Valuation of Risk Mitigation in Industrial Processes Safety with Real Options

Abstract

This paper researches the academic and market state of the art relative to financial quantification of risks in Process Safety and develops a Real Options methodology for valuation of these risks. Contingent asset valuation methodologies are used, such as insurance and contractual clauses, using in particular the Real Options approach. This makes it possible to correctly quantify projects and assets under an environment of uncertainty, in the case of events such as accidents, or equipment breakdown, of low statistical occurrence, but with harmful and loss incurring consequences. And also investments to mitigate these risks, thus reducing the negative financial effect of the occurrence of these events.

Keywords

Processes Safety, Risk Mitigation, Real Options

1. Introduction

Valuation models applied to technological management are based on delivering value, with an estimated financial return on the investment made. Specifically, in the case of issues related to the production process, it is usually difficult to obtain the financial value added by the individual contribution of investment in R&D projects related to the mitigation of impacts in the processes, whether due to aspects of indemnities, fines or interrupted production.

Inability to value such financial contribution, reduces the value leverage of these investments as it does not capture the positive effects related to the development of R&D solutions to processes risk mitigation.

This article aims at the development of academic research with the objective of obtaining a mathematical modeling to quantify the marginal value arising from the development of risk mitigation solutions in process safety to compose the financial valuation of R&D adding to it the monetary benefits associated to mitigation of these risks.

The model should, in the case of process safety, account for the result related to the mitigation of the risks of accidents and their impact on production.

Process safety is here understood to be the prevention of accidents involving the loss of containment of hazardous materials, which can lead to fires and explosions, which can cause multiple injuries and significant damage to facilities, as well as contamination of land and waterways, with direct impacts to the environment and society.

1.1 Problem

There is a recognized difficulty in obtaining financial value for investments in research, development and innovation (R&D) on mitigating man's exposure to the risks inherent to unfolding impacts in processes involving indemnities, fines or interrupted production. We also noted a lack of bibliographic production as well as a market benchmarking on the subject. Also the inexistence of an academic concentration area of valuation and

financial analysis that contemplate the investment in solutions for mitigating process risks, is a gap that should be considered in this paper.

1.2 Objective

This articles' objective is thus to develop an academic research on mathematical modeling with the objective of quantifying the incremental financial value of risk mitigation solutions in production processes, for example operation failure due to lack of maintenance, stoppage of equipment due to operational accident leading to interruption of production, etc. And to develop a mathematical/ quantitative methodology for generic modeling of broad applicability in order to quantify the financial value for risk mitigation solutions in the field.

2. References

This paper´s proposal is to develop a financial quantification methodology to mitigate risks in occupational and process safety. Initially, academic research will be carried out on the following topics related to the R&D project:

• Methodologies for financial quantification of investments in preventive maintenance in industrial facilities, prospecting (mining, O&G, etc.), construction, etc.: Endrenyi, et al. (2001), Haddad et al. (2014), Lee (2008), Lofsten (1999), McCall (1965), Pelajo et al. (2019).

• Quantification of operational risk by statistical and stochastic approaches, as well as methodologies for financial valuation of these risks by statistical analysis methods such as Value at Risk (VaR), Conditional Value at Risk (CVaR) or Expected Shortfall, and Omega Measure (ω): Barua, et al. (2016), Carneiro, et al. (2010), Khor, et al. (2008).

• Methods for quantifying occupational safety risk and estimating the probability of events involving related costs (fines, indemnities), effects on operational production: Sousa, et al. (2014), Badri, et al. (2012).

3. Methodology

In order to achieve the desired objectives, the approach of Real Options or Dynamic Optimization under Uncertainty is mostly used, as it allows evaluating flexibilities in the presence of future uncertainty.

To quantify the types of investments in contingent assets, the Discounted Cash Flow (DCF) approach is not appropriate as it assumes that, once the investment is made, the projection of cash flows will occur deterministically. The correct approach to price investments in contingent assets is known as the Real Options Methodology (or Real Options Approach – ROA), which correctly quantifies the value of investments made in the presence of uncertainty and managerial, strategic or contractual flexibility. As the operational risk environment is highly uncertain, statistical models that best describe these uncertainties mathematically must be used, and the methodology developed should allow the adequate choice of each statistical model that best adapts to the

mapped risk. Stochastic process models are be used to quantitatively describe the uncertain behavior of risk events associated.

