PERSPECTIVE

Risk Analysis Perspective in the Mining Industry

March, 2023

Paving the way for the future of mining

INDEX

ABOUT GEM

With over 14 years of experience and over 400 successful projects Implemented globally, GEM is the leading consultig firm in the mining industry risk analysis consulting.

MISSION

We are a company that provides products and services of excellence for the mining industry. We seek to pave the way for the future of mining while maximizing the business value of our clients by providing their ability to make strategic decisions through innovative services effectively delivered by highly qualified professionals.

We have six areas of business:

Analytics	Training	Economics
Strategy	Evaluation	Optimization

INTRODUCTION

Historical Challenge

Over the last years, the mining industry has faced several challenges. One of them, associated with a significant economic impact, is the fulfillment of production goals of mining operations and the materialization of the planned Net Present Value (NPV) for projects. Failure to achieve the proposed objectives at the planned or deterministic level results in significant losses for mining companies, so it is important to know the reason why the productive and/or economic goals are not met. The reason for this is to reduce future deviations from what was planned.

According to GEM's experience, one of the main causes of non-compliance with deterministic goals refers to the fact that, at the time of the evaluation, not all uncertainties that could affect a given project or operation are considered, or that uncertainties are identified, but their impact on the assessment is underestimated.

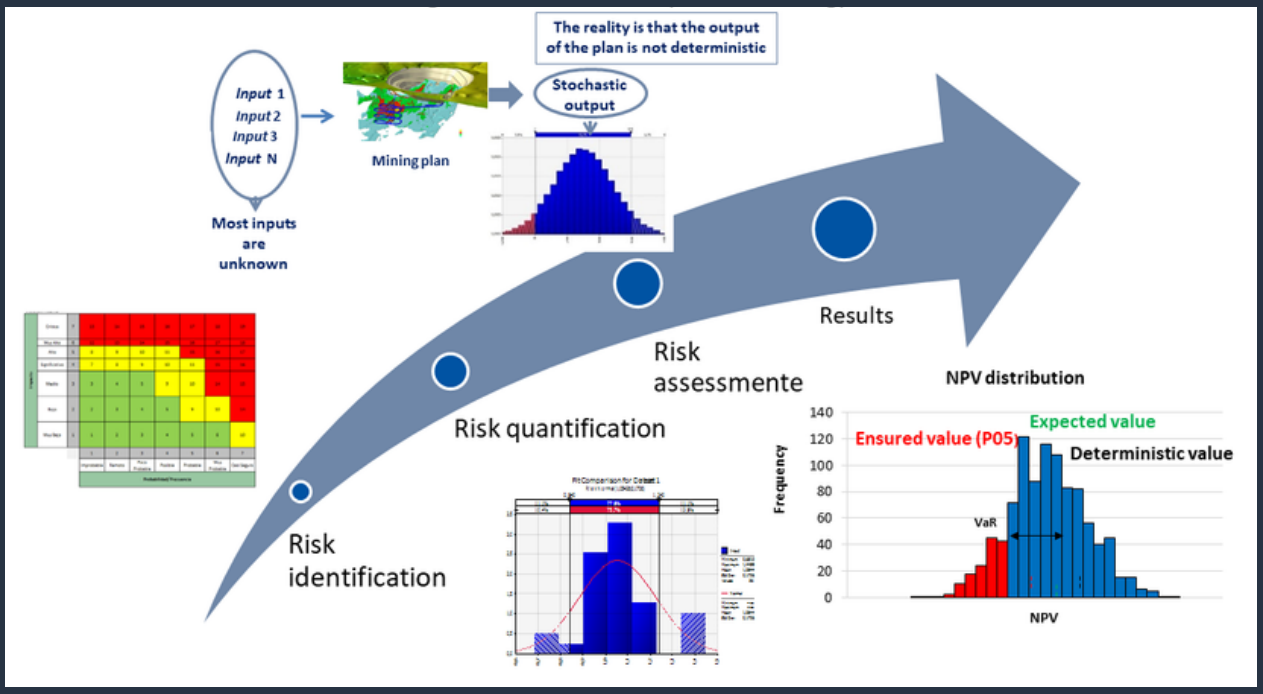
Risks are present throughout the entire production chain in the mining industry. There are different types of risks that can have an impact on different stages of the mining process, such as technical, environmental, economic or socio-political risks. Some of the most common risks in mining are the price of the commodity or main product, the project execution time, the variability of CAPEX or the metallurgical recovery of the products. Due to the probability that one or more of these risks materializes, the possibility of deviations in the planned indicators or changes in the viability of a project or operation is always present. The solution to this problem, widely used in other industries, is the realization of the so-called Risk Analysis, which allows to give concrete solutions to the problem posed.

