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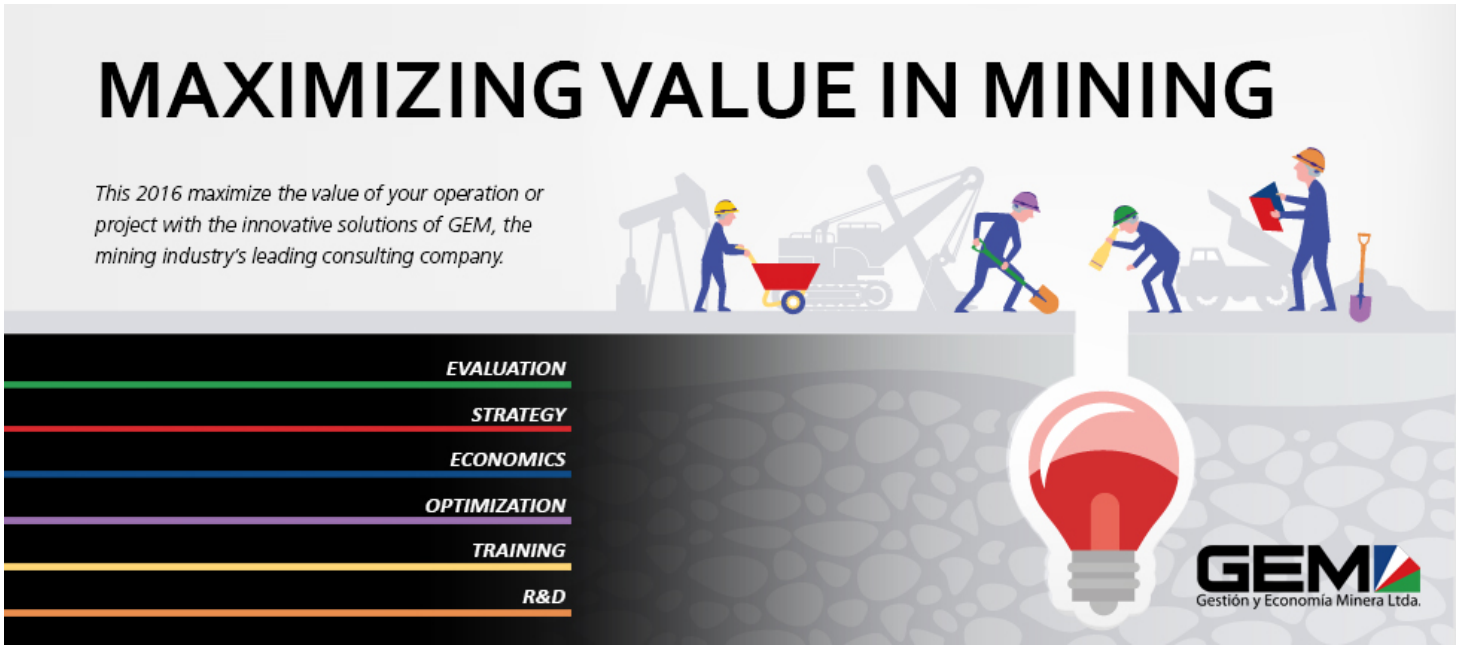
# PERSPECTIVE N°14

## *RISK ASSESSMENT IN TENDERS: CORRECT BALANCE BETWEEN COST AND RISK*

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***WEBSITE:*** *www.gem-ing.cl*

***PHONE:*** *+ 56 2 2225 30 21*

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***EMAIL:*** *contacto@gem-ing.cl*

# RISK ASSESSMENT IN TENDERS: CORRECT BALANCE BETWEEN COST AND RISK

*Josefina Correa, Carlos Hinrichsen, Matías Marañón*
*GEM | Gestión y Economía Minera Ltda.*

## INDUSTRY OUTLOOK: PRICE AND COSTS TRENDS

Since 2011, copper price has shown a downward trend that has alerted the main producers around the world. In the period between 2011 and 2015, the price showed a 43% reduction, going from 4.15 US$/lb to 2.72 US$/lb (real terms, base year 2016). This tendency has continued during this year with an observed drop of 20%, when comparing the average price of the first trimester of 2016 (2.11 US$/lb) with the average price of the same period in the previous year. At the same time, expectations for copper price in the future are not so encouraging. Researches done by COCHILCO forecast an average copper price close to 2.15 US$/lb for the year 2016, and 2.20 US$/lb for the next year. Recent declines in copper price are attributable mainly to a slowdown in the growth of the main copper consumer's economies, being the Chinese economy one of them (consuming 50% of world copper production). The latter has shown a clear deceleration, directly affecting the demanded volumes of copper. On the other hand, an increase in production has been observed, driven mostly by the entrance of huge projects in Peru, worsening the situation.

