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Corporate Risk Strategic Management and Probabilistic Analysis Related to Environmental Liabilities: A Case Study

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Abstract

Environmental stewardship is one of the main indicators of corporate performance and reputation among investors today. However, historical operational practices and accidents have created significant environmental liabilities in the industrial sector, and now require significant investments for appropriate management and resolution. A strategic approach is imperative to assure that company's financial resources are effectively allocated, and shareholders' interests are protected. In addition, these liabilities must be appropriately and continuously reported, which require the use of robust forecasting techniques such as Monte Carlo Simulation. The present study results demonstrate that under an optimized strategic approach, liability management costs may be reduced in approximately 50%. In addition, the financial forecast under the selected approach may support appropriate reporting of company's liabilities.

Keywords

Business Risk Management, Strategy, Environmental Liability, Monte Carlo Simulation, Environmental Accounting

1. Introduction

Business risk management requires a multidisciplinary assessment including financial, governance, social, reputational, and environmental aspects, among others, that are critical to define success or failure of the organization. In addition, with the advent of exponential technology, big data and real time information, corporate transparency including cash flow projections and accurate identification of assets and liabilities is a mandatory factor required to maintain credibility with credit rating institutions, shareholders and creditors. In this context, the importance of environmental liabilities cannot be understated, both in terms of corporate reputation as well as legal/regulatory compliance in addition to business long-term sustainability [1].

However, it is often claimed that the inherent uncertainties involved in predicting environmental liabilities are a major challenge for managers. Therefore, companies tend not to comply with disclosure standards, owing to the indeterminacy of the real dimension of environmental liability [2].

Additionally, despite the recent increase in the level of climate change awareness and establishment of strict environmental legislation throughout the globe, the disclosure of environmental liabilities is still considered a matter of less importance, when compared to other aspects such as the disclosure of pollutant discharge data or resource consumption measures [3], which indicates this is not a priority issue for many corporations.

The lack of accurate and clear environmental liability disclosure is an inadequate practice and, consequently, a risk driver for corporations and their executives, board members, managers and even auditors who eventually get involved in such situation, voluntarily or not [4] [5], which is another evidence of the growing importance of this issue to companies [6].

Another fact that indicates the relevance of an appropriate communication regarding environmental liabilities is its crucial importance to obtain a good Environmental Disclosure Score (EDS) [7], required by various investors due to its company positive valuation impact [8].

In order to change this scenario, it is fundamental to employ accurate environmental liability assessment techniques [2] [4]. One of the most promising ones is the Monte Carlo forecasting technique, which has already been employed in many cases in which it was necessary to determine environmental liabilities [9] [10] [11].

A case study of a risk profile assessment for the closure cost of a large contaminated industrial facility in São Paulo, Brazil, has been analyzed. The current study provides the basis for understanding how the Monte Carlo simulations can be used as a powerful tool to lead to a more precise determination of environmental liabilities, and, therefore, to more accurate business decisions which will ultimately result in business sustainability and market confidence.

2. Objective

This empirical case study consists of a probabilistic analysis in which the primary objective is to demonstrate the importance of a strategic approach to manage business risk. A secondary objective is to evaluate the application of Monte Carlo simulation technique for decision-making, liability forecasting and reporting.

Literature Review

Environmental Liability Management

Environmental Liability can be defined, according to [12], as “not only liability for damage to natural resources, but also for property damage and injury or disease caused by exposure to hazardous materials or products in the environment". Additionally, these liabilities are connected to the legal ownership of property, which means that, when the property is transacted, so is the environmental liability and, most importantly, the responsibility for managing and contingency it [13].

Several types of pollution that do not disappear easily are considered environmental liability. Not only that, but the indirect consequences caused by it, such as related illnesses, are also considered a part of this liability, and any eventual buyer would have to take responsibility for dealing with that issue [12]. The existence of potentially hazardous contamination in a property, and the possible obstacles to the land's rehabilitation it causes, are what define an area as a Brownfield, or a contaminated area [14].