A COMPLEMENT TO THE PERFORMANCE OF ECONOMIC GOALS

Since its foundation in 2008, GEM has performed around two hundred Risk Analyses to mining operations and projects, which not only allows to identify the uncertainties that generate variations in an evaluation, but also allows to know the impact they have individually on the NPV. The result is shown as the updated value considering these variables, giving competitive advantages to the company by being able to mitigate everything that represents a greater threat. To meet the productive goals of the operations and the NPV planned in projects, it is necessary to consider all events that may cause deviations, allowing reactive measures to be taken in the event of these changes happening. To prevent, mitigate or take advantage of these deviations, Risk Analysis appears to be an effective and necessary tool to determine the expected value of the planification and evaluate its robustness against new scenarios.

GEM has used this tool to support the mining industry in evaluating operations (mines in production) and projects (in search of financing or under development), identifying opportunities for improvement and proposing alternatives for their development. To do this, GEM uses a methodology represented in **Figure 1**, which consists of three main steps based on the international standard ISO 31000 (Risk management):

Figure 1-GEM Risk Analysis Methodology



Risk identification: A survey of all uncertainties is performed, and all risks considered significant for the assessment are identified, considering their frequency and magnitude of impact. The relevant risks are determined based on the level of criticality of the risk evaluated according to the characteristics of the study.

At this stage, **the participation of all the areas involved** in the development or execution is of great importance so that the list of uncertainties generated accurately represents the risk scenario in which the operation or project under evaluation is immersed.

Risk Quantification:

A quantification is made based on historical data (objective quantification), expert judgment (subjective quantification) or both (mixed quantification). In this way, **the risks identified as relevant are modeled through probability distributions to represent their variability**. This stage is critical within Risk Analysis since it is expected to represent reality through mathematical models. Risks can have two origins, one of them being external risks, whose variability is external to operations and projects. On the other hand, internal risks are those that depend on the action plan and strategy of the companies.

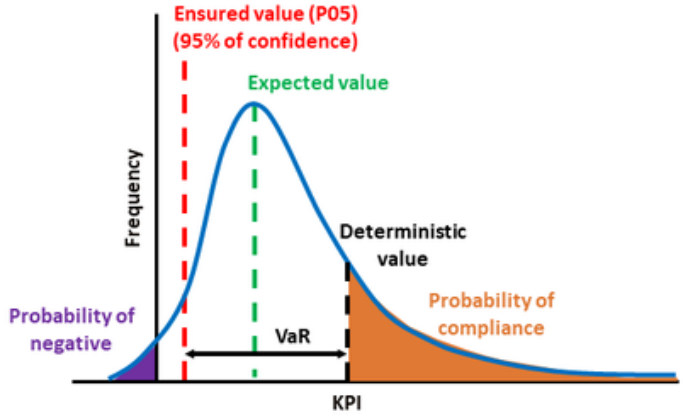
Risk assessment: With the risks once quantified, they are incorporated into the planification. Monte Carlo simulations are performed in @Risk to determine the individual or collective impacts of the quantified risks in the mine plan. The result of this stage is a **histogram showing the distribution of the NPV** based on the iterations performed applying the respective variability and bias of the risks included.

Generally, and under the GEM experience, there are biases between the planned variables and the expected value of these variables.

The results of the Risk Analysis are important to know the risks that most affect planification, the robustness of the project against risks and the flexibility of the project in different scenarios. Among the important statistical results are the Safe Value (95% statistical confidence is the value most used in the mining industry according to the GEM experience), the Expected Value and the Probability of Compliance, which highlights the number of simulations that exceeded the initial planning.

Associated with the Safe Value is the Value at Risk, which represents the value contributed by the risks to the initial deterministic valuation. **Figure 2** shows these and other metrics graphically. Similarly, **Table 1** details the average values for these key performance indicators (KPIs) based on data collected by GEM for mining projects and operations over a 13-year period (2010-2022).

Figure 2 - Risk Analysis relevant indicators



Expected loss (%)	(Deterministic value − Expected value) / Deterministic value
Value at Risk (%)	(Deterministic value − Ensured value (P05)) / Deterministic value
NPV probability of compliance (%)	N° of iterations with NPV > Deterministic value / Total iterations
NPV probability of negative (%)	N° of iterations with negative NPV / Total iterations

The importance of knowing these metrics lies in the goals that the company itself must establish. On the one hand, goals with a high probability of compliance may be easy to meet, but they do not encourage efficiency and do not maximize the value of the company.

To avoid this, it is necessary to set challenging goals, but at the same time they need to be feasible to meet the interests of the associated stakeholders.

On the other hand, a low probability of compliance of the mining plan or the value of a project according to the company's reality may not materialize, generating conflicts by not fulfilling what was promised.

For the planned value targets, the probability of NPV compliance is 35.2%. In other words, almost two thirds of the projects and operations analyzed do not meet the planned or deterministic NPV. From the same sample analyzed, the average probability of total NPV loss (project or operation with negative NPV) is 5.9%. Although this can be considered a "worst case" scenario (less than 6% of the cases could a lower value be obtained), it is avoidable through a correct Risk Management that includes the results obtained from the Risk Analysis.

