60.00
Hex key (Set)	R$ 198.00
Pliers	R$ 144.00
Socket wrench (Set)	R$ 450.00
Spanners	R$ 102.00
Screwdriver (Set)	R$ 372.00
O-ring pull kit	R$ 288.00
Accumulator pre-charge case	R$ 5,435.00
Pipe wrench	R$ 75.00
Digital caliper of 200 mm	R$ 327.00
Subtotal	R$ 7,451.00
Hydraulics certification	R$ 15,000.00
Total	**R$ 59,170.24**

Source: Prepared by the authors (2023).

In addition to the initial investment, the annual expenditures on uniforms, personal protective equipment, and employee salaries were also estimated. The outsourced company has hired a total of 06 professionals, including a supervisor, four technicians, and an engineer, which are responsible for the contract.

The possibility of insourcing the contract would include hiring six hydraulic professionals. However, the company's salary is higher than the contractor's base salary, since benefits like a food card, additional vacation pay at 70% of the salary, and profit-sharing are also included, in addition to the fixed company wage payroll charges. Table 5 shows the projected fixed annual costs.

Table 5. Fixed annual cost.

Fixed annual costs	
Uniforma	R$ 4,309.80
Individual protection equipment	R$ 6,391.20
Salaries	R$ 508,599.00
Total	R$ 519,300.00

Source: Prepared by the authors (2023).

The Net Working Capital Requirements, per days, were stipulated according to the Table 6.

Table 6. Net Working Capital Requirement in days.

Company resources outside its cash flow	**Number of days**
1. Accounts Receivable	60
2. Term Inventories	30
Subtotal Resources	90
Third-party resources in the company's cash flow	**Number of days**
3. Suppliers - average purchase period	30
Subtotal Third-party cash resources	30
Net Working Capital Requirement in days	90-30 = 60

Source: Prepared by the authors (2023).

Regarding the working capital needed to meet the necessary expenses of the contract, we multiply the Net Working Capital Requirement in days by the Total daily cost, stipulating an amount of R$ 97,208.47, shown in Table 7.

Table 7. Working capital.

Annual spend	
Fixed annual cost	R$ 519,300.00
Annual variable cost	-
Total company cost	R$ 519,300.00
Total daily cost	R$ 1,422.74
Net Working Capital Requirement in days	60
Total – Minimum Cash	R$ 85.364,38

Source: Prepared by the authors (2023).

To analyze the economic feasibility of insourcing the maintenance contract, a Minimum Acceptable Rate of Return (MARR) was stipulated at 12.75%. Table 8 shows the achieved values for seven years. The depreciation is calculating by stipulating a rate of 10% for tools and maintenance equipment, and by stipulating a rate of 5% for office equipment.

Table 8. Maintenance contract investment analysis for hydraulic systems.

Years	1	2	3	4	5	6	7
Outsourced contract (R$)	576,553.5	574,672.5	582,880.5	587,098.5	589,492.5	575,641.5	590,176.5
Cost without depreciation (R$)	519,300.0	519,300.0	519,300.0	519,300.0	519,300.0	519,300.0	519,300.0
Gross Profit (R$)	57,253.5	55,372.5	63,580.5	67,798.5	70,192.5	56,341.5	70,876.5
Tools and maintenance equipment depreciation (R$)	957.99	862.19	775.97	698.37	628.53	565.68	509.11
Office equipment depreciation (R$)	4,983.33	4,734.16	4,497.45	4,272.58	4,058.95	3,856.00	3,663.20
Total Depreciation (R$)	5,941.31	5,596.35	5,273.42	4,970.95	4,687.48	4,421.68	4,172.31
Net operating profit (R$)	51,312.19	49,776.15	58,307.08	62,827.55	65,505.02	51,919.82	66,704.19
Income tax (34%)	17,446.14	16,923.89	19,824.41	21,361.37	22,271.71	17,652.74	22,679.42
Profit after income tax (R$)	33,866.04	32,852.26	38,482.67	41,466.18	43,233.31	34,267.08	44,024.76
Cash Flow (R$)	39,807.36	38,448.61	43,756.09	46,437.13	47,920.79	38,688.76	48,197.08
Attractiveness rate of 12.75%.							
Discounted Cash Flow (R$)	35,305.86	30,244.58	30,527.33	28,734.21	26,299.12	18,831.53	20,806.78
Accumulated cash flow (R$)	-23,864.38	6,380.20	36,907.53	65,641.74	91,940.86	110,772.39	131,579.16

Source: Prepared by the authors (2023).