The definition of contaminated area is very broad, encompassing topics as diverse as contamination by radioactive substances [15] [16], metals [17] [18] [19] [20], some of which are carcinogenic, and therefore even more dangerous [21], Volatile Organic Compounds (VOC) [22] [23] [24], Total Petroleum Hydrocarbons (TPH) [25] [26], among other groups.

The contamination of an environmental media (soil, water, air) by a specific compound is determined through comparison with a regulatory standard (Ferguson, 1999). That means a property is only effectively considered a contaminated area if it exceeds the established standard for its specific region, and it might or not be considered contaminated depending on the stringency of local and current regulations, and even one exceedance is sufficient to grant this status to an area [27].

The procedure to assess contaminated areas usually follows 4 phases, according to the United States Environmental Protection Agency (US EPA) and the Department of Urban Affairs & Planning (DUAP) [28]: Preliminary Investigation, Detailed Investigation (In Brazil, this step is preceded by the Confirmatory Investigation [29], Site Remedial Action Plan, and Validation and Monitoring).

In summary, investigations are conducted to determine the type and magnitude of contamination (steps 1 and 2), and based on their results, a set of techniques may be implemented to mitigate or eliminate the associated risks to potential human or ecological receptors, and, lastly, a long-term monitoring program ought to be established.

Furthermore, it is relevant to mention that, once it is investigated, detected, and characterized, there are many techniques used to mitigate contamination and ensure compliance with standards [30] [31] [32]. Each technique, or combination of techniques, is appropriate to specific contamination scenarios [33].

The mere presence of contamination does not necessarily result in remediation. Engineering controls and deed restrictions may be used as a contaminant management alternative. Thereafter, choosing the best strategy for remediation is one of the most important steps to rehabilitate a contaminated area [33].

The wrong choice of remediation strategy can lead to incredibly significant financial expenditures, which can last for several years if this inadequacy is not detected. Even worse, not only does the project remain a continuous money drain to the company, but also become an endless one, as an inadequate strategy based on inadequate premises will be unable to meet agreed-upon goals over a reasonable timeframe. Therefore, it is critical for both managers and corporate executives to assure model applicability which highlights the importance of an independent second opinion [34].

The adequacy of a remediation strategy depends on a series of factors, the most important being [33] [35]:

- Proper environmental diagnosis: Properly conducted studies and comprehensive data analysis are imperative for the establishment of the remediation strategy.
- Risk-based remediation goals: that are, the remaining contaminant levels allowed based on future land use intended upon environmental remediation completion.
- Property Characteristics: Each property has its own characteristics, such as the type of contaminants present in the environment, their concentrations and spatial distribution in the context of local hydrogeological features. The more contamination is found in challenging conditions, the more challenging remediation will be [33].

Environmental accounting

Environmental Accounting is a subarea of accounting, a particularly important and traditional field whose origin and development is deeply connected to humanity's own history [36].

Accounting has become more important when trade began to play a central role in society, and it evolved along with the market [36], a phenomenon observed both in Europe, where it began [37], and in more recent societies, such as the Brazilian [38].

Therefore, accounting has always had a significant role in influencing society, and was also influenced by its changes [36] [37]. Given so, it is not surprising that, when the thematic of environmental preservation began to gain importance, in the beginning of the 1970-decade, Accounting reacted quickly to adapt to this major change [39] [40].

This adaptation came in the form of environmental accounting, which has begun to become consolidated as a field in the following decades [39] [40] [41], and especially in the decade of 1990, in which the importance of environmental impacts became widely researched and evident throughout the world [42].

Among its objectives, one of the most important is to disclose information regarding environmental events that may affect the company, whether they are assets or liabilities [41]. In addition, it must register all financial transactions of the company that directly or indirectly affect the environment [39] [40], and also organize and disclose such information to shareholders in order to enable external entities to correctly review or audit corporate information [39].