The characteristics of the risks to be dealt with relate to possible events with a low probability of occurrence, but which entail costs (fines, indemnities, etc.) and/or reduced revenue such as interruption or drop in production, if they materialize. Therefore, R&D projects with solutions to reduce this type of lost revenue or cash outflow, but involving additional costs (OpEx) or additional capital investments (CapEx) should have these values compared to the "incremental cash flow" arising from the reduction of loss of income or cash outflow that they intend to mitigate, such as indemnities, fines or interruption of production. As these are uncertain, they must be measured using an adequate statistical approach and quantified as "contingent" assets for the occurrence of these events.

The methodology quantifies and optimizes the degree of investment in risk mitigation, allowing investment decisions to be made or operating costs related to occupational safety and production processes. Thus, it quantifies monetarily the risks mentioned and compares with the financial expenditure of the risk reduction options to be defined. The financial quantification result of the proposed methodology is the comparison between the proposed optimized value of investment or cost and the value resulting from the corresponding risk reduction.

In the cases studied, the article envisioned two types of modeling applicable to different types of investments in exposition to processes risks.

In the first type of modeling, cases involving permanent and recurring expenses related to systems, activities or processes to increase the level of safety are considered, which lead to a probabilistic reduction of detrimental events and other types of events that cause fines, indemnities, interruption of production, damage to the company's image, etc. These events are modeled based on the projection of a stochastic process referring to variables such as the degree of danger, the level of security offered by the existing situation, among others, generating a statistical expectation of the occurrence of claims and other types of events based on their simulation. As investments in safety R&D improve these indicators, by stochastic simulation or Monte Carlo simulation, one can estimate the gains in financial value arising from these investments, treating them as a set of real options of the European type, which are exercised at all times regardless of what has already happened or what would happen. Examples of this type of treatment can be seen at: Leite , et al. (2022), Santanna, et al. (2022), Bastian-Pinto, et al. (2021), Bastian-Pinto, et al. (2015), Rodrigues, et al. (2015), Santanna, et al. (2022), Ozorio, et al. (2013), Brandão, et al. (2012), Bastian-Pinto, et al. (2010).

This technique for measuring the financial value of contingent assets, such as insurance and others dependent on low-intensity statistical events and adverse or positive consequences, can be seen in the works mentioned above, but also in many others with varied and wide application.

In the second type of possible modeling, cases involving permanent investments are considered, often in improvements or equipment changes, costly preventive maintenance, etc., which, despite generally having an implementation schedule, are

either poorly followed or do not correspond to the optimized perspective of risk reduction from the perspective of this study. Also this type of investment, which entails an increase in the level of occupational safety and a probabilistic reduction of claims and other types of events, has a high financial cost and, therefore, its optimization needs to be estimated taking into account not only the operational aspects, but especially the financial benefits from the reduction of risk associated with the prevention of incidents that cause fines, indemnities, interruption of production. As this type of capital investment decision making is subject to uncertainties with increasing probabilities of occurrence over time, the adequate methodology to deal with these cases is the one that involves real options of the American type, which can be exercised at any time. before the expiration date of the option. This methodology, also already well developed, involves discreet approaches due to the fact that they do not have analytical solutions, but with ample flexibility which is well applied to the risks addressed in this study. Among numerous other works already published, we can mention: Haddad, et al. (2014), Lee (2008), Pelajo, et al. (2019), Bastian-Pinto, et al. (2009), Marques, et al. (2021), Bastian-Pinto, et al. (2015), Ozorio, et al. (2013), Dias, et al. (2011).

4. Cases application

Two cases of application in a big energy industry in Brazil are being studied and will provide the examples and calibration data for the work in progress.

Despite being challenging, as it has not yet been applied to the subject of this study, the Real Options methodology is objectively inserted in this topic since it manages to return incremental financial value on investments in risk control by dealing with the uncertainty of occurrence of events of claims and failures, as well as their flexibility to take decisions depending on the objective to be achieved (in this case, reduction or even extinction of the risk associated with negative events).

5. References

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