TABLE 1. VAN AT RISK INDICATORS FOR PROJECTS AND OPERATIONS EVALUATED BY GEM (2010-2022). SOURCE: GEM.

VARIABLE	AVERAGE [%]
NPV Expected loss (N=60)	7.2%
Value at Risk (N=61)	57.6%
NPV probability of compliance (N=51)	35.2%
Probability of negative NPV (N=51)	5.9%

***Note**: N corresponds to the number of observations*

This background shows how fundamental it is to consider risks in any plan, so that in this way feasible goals are obtained and the companies themselves develop measures to be able to face these risks, increasing their value and ensuring their sustainability over time.

RISK ANALYSIS: CAPTURED EXPERIENCE

The identification of uncertainties initiates the Risk Analysis. The list of uncertainties to be considered depends on different differentiating factors between evaluations, such as the risk perception of the relevant stakeholders of the study, the project objectives, company strategy, geological and geomechanical conditions of the deposit, operation conditions and mine planning, among others.

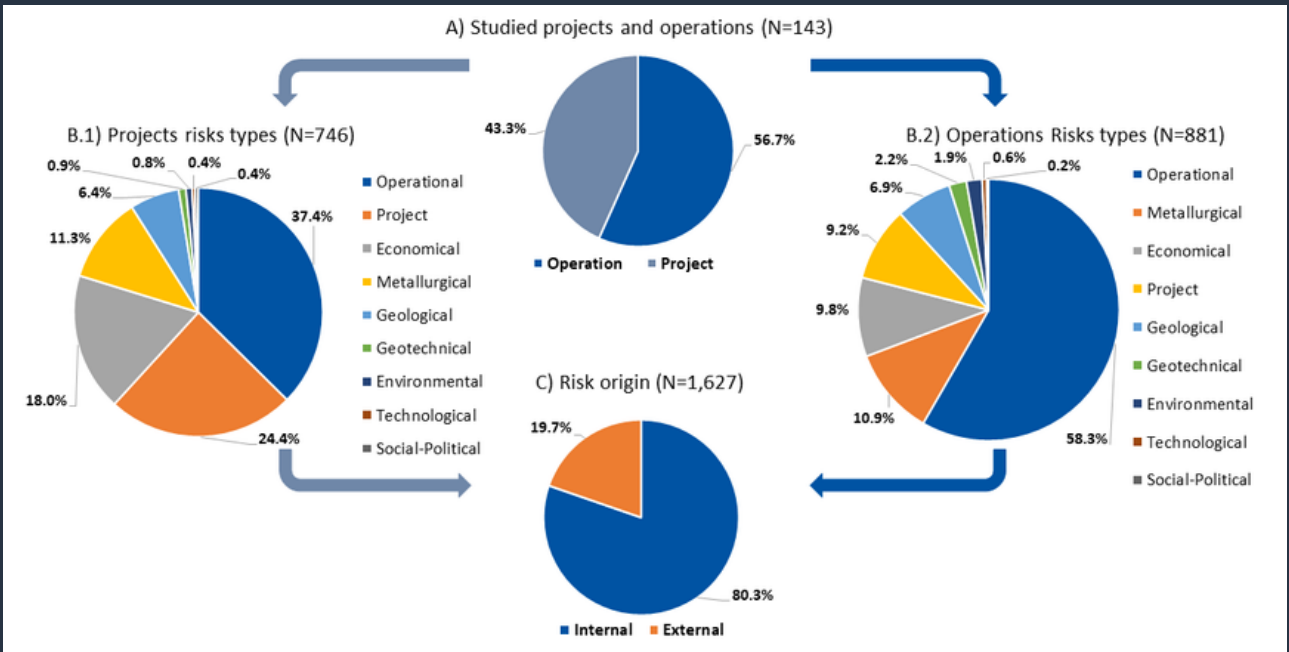
The composition of the team in charge of the identification is one of the most relevant factors since it can generate a bias given the inclination to identify uncertainties of a particular study area and/or the non-inclusion of significant uncertainties due to the lack of a multidisciplinary team. Hence, it is important that all areas are involved in risk identification.

CHARACTERIZACTION OF THE SAMPLE

A study was made based on 143 Risk Analyses carried out by GEM in the period 2010-2022, allowing to identify the main risks identified in mining projects and operations, along with the type to which they belong, their origin and impact generated on production and/or associated NPV.

Based on the data collected, some tendencies in the identification of certain types of risks over others in projects and operations are confirmed. This is relevant information for the knowledge of the risks to be considered in early phases of the Risk Analysis, as shown in **Figure 3**.

Figure 3 - Data base description, projects/operations & types of risks



Within the sample analyzed, 56.7% corresponds to operations, while 43.3% are projects (**Figure 3**, **A**), showing a slight inclination to the analysis of operations even though in recent years the analysis of projects has increased significantly.