It is also noticeable that environmental assets are especially important for green marketing [43], which is a valuable tool to raise the society's perception of a brand and its commitment to sustainability, ultimately leading to a better reputation and financial growth [44] [45].

On the other hand, the proper management of the environmental liabilities is of utmost importance to preserve corporate prestige and, subsequently, its competitiveness [4]. However, many companies are still uneasy about disclosing information regarding their environmental liabilities.

The main reason for this practice is uncertainty regarding the true magnitude of the problem and the fear of disclosing inaccurate information that may potentially harm the company based on pessimistic assumptions not empirically confirmed [2]. Based on this premise, the company would lose reputation and market value based on an incorrect financial liability forecast.

Obviously, this argument does not stand and there are various tools and methodologies available for proper and accurate environmental liability valuation [2] [4].

Valuation of environmental liabilities

As it was seen in the previous section, while environmental assets are important to illustrate to the society company's environmental actions, thus attracting new opportunities and increasing profit, environmental liabilities, if not well managed, can negatively and deeply impact corporations.

Since the Sarbanes-Oxley Act (2002), which established strict information risk controls, it became extremely complicated to create or maintain fraudulent accounting schemes in companies in the United States. More than that, CEOs and CFOs started to be personally responsible for the authenticity of the submitted accounting reports which increased the fear of these actors on this issue [5].

Therefore, it became even more important to properly disclose accounting information after the enactment of that law. And the same holds true when it comes to the matter of environmental liabilities [1] [6], and the only way to properly do so is by correctly valuating them [2] [4].

The valuation of environmental liabilities is another broad area of research, and it recognizes contamination as an incredibly significant liability. Left unremedied, those environmental liabilities consist of financial liabilities, extrapolating to the environmental sphere and directly affecting the company's financial statement [46].

Its origin is deeply related to the rise of Environmental Economics, a field that englobes Environmental Accounting as well, and which originated in the 1960's. Specifically, the environmental liabilities began to be considered truly relevant only in the late 1980's, when researchers began to realize that the concepts of valuation could be applied to environmental liabilities as well [47].

There are many techniques used for valuing environmental liabilities, integrating both technical and economic solutions. Among them, some of the most noteworthy are the use of a Decision Tree model [48] and Monte Carlo Analysis, which stands out a powerful tool to aid in determining the most accurate valuation scenario for numerous types of environmental liabilities by internalizing uncertainties [49] [50] [51], even considering the intrinsic limitations of the method [52].

Additionally, this investigation for optimal technologies and new methods of analysis becomes more relevant as the use of the most common and preferred by the market solutions, which simply "take the liability away" from the property, such as the excavation of contaminated soils, are currently being rethought, as they simply do not actually solve the problem, but transfer it [53].

3. Case Study Definition

In order to analyze an example of how the correct and precise assessment of the environmental liabilities associated with a contaminated industrial facility can lead to optimized strategic decisions, a project closure case study is presented and thoroughly analyzed.

The considered property consists of an industrial facility, in which many chemicals were historically released into the environment, located in São Paulo, Brazil. It is important to state that, owing to the confidentiality of company data, some information have had to be omitted. Such omission does not affect the analysis of results obtained, though.

The subject area has had a history of many environmental studies and mitigation actions, when, in 2010, it was concluded that the area was fit for closure, considering risk-based models at the time. However, 10 years later, the project does not seem to be on the closure path.

The 53.5 ha area has had historical hydrocarbon contamination from past operations, especially BTEX (Benzene, Toluene, Ethylbenzene, and Xylene), and it has spread out of the industrial area as well – however, no receptor had been yet affected. A free phase of 30 cm (about 11.81 in) has been detected in some monitoring wells, indicating parts of the soil were saturated with product. Despite that, contaminant's concentrations were low, which made source removal or attenuation strategies inefficient.

Even though it had been stated that closure was perfectly achievable, there has not been a clear strategy for doing so, and, as a result, the past decade consisted of a series of studies and an unfocused, generic environmental management strategy.