Finally, the total expenditure for the maintenance contract was calculated, where an income tax rate of 34% was applied. According to Table 9, the maintenance contract investment analysis for hydraulic systems was stipulated with an increment of production by 3% per year and a contract increment of 5% per year.

Table 9. Maintenance contract investment analysis for hydraulic systems with increased of production (5%) and outsourced contracts (3%) per year.

Years	1	2	3	4	5	6	7
Outsourced contract (R$)	576,533.5	593,122.5	620,334.0	644,125.61	666,680.42	673,595.06	709,518.66
Gross Profit (R$)	57,253.5	73,822.5	101,034.0	124,825.61	147,380.42	154,295.06	190,218.66
Profit after income tax (R$)	37,787.31	48,722.85	66,682.44	82,384.90	97,271.08	101,834.74	125,544.32
Cash Flow (R$)	37,787.31	48,722.85	66,682.44	82,384.90	97,271.08	101,834.74	125,544.32
Discounted Cash Flow (R$)	33,514.24	38,326.54	46,522.37	50,977.84	53,382.75	49,567.46	54,197.74
Accumulated cash flow (R$)	- 25,656.00	12,670.54	59,192.91	110,170.75	163,553.50	213,120.96	267,318.70

Source: Prepared by the authors (2023).

Thus, by calculating the current and proposed cash flows, the following values were obtained for seven years, as shown in Table 10.

Table 10. Parameters considered.

Criteria	Current	Proposal
Present Value (PV)	R$126,764.10	R$326,488.90
Net present value (NPV)	R$67,593.90	R$267,318.70
Internal rate of return (IRR)	48.8%	65.97%
Profitability Index (IL)	2.1424	5.5178

Source: Prepared by the authors (2023).

Given the resulting average values pertinent to the contract, we have PV - R$326,488.90, NPV - R$267,318.70, and a Profitability Index of 5.5178. For the Monte Carlo method simulation, the minimum, most probable, and maximum values were simulated, where the average cost of the contract showed a total value at R$ 634.070,50, after having applied a penalty of 1% for corrective maintenance in the hydraulic systems. Table 11 gives these estimated values.

Table 11. Parameters considered.

Parameters	Minimum	More likely	Maximum
Cost of Steel Ton (R$)	320.00	333.00	352.00
Annual Production (Tons)	1,900,000	2,410,793	2,546,82
Total Corrective Maintenance (Minutes)	1,308	3411	3,747
Hydraulic Corrective Maintenance (Minutes)	871	895	1,415
Contract Cost (R$/Year)	615,000.00	634,070.50	734,342.00

Source: Prepared by the authors (2023).

Based on the collected data, the Monte Carlo method was simulated with 5,000 iterations, resulting in the values shown in Table 12.

Table 12. Statistical measures.

NPV Statistical Measures	
Minimum	R$ 105,438.00
Maximum	R$ 499,754.00
Expected value	R$ 303,061.00
Median	R$ 302,331.00
Standard deviation	R$ 101,681.00
CV (Coefficient of variation)	0.34

Source: Prepared by the authors (2023).

Figure 4 shows the distributed data simulation, where a histogram representing the frequency of each set of NPV classes is given.

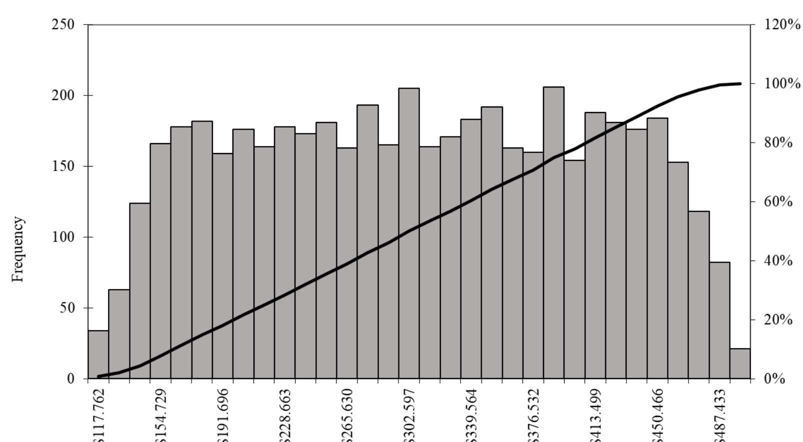

Figure 4. Distribution of the NPV's. Source: Prepared by the authors (2023).

Based on the results, we can verify that the probability of the NPV being greater than zero is 99.9%. Thus, the technical and economic details of the two alternatives, which have been compared here (insourcing x outsourcing) allow us to conclude that insourcing is a profitable alternative. The randomization technique of the Monte Carlo method proved to be a valuable tool for decision-making.