The Risk Analysis exercises contemplate a universe of 1,627 different risks among the operations and projects analyzed by GEM.

For both cases it is shown that the risks associated particularly to the mining process (operational) have a higher frequency given by 37.4% (**Figure 3**, **B.1**) in the case of projects and 58.3% (**Figure 3**, **B.2**) in operations, highlighting the importance of operational risks even as early as in the project stage. Mechanical availability or Equipment performance are part of this type of risks.

The next most frequent types of risks for the analyzed sample are metallurgical (i.e. recovery, processing times, etc.), economical (price of the main commodity and/or by-products, exchange rate, among others) and project type (delay in the execution time, ramp up, among others). The distribution of the frequency of risk classes observed has remained relatively constant over the time evaluated.

The origin of the risks identified is mainly internal, comprising 80.3% of the sample (**Figure 3**, **C**), while the remaining 19.7% corresponds to external risks, where the latter account for the approximate proportion of risks within a project or operation whose source does not lie in the internal planning or execution of an operation, so that the action plan against these risks consists mainly of mitigation measures.

Figure 4 shows the distribution of types of analysis used, from where it follows in similar proportions the studies are focused on the impact generated on NPV (48.1%) and production (44.4%), these being the main variables that determine the value of a project or operation.

For the quantification of the identified risks, the most frequently used type is objective (70.7%), resulting in more than two thirds of the sample. In general, there is a tendency to this type of quantification because it is the one that generates less bias in the process, as shown in **Figure 5**.

Figure 4 - Types of Risk Analysis used (N=108)

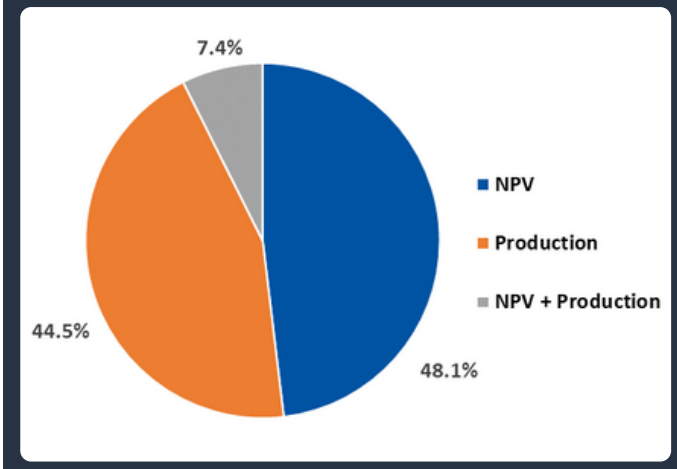
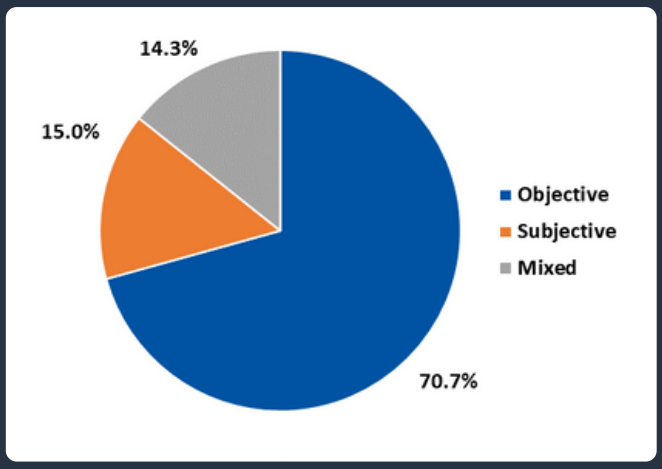


Figure 5 - Types of quantifications used N=1,136)



Note figure 4: *The number of observations (N) corresponds to the Risk Analyses that specified whether the study was aimed at NPV, production or both*
Note figure 5: *The number of observations (N) corresponds to the quantified risks that specified the type of quantification used*