Instead of focusing in proving that the main receptors—groundwater, the soil and a nearby river, were safe, and subsequently the area could be closed without further impacts to the environment, workers and community, the project team opted for a strategy focused on contaminant source removal without clear goals and a reactive approach toward regulators.

Additionally, a recent minor oil leakage has contributed to worsening the impression that the facility is heavily contaminated. Even though available data has demonstrated that this event did not significantly impact environmental media and there is no realistic risk to human and ecological health, this information has not been effectively communicated to public authorities. As a result, the environmental agency has demanded continuous and expanded actions to eliminate hypothetical risks. Figure 1 presents a summary of historical environmental actions at the subject industrial facility.

Management strategy

The main reason for project closure failure is the disconnection between actions planned and executed and clear remediation objectives and target conditions to resume activities.

None of the actions have been linked to protection of a nearby river or protection of human health, both already empirically characterized as safe. The actions seemed to be reactive, instead of directed towards a clear objective. Thereby, the lack of remediation goals and defined triggers for implementation of remediation or emergency measures resulted in the actions existent by that time not moving the project to closure.

Project managers have forecasted an amount of R$8,000,000.00 in expenditure for the next 5 years based on current management approach. A third party involved has requested an independent review of cost projections with a focus on project path and closure alternatives.

In order to reduce the cost of environmental actions and bring the project on a path towards closure, an exit strategy is needed demonstrating that the residual contamination at the industrial facility does not pose risk to potential human or ecological receptors. This strategy includes the development of triggers that will result in contingency actions being implemented if there is a change in measured conditions. The contingency action shall consider passive/green techniques for long-term cost effectiveness and sustainability.

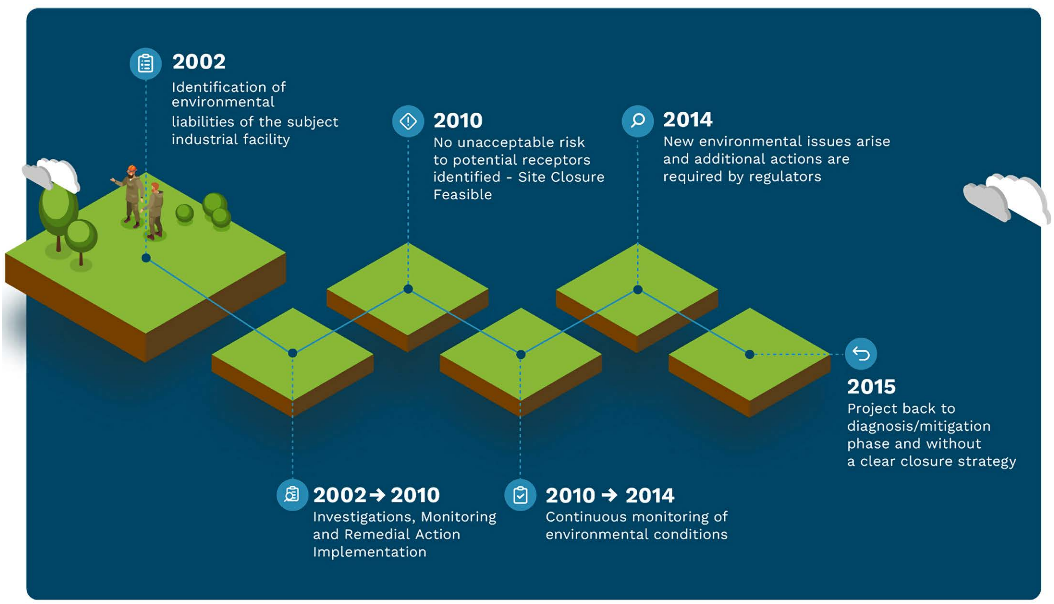

Figure 1. Project timeline.