With the outsourced contract, the maintenance department spends an average of R$582,359.36, considering the penalties. By insourcing maintenance services, the maintenance department can train employees without needing to depend on outsourced services, and can achieve a total of R$ 131,579.16 in savings at the end of seven years, allowing the company to allocate these resources towards maintaining other assets.

Through the proposed framework, we were able to perform a sensitivity analysis, aiming to identify the probability of the economic feasibility of insourcing hydraulic maintenance services. The Monte Carlo simulation proved to be an effective method since it provided evidence to aid in optimal decision-making among maintenance managers.

Insourcing services is a management decision to abandon outsourcing and reinstate previously outsourced services within the company. Although outsourcing has several benefits for some kinds of contracts at organizations, in this study, there is empirical evidence showing that insourcing is economically viable.

This study, in contrast to previous studies, provides a theoretical background and empirical support for an economic feasibility analysis evaluation framework for insourcing hydraulic maintenance services using the Monte Carlo method, aiding in the decision-making process for industrial managers.

Risk is inherent to organizational activities, and managing risk is a step towards achieving organizational goals. Through the Monte Carlo method, it was possible to monitor the distribution of values that best describe the behavior of the analyzed data. Furthermore, the cash flow demonstrates “the gain or loss” of the investment required for each application, besides adding quantitative value to the management process (Etges et al., 2017).

Concerning the theoretical implications, this research presented results under constant development, which addresses the economic feasibility analysis for insourcing vs. outsourcing maintenance services in the steel industry. Thus, the results presented in this study are relevant for organizations that have investigations under development that may include uncertainties associated with maintenance management contracts.

Regarding the practical implications of using the proposed framework, which contains a sequence/coupling of both methods i.e., the Cash Flow and Monte Carlo simulation, we were able to identify the negative or positive probability (economic feasibility) for insourcing hydraulic maintenance services. Usually, only the discounted cash flow is used, but by also employing the Monte Carlo method, greater assertiveness in the results can be obtained. The connection between these methods is fundamental for assisting managers in decision-making, which can lead to implementing these tools for analyzing insourcing or outsourcing contracts within organizations.

5 Conclusions

Maintenance management is a continuous improvement process aiming to guarantee high-performance technical assistance within organizations, focusing on people's safety, competitive costs, and operational reliability.

The main goal of this study was achieved, i.e., we were able to develop, employ, and verify an evaluation framework for analyzing the economic feasibility of insourcing hydraulic maintenance services, seeking to present tools for assisting managers in decision-making and optimizing maintenance strategies. The Monte Carlo method allowed us to identify that there is a 99.9% probability of a positive NPV, thus making insourcing economically viable.

This study demonstrated that the applied framework with the cash flow and Monte Carlo methods allows evaluators to have an overview of the results for insourcing or outsourcing services. In this context, the economic analysis was profitable for insourcing services, which provides a significant improvement in the maintenance management of the production line, with a competitive industrial environment with trained employees and without depending on the outsourced company, which resulted in a strategic advantage for the organization and contributed to achieving the established goals. The cost reduction in the maintenance department allows for resources to be allocated to other assets. The applied framework is a valuable tool for decision-making, contributing to the optimization of resources among industry managers.

Regarding the research problem proposed in this study, we have demonstrated that the economic feasibility analysis evaluation framework for insourcing hydraulic maintenance services using the Monte Carlo method is fundamental for assertive decision-making. With this tool, managers can design strategies based on data collection, where ever more demanding and competitive industrial sector challenges can be overcome.

Regarding the limitations of this study, we compared only one outsourced company. Other outsourced companies could be evaluated to offer a better contractual cost-benefit.

Other types of contracts should also be considered. Perhaps ones which are more attractive, for example, by including predictive maintenance analysis or supplying some maintenance items, like gaskets, O-rings, etc. Economic feasibility analysis can be applied to other proposals, considering which strategy is best for implementing insourcing or outsourcing.

The aforementioned limitations can be considered opportunities for future research, as well as applying other decision methods, in addition to those used here.

Finally, this study can serve as a theoretical reference for other studies that involve decision-making evaluations on the economic viability of maintenance service contracts.

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Authors contribution

Nuno Miguel de Matos Torre, and Nilson Brandalise worked on the conceptualization and theoretical-methodological approach. Nilson Brandalise and Andrei Bonamigo conducted the theoretical review. Nuno Miguel de Matos Torre led the data collection, and Nilson Brandalise coordinated it. All the authors participated in the writing and final revision of the manuscript.