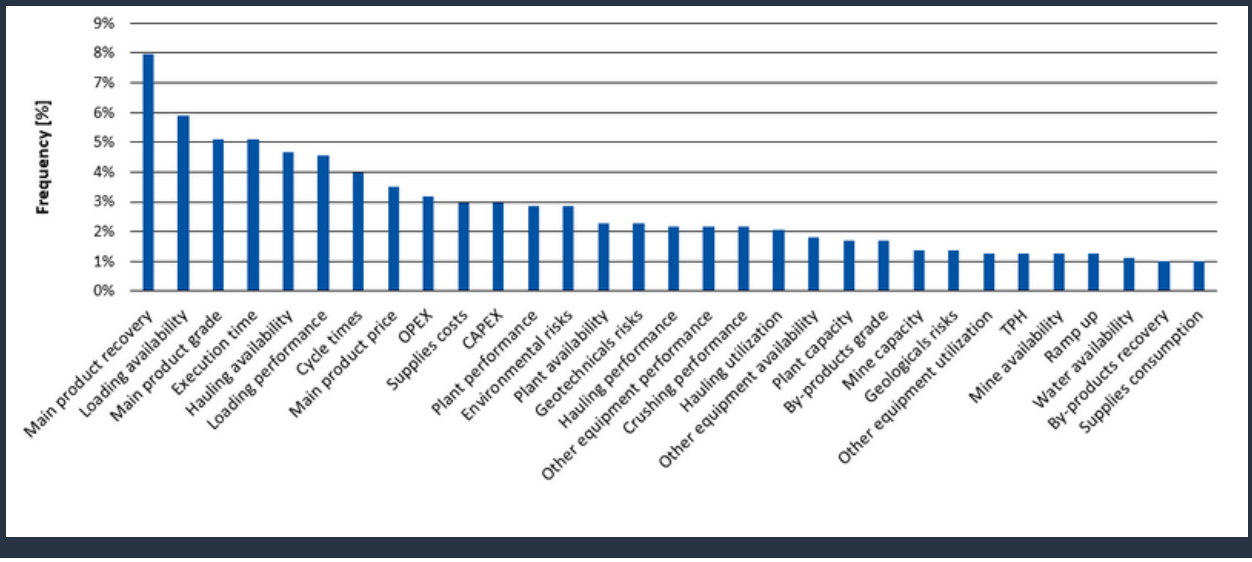
It should be noted that, although objective quantification is dominant in Risk Analysis, based on the GEM experience there is evidence of an increase in subjective and mixed quantifications in recent years. This is mainly due to the increased use of expert criteria in quantification due to the increase of risks that lack historical data for quantification and/or due to the emerging awareness that not in all cases history faithfully represents the current and future state of a project or operation.

LESSONS LEARNED

Focusing on the risks identified and quantified along with their impact, it is also necessary to analyze which risks specifically present the highest frequency within the study to understand their importance. **Figure 6** highlights the risks with the highest frequency for the operations assessed through Risk Analysis.

Recovery of the main product together with loading equipment availability are the most common risks within the evaluations performed by GEM, with 8% and 6%, respectively. Then it is observed that the risks associated with the grade of the main product, execution time, transport equipment availability and loading performance are the following in relation to their frequency of occurrence in the sample.

Figure 6 - Frequency of operational (other risk represent 15.3% of the sample) (N=881)

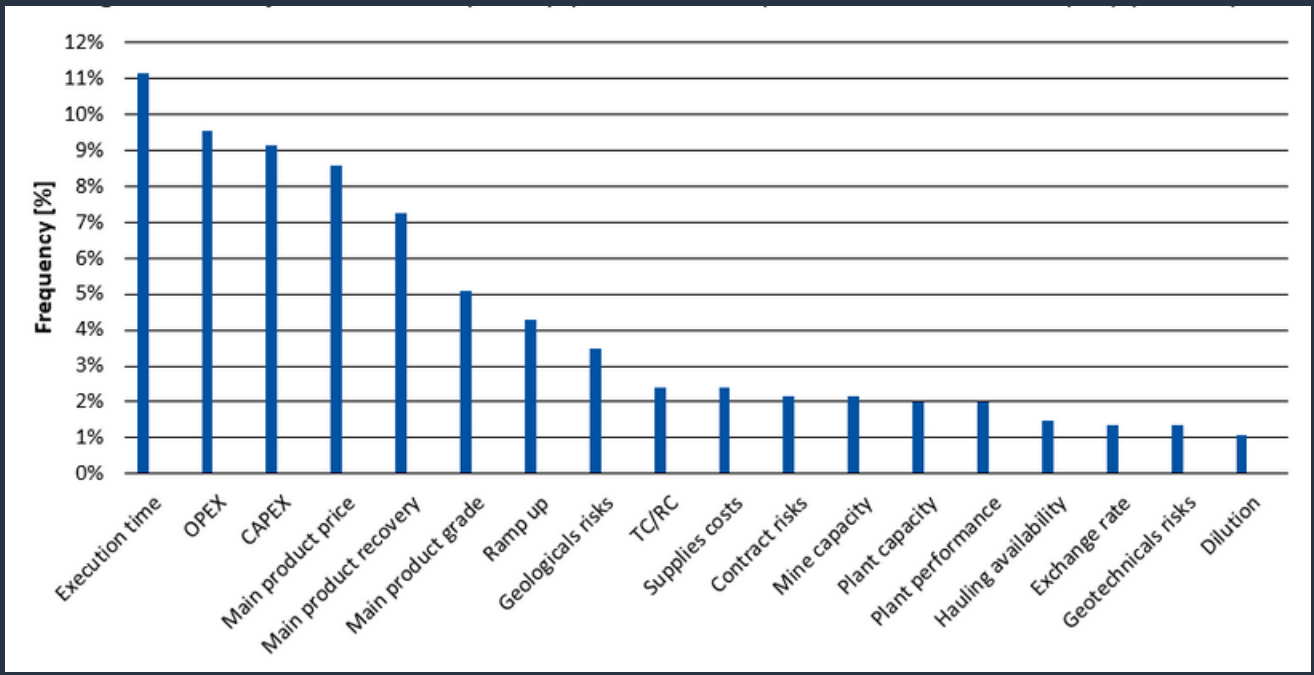


Note: *The number of observations (N) corresponds to the total number of risk of operations*