4. Metodology

Monte Carlo's Simulation

Estimating the cost for remediating environmental impacts at major industrial facilities presents challenges which require the use of sophisticated methodologies and tools to accurately represent costs under uncertain conditions. For this reason, a probabilistic cost analysis was performed for the subject industrial facility.

The cost estimates have been performed utilizing Monte Carlo forecasting techniques and analysis for the purpose of assessing the uncertainty in the costs and highlighting the factors which could result in higher environmental costs. The exit cost estimates present realistic potential future costs by evaluating past environmental costs, the planned actions intended for execution, and the future contingency and possible closure actions at the subject property under the regulatory framework. Also, the analysis did not consider any possible financial risk associated with hypothetical public prosecutor engagements, natural resource damages or potential civil class actions.

The probabilistic cost estimate provides an overall cost range through combined Monte Carlo simulations. The simulations are based on cost models defined for individual remediation scenarios involving investigation, monitoring, and remediation elements, with cost distribution ranges developed to encompass uncertainty in the variables. The probabilistic cost estimate considers the uncertainties of the potential work elements, resulting in an overall estimate that reflects a likely cost range rather than an improbable worst-case scenario where every uncertainty is depicted as the higher costs.

In contrast, the deterministic cost estimate is generally a summation of worst-case scenarios, which result in depicted costs being unrealistically high. The probabilistic cost estimate accounts for the principle that when dealing with large, multifaceted, and complex projects, the worst-case scenario will not be the result in every area for every aspect.

In reality, the actual cost outcome will be a sum of expected cost outcomes for each required action where some actions will exceed the expected cost, and some will be below the expected cost. This is the basic function of Monte Carlo simulations, which provide a robust measure of uncertainty in overall cost [54], having been used successfully in similar situations [50].

To perform this probabilistic cost analysis, the software package, Oracle Crystal Ball, was utilized [55]. The Crystal Ball Monte Carlo analysis [56] was used as a platform to forecast cost values considering probabilities of each scenario across a given range and anticipated cost distributions as well as the probability of the combinations of the different scenarios.

This analysis provided a simulation of 10,000 scenarios or combination of these variables, generating a probabilistic cost estimate and associated cost curves for each scenario evaluated.

The same steps are applied to prepare the project closure cost estimate:

- Step 1: Define the variables in the project.

- Step 2: Define the most likely value and range in values for each variable.
- Step 3: Define the most and least favorable scenarios for actions at the subject property.
- Step 4: Develop a cost model to evaluate potential combination of actions and associated variables for achieving project closure.

The ranges of quantities and costs for each variable are defined by:

1) Past documented project costs.

2) The company's unit prices for environmental studies and mitigation/remediation.

3) Professional engineering judgment.

4) Consideration of potential environmental management requirements already proposed or likely under the regulatory framework.

Costs uncertainty generating factors

The main uncertainties given consideration in the cost model are:

1) Remediation Actions:

- Will the planned actions be continued or expanded beyond their current scope?
- Will actions be required along the river boundary?

2) Remediation Target:

- What are the criteria and monitoring approach to measure attainment of the remediation criteria?

3) Strategy for Remediation of Remaining Concentrations:

- There will likely be residual contamination measured in groundwater and potentially free phase after the remedial actions. What will be the approach to close the project with residual contaminant levels?

4) Confirmation:

- There is no long-term monitoring network or program yet developed for the property. How many wells will be in the network?
- What will be the monitoring frequency?
- Will an additional investigation be required?

5) Development of Areas Requiring Deed Restrictions:

- Will offsite areas not controlled by the industry require use restrictions?
- Will the Environmental agency approve closure?
- What is the methodology for closing offsite activities with residual contaminant levels?

6) What is the future of the property?

- Will the subject property remain an active industrial facility?
- If the industrial facility is closed, it could trigger excavations of impacted soils. How to separate future liability from either future releases or land use changes or regulatory changes from past environmental contamination?

5. Results

Property closure cost model scenarios

Figure 2 presents the primary components of two cost model scenarios developed for the project:

• One representing the base case (current management approach) taken for the project including potential for additional contingencies.