For the case of the projects considered in the analysis, **Figure 7** shows the frequency of the respective risks in the sample. The execution time emerges as the most frequent risk with 11.1% of the data, mainly because the delay in the execution of a project is an inherent risk in this type of evaluations. OPEX, CAPEX and the price of the main product are the next most frequent risks with 9.5%, 9.1% and 8.6%, respectively. Then comes the risks of recovery of the main product, grade of the main product and ramp up with a frequency between 8% and 4%.

It is important to mention that there are risks that are evaluated in both projects and operations, as is the case of the risks of recovery and grade of the main product, as well as the risk of execution time. However, regardless of the frequency of the risks used, the impact they generate also determines their relevance for inclusion in the evaluation.

Figure 7 - Frequency of project risks (other risks account for 23.2% of the sample) (N=746)

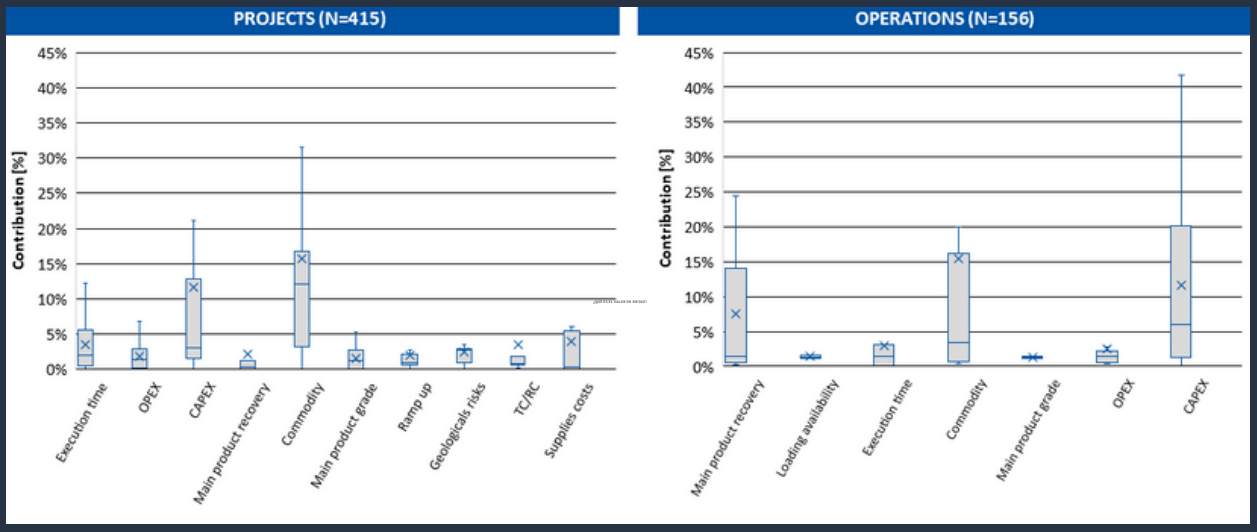


Note: *The number of observations (N) corresponds to all project risks*

What is Value ar Risk (VaR)?

VaR (Value at Risk), the most widely used risk indicator in Risk Analysis, is defined as the difference between the expected value of NPV, production, or some other relevant variable (which can also be defined as a commitment or target), and its 5% percentile (or safe value at 5%), thus considering a statistical confidence level of 95%. The introduction of VaR makes it possible to understand the magnitude of the potential losses in value that the business scenario or mining plan evaluated could present. By comparing the VaR of different scenarios, the loss of value can be measured by the effect of uncertainties. For example, two business scenarios may have the same expected NPV value, but have very different reactions to risk, i.e., a different VaR.

Figure 8 - Contribution of assessed risks to the Value-at-Risk of project and operations



Note: *The number of observations (N) corresponds to the risks that present information regarding their contribution to the Value ar Risk*

Figure 8 presents the risks with the greatest impact in terms of their contribution to the VaR for the projects and operations evaluated. In projects, the execution period, CAPEX and the price of the main product are the risks with the highest contribution to the VaR.

FULFILLMENT OF PLANNED VALUE

One of the main challenges in mining is the incorporation of variability in mine plans and cash flows since deterministic evaluations are not capable of capturing the robustness and flexibility of projects and operations in the face of the materialization of risks that constantly occur during their development. In this line, Risk Analysis proposes a solution to this problem, generating stochastic plans that allow the decision maker to perform a complete analysis that considers the risk environment in which the evaluation is located and provides the most favorable and pessimistic scenarios to be considered.