• And the second representing an optimized approach for the project, where previously planned actions were considered coupled with development of risk-based closure criteria, a long-monitoring program, and passive contingency actions to be implemented if there is a change in measured conditions.

Estimated environmental costs and analyses

Figure 3 presents an estimate for Total Project Cost for attainment of environmental closure:

There are two cost scenarios presented:

1) Base Case, current management approach (2018).

2) Optimized Case.

The cost reduction in the Optimized Case is attributable to implementation of an exit strategy and needed monitoring for implementation of data driven remediation triggers. This did not exist in the management approach taken previously at the project, in which remediation actions have been reactionary. The optimized case is not achievable at the project based on current management approach but is provided as a benchmark for project costs.

As mentioned previously, the project will require R$8,000,000.00 to fund the next 5 years of environmental operations. As shown in Figure 2, this represents the 10th percentile of the total expected project cost. Total project cost to closure is significantly higher than the current funding due to high uncertainties on proposed actions being extended and additional actions being required, besides considering the lack of a long-term closure plan or well-defined risk-based remediation targets.

Figure 2. Components of the two cost model scenarios developed.

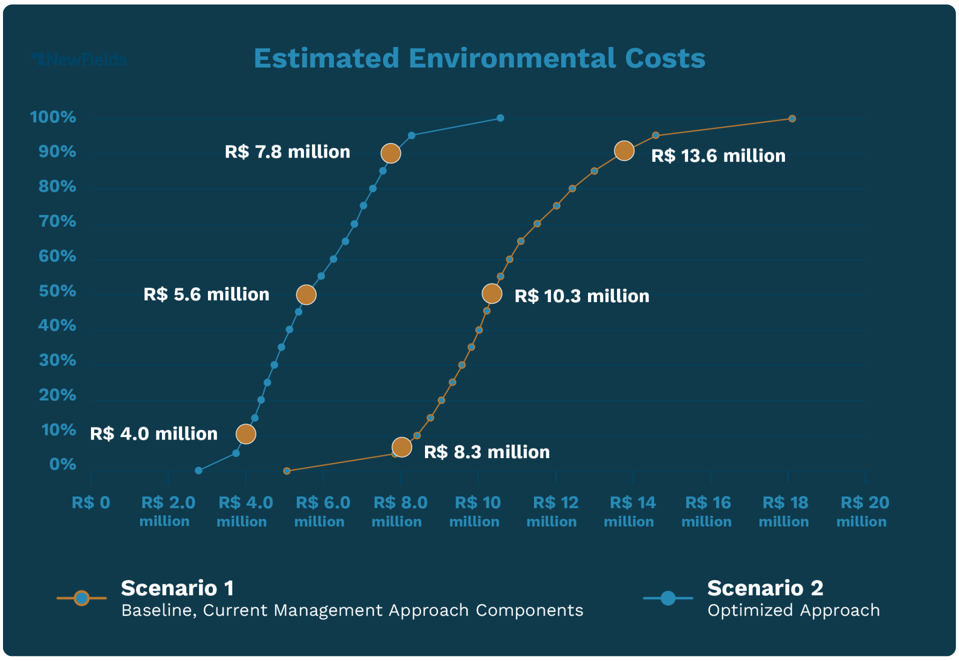

Figure 3. Estimated total costs for environmental remediation and closure.

Table 1 presents the low, median, and high-cost percentiles for the Base Case and for the Optimized Case. The cost percentiles reflect the likelihood for the total project cost to be at that value or less. For example, in the Base Case, the 90th percentile cost is R$13,698,000, which translates on a 90% chance that company's cost exposure will be R$13,698,000 or less.

Table 1 illustrates that company's cost exposure for environmental liability closure associated with the subject property ranges between R$8,393,000 and R$13,698,000 in case there is no change in current management strategy (Base Case). The 10th and 90th percentiles are considered the lower and upper bounds on probabilistic estimates, conservatively. The costs of the Optimized Case are approximately half of the costs of the Base Case which illustrates the inadequacies of strategy currently employed on this project

In order to provide an insight on what is considered in the model, Table 2 provides the basis for cost simulations on low, median, and high-cost estimates. Additionally, it is important to point out that the Monte Carlo analysis simulated 10,000 trials of the cost estimate for achieving project closure. Each model scenario randomly determined whether additional actions should be implemented, if actions should be carried out, the duration of mitigation/remediation actions and monitoring, and the costs for elements comprising each item of the cost model.

6. Discussion

Results demonstrated the application of Monte Carlo Simulation Technique for estimating liabilities even in a case with a significant level of uncertainty. Furthermore, it is noteworthy that the 90th percentile cost (R$13,698,000) represents

Table 1. Low-median-high estimated closure costs for Scenarios 1) and 2).

Percentile (%)	Total Closure Cost	
	Scenario 1)	Scenario 2)
10% (low)	R$8,393,000	R$4,000,000
50% (median)	R$10,368,000	R$5,620,000
90% (high)	R$13,698,000	R$7,800,000

Table 2. Representative actions comprising the low, median, and high estimated costs to closure scenario.

Total Project Costs, considering different projections				
Yearly Cost Breakout for Low Cost to Closure (10th percentile)				
Item	**Basis**	**Description**	**Duration**	**Sum (R$)**
1	Prescribed action on chronogram	Contingency surface water/sediments sampling	13 years	949,000
2	Prescribed action on chronogram	Performance Based Action for Free Product	2 years	1,611,000
3	Contingency	Risk of continuation of Free Phase Action	2 additional years	588,000
4	Prescribed action on chronogram	One round of remediation	2 years	1,750,000
5	Likely required and based on 2017/18 monitoring results	Near term monitoring for performance confirmation	2 years	410,000
6	Contingency	Multilevel investigation	did not occur	0
7	Contingency	Additional rounds of remediation	2 years	1,270,000
8	Likely requirement once prescribed actions complete	Long-Term Monitoring Program	11 years	1,565,000
9	Likely requirement once prescribed actions complete	Report on delineation and use restrictions for obtaining Terms of Rehabilitation	1 event	250,000
			Total	8,393,000
Yearly Cost Breakout for Median Cost to Closure (50th percentile)				
Item	**Basis**	**Description**	**Duration**	**Sum (R$)**
1	Prescribed action on chronogram	Contingency surface water/sediments sampling	11 years	759,000
2	Prescribed action on chronogram	Performance Based Action for Free Product	2 years	1,603,000
3	Contingency	Risk of continuation of Free Phase Action	2 additional years	533,000
4	Prescribed action on chronogram	One round of remediation	2 years	2,370,000
5	Likely required and based on 2017/18 monitoring results	Near term monitoring for performance confirmation	2 years	460,000
6	Contingency	Multilevel investigation	5 years	839,000
7	Contingency	Additional rounds of remediation	2 years	2,370,000
8	Likely requirement once prescribed actions complete	Long-Term Monitoring Program	8 years	1,159,000
9	Likely requirement once prescribed actions complete	Report on delineation and use restrictions for obtaining Terms of Rehabilitation	1 event	275,000
			Total	10,368,000

Continued

Item	Basis	Description	Duration	Sum (R$)
Yearly Cost Breakout for High Cost to Closure (90th percentile)				
1	Prescribed action on chronogram	Contingency surface water/sediments sampling	15 years	990,000
2	Prescribed action on chronogram	Performance Based Action for Free Product	2 years	2,172,000
3	Contingency	Risk of continuation of Free Phase Action	3 additional years	807,000
4	Prescribed action on chronogram	One round of remediation	2 years	3,268,000
5	Likely required and based on 2017/18 monitoring results	Near term monitoring for performance confirmation	2 years	664,000
6	Contingency	Multilevel investigation	4 years	1,039,000
7	Contingency	Additional rounds of remediation	2 years	3,268,000
8	Likely requirement once prescribed actions complete	Long-Term Monitoring Program	13 years	1,237,000
9	Likely requirement once prescribed actions complete	Report on delineation and use restrictions for obtaining Terms of Rehabilitation	1 event	253,000
			Total	13,698,000