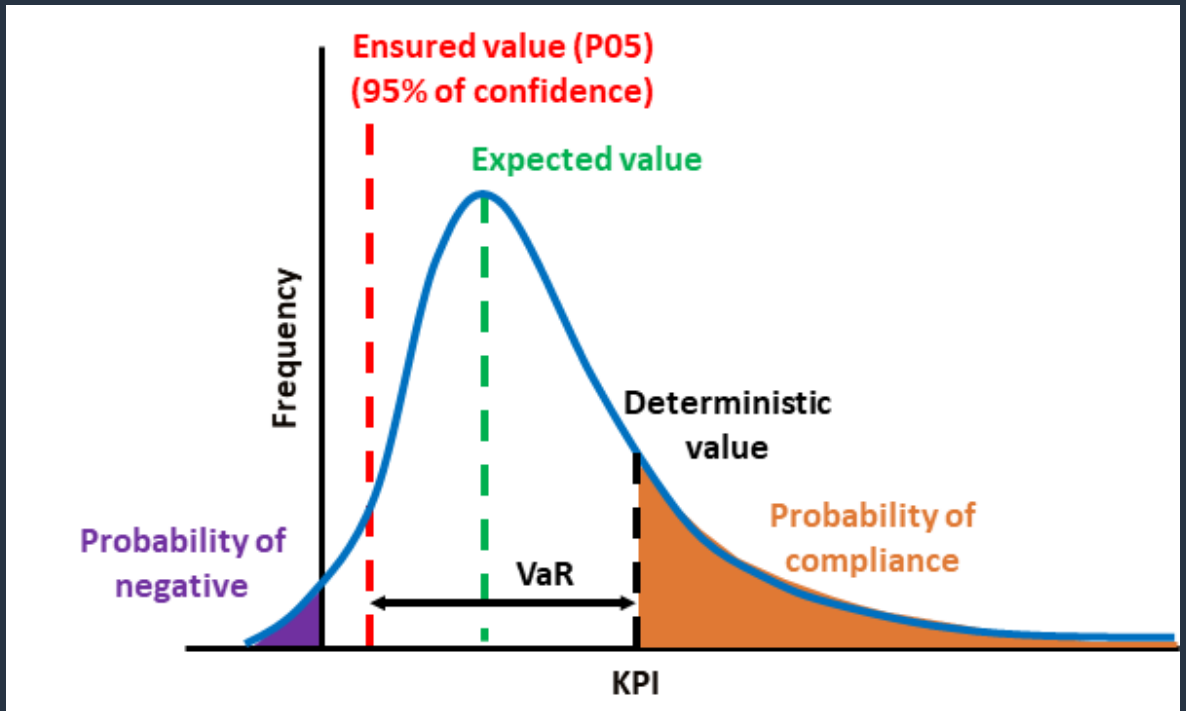
"Deterministic evaluations are not capable of capturing the robustness and flexibility of projects and operations"

By evaluating the probability of occurrence and impact generated by a group of risks to be considered in a plan, it is possible to identify the most relevant risks for the study and thus take control and/or mitigation measures. It is for this reason that Risk Analysis is a powerful tool for Risk Management.

Based on the analysis of the contribution of the main risks identified to the Value at Risk based on the results obtained from the sample analyzed, it is concluded that the risks with the greatest impact on operations are CAPEX, the price of the main commodity and the recovery of the main commodity, while for projects the main risks are the price of the main commodity and CAPEX.

Figure 9 presents the main NPV metrics resulting from the GEM experience based on the sample of different Risk Analysis studies executed in the past.

Figure 9 - NPV relevant indicators & GEMs industry categorization



NPV at risk indicators	GEM categorization		
Variable	Fragile	Neutral	Robust
% NPV expected loss	>8%	-1% - 8%	<-1%
VaR (P05) / Deterministic	>61%	23% - 61%	<23%
NPV prob. Compliance	<17%	17% - 48%	>48%
NPV prob. of negative	>4%	0% - 4%	0%

(*)Expected loss is negative in the case the expected value of the Project is superior that the deterministic value
Note: *The number of observations (N) corresponds to projects reporting metric data*

As can be seen, the table within the figure shows three intervals for each of the metrics evaluated. The "Fragile" category corresponds to data between the 0% to 25% percentiles, the "Neutral" category corresponds to data between the 25% to 75% percentiles and finally the "Robust" category corresponds to data between the 75% to 100% percentiles. The corresponding intervals for each category are indicators that can be used by projects to assess both robustness and vulnerability in each of the metrics evaluated.

Taking a large copper mining project in Chile as an example, it is possible to identify the positioning of it compared to the industry characterized by GEM in each of the metrics presented. **Figure 10** shows the positioning of this project.