the upper range of potential costs and may be used as an upper threshold for overall environmental liability associated with this industrial facility to be reported in company's balance sheet, in accordance with accounting principles. As an alternative, Optimized Case 90th percentile estimates, in the range of R$7,800,000, may be reported as representative of Company's environmental liability in case the alternative and proactive strategy is chosen by management.

Evaluation of Monte Carlo technique effectiveness in reducing uncertainty regarding project environmental liabilities

Monte Carlo simulation of liabilities associated with the subject property has demonstrated the importance of a rational strategy to manage intrinsic uncertainties regarding project closure. It becomes clear by analyzing the output that the current management approach is inefficient in comparison with a plan that appropriately considers and deals with uncertainties.

Figure 2 shows that the 90th percentile cost for the Optimized Case presents a similar value to the 10th percentile cost for the Base Case, evidencing the inappropriacy of the current management strategy. If this strategy is maintained, project closure may not be achieved and, potentially, will have significant financial consequences.

Therefore, this case study indicates that pursuing a better strategy, by investing in specialized consulting and independent studies may provide agency cost reduction and accurate forecasting, management, and reporting of environmental liabilities. The establishment of comprehensive and strategic management protocols is critical for proper allocation of financial resources and achieving the company's goals in the most effective manner.

Lastly, the Monte Carlo technique was successful in internalizing the uncertainties and providing a manageable approximation to the most probable scenarios. This meets the information presented in the consulted literature by [10], [49] [50] and [51]. The model output consists of two cost profiles which may be used as a tool throughout project life cycle for monitoring and decision-making. The model can be continuously updated based on regulatory or strategic reviews.

It is, however, important to remember that the forecasts presented by the Monte Carlo Simulations are strongly dependent of the cost uncertainty generating factors considered in the cost model. If these premises are not correctly outlined, the model's prediction will not be representative of the reality and may mislead the entire plan.

Thereafter, this important limitation reassures the relevance of relying on competent professionals to develop the cost models based on correct premises and appropriate boundary conditions, which is in line with the conclusion of reference [37].

7. Conclusions

This case study's results demonstrated the importance of a strategic approach in managing environmental liabilities and, consequently, company's business risk. The project risk profile can drastically change based on one simple decision: to change the strategy. This simple modification, in this case, would result in an approximately 50% project cost reduction. The amount requested by management for project expenditures during the next 5 years, R$8,000,000.00 is within the Optimized Case's upper boundary cost for the entire forecasted life cycle. In addition, reported liabilities could be significant lower, creating less impact on company's balance sheets.

Moreover, Monte Carlo simulation has been demonstrated to be a rational and very applicable tool for environmental liability management. The cost curves are simple and effective in communicating the risks, indicating that different decisions are the main reason for the observed variations. This tool, despite its limitations, is also practical in allowing decision-makers to base their decisions on different probability levels, according to company's cultural risk tolerance, if the model is developed relying on a cost model based on solid assumptions and premises. Finally, it provides a robust financial forecast throughout the entire project life cycle providing critical information required for corporate cash flow planning and accounting reporting for compliance purposes.

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We dedicate this paper to NewFields chairman and founder William Hall. His legacy in the environmental field cannot be overstated. He has developed various environmental liability management tools including Total Cost Control and Decision Consequence Analysis. Billy has contributed not only with the understanding of technical challenges, but also cognitive-psychological barriers that impact project schedule, cost and stakeholder agreement. Since the early 2000's he has been sharing his views and training various professionals throughout Brasil. NewFields Brasil staff has been carrying out his lessons, working diligently to eliminate these challenges and achieve efficient problem resolution on various cases. Thanks Billy!

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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