Figure 10 - Relevant NPV-at-risk metrics and GEM categorization for the example project

NPV-at-Risk metrics	GEM categorization			Example project	
Variable	Fragile 🔴	Neutral 🟡	Robust 🟢	Value	Category
% NPV expected loss	>8%	-1% - 8%	<-1%	4.8%	🟡
VaR (P05) / Deterministic	>61%	23% - 61%	<23%	10.1%	🟢
NPV prob. Compliance	<17%	17% - 48%	>48%	7%	🔴
NPV prob. of negative	>4%	0% - 4%	0%	0%	🟢

The project has an expected loss of 4.8%, so it is considered neutral according to the GEM categorization in that KPI. On the one hand, it is a robust project in terms of risk, since it has a VaR of 10.1%, and does not run the risk of loss of NPV (i.e., it is a project that generates value for the investor even in a very negative scenario of risk materialization).

On the other hand, the probability of NPV compliance is only 7%, which is considered fragile, thus showing that, although the project is robust in terms of no loss of value, the economic goals proposed by the project will probably not be achieved (so they can be considered optimistic).

CONCLUSION

Meeting production and economic goals, as well as executing projects within the planned deadlines and amounts, are part of the great challenges faced by the mining industry. This can result in significant losses for a mining company.

According to GEM's experience in the industry, one of the causes of not meeting the goals is that when evaluating a project, not all the uncertainties that could affect its **execution or the operation's performance are considered**. Another important aspect is that sometimes **uncertainties are identified, but their impact on the evaluation is underestimated**.

This Perspective report presents a tool capable of providing a solution to the above problem: Risk Analysis. This is an effective and necessary tool to determine the expected value of the planning and evaluate its robustness against new scenarios. In addition, it allows to know the impact that each risk generates in the NPV, to identify improvement opportunities or to propose development alternatives.

GEM is the leading consulting company in the mining industry in Risk Analysis. It has conducted around 200 Risk Analysis studies for mining operations and projects of various mining companies (nationally and internationally). This has allowed it to generate relevant metrics to determine the robustness of a project or operation.

Based on GEM experience, the risks with the highest frequency and impact in mining operations are: (1) CAPEX, (2) recovery of the main product and (3) price of the main product. For projects, the risks with the highest frequency and impact are: (1) price of the main product, (2) CAPEX and (3) execution time.

Considering the impact of risks on NPV, it is possible to report relevant indicators to determine deviations of operations and projects from the planned NPV. In the Risk Analysis studies carried out by GEM, the percentage of expected loss of NPV on average is 7.2%, the percentage of Value at Risk is 57.6% and the probability of NPV compliance on average is 35.2%.

All of the above shows that Risk Analysis is an essential **tool for incorporating risks in any plan, identifying opportunities for improvement and thus establishing feasible goals for a company**, in order to generate robust projects in the face of the materialization of risks.

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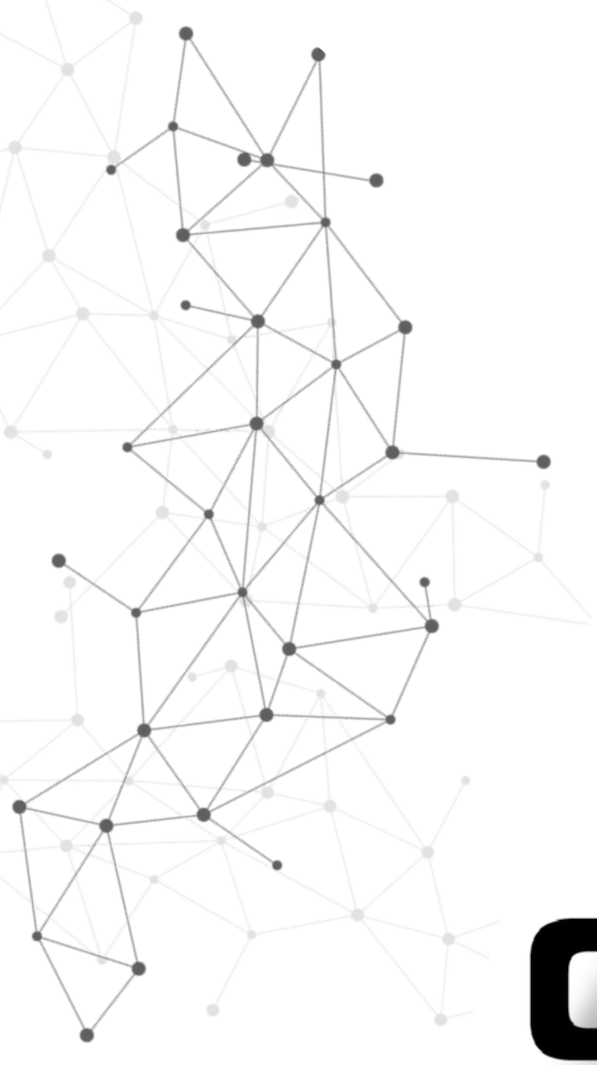

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