One of the major problems associated to the observed drops in price during the last period, comes – paradoxically – from the long period of high prices that preceded it, because by betting on higher production, and therefore taking full advantage of the high-price part of the cycle, production costs were neglected. Copper price increases were accompanied by sharp increases in C1 costs, as exemplified by the changes in the Chilean industry cash cost which went from 0.51 US$/lb in 2005 to 1.63 US$/lb in 2014 according to COCHILCO. Somehow, the long period of prosperity experienced by copper mining companies led to an organizational culture of high expenses and low productivity, which was compounded by rises in basic input costs.

TTo address the current scenario, mining companies have had to make their best efforts to reduce costs and thus keep operating. Some of the main actions that have been observed are related to decreases in OPEX, replanning, changes in production capacities and investments revaluations. As for the OPEX, the most popular actions observed are related to simplifying the administrative structure, along with staff reductions, plans to optimize maintenance of crushing and grinding lines, and the renegotiation of contracts. In replanning, they have raised the cut-off grade, lowered the stripping ratio, and discarded marginal areas (all with the idea of improving cash flow in the short term). In terms of capacity, it has been both increased and decreased, along with optimizations in the comminution line. Finally, regarding investments, projects have been slowed (or even halted), exploration expenditures have been closed, and just investments on sustaining CAPEX have been kept.

All these measures have started to yield results. During the past year, the average industry cash cost has begun to decline. However, there are still operations that are producing with costs above the current and projected prices, or in an extreme situation, where margins are at risk. That is why it is necessary to find new ways for cost reduction and optimization of available resources, such as finding the right bidder in a tender.

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## TENDERS EVALUATION

Nowadays, there are many mining companies that are developing new projects, expansions or renegotiating contracts. Nevertheless, only a few of them conduct deep studies in these areas, incorporating different types of assessments and approaches to help the decision making process when it comes to selecting the best bidder. That is why a correct evaluation of tenders must incorporate traditional evaluations (technical and economic) and also strategic and risk evaluations, in order to be more efficient and sustainable in the use of resources and lower the risk of the project.

## RISK ANALYSIS IN TENDERS

### METHODOLOGY

As it was mentioned earlier, there are different methodologies to evaluate tenders. Among them, the risk evaluation developed by GEM is capable of differentiating itself from others because of its capacity to incorporate uncertainty when evaluating the real convenience of one offer over the rest. Two fundamental characteristics are considered of high value when doing a risk evaluation of tenders: the robustness of the proposals and the flexibility that companies have to react to risks.

The robustness concept is related to the determination of whether the planned deadlines and costs of each tender can be affected by the materialization of technical and economic uncertainties. When comparing offerors, their

### TECHNICAL EVALUATION

The technical evaluation is mainly based on studying whether the companies presented in a tender have the capacity to carry out the project. Various factors can be measured in order to assess their capability to complete the work within the agreed conditions. A common way to do this type of evaluation is to establish, first, the relevant parameters to be considered and then use a measuring scale that allows the evaluators to rate companies in each specific area. From these parameters, a score for each company can be calculated, and thus prioritizing them.

One of the main characteristics to evaluate is the companies' previous experience. A deep study of the works in which each company has participated has to be done. Check that on these occasions they have met the contracted works and the agreed conditions. Furthermore, it is important to evaluate the experience and training of the people who perform key tasks in the project, as well as analyze whether the allocation of functions were done based on the preparation of the professionals. Other relevant technical variable to be considered is the availability of the required equipment for the project. It is important to assess whether the allocation of resources is adequate to meet deadlines and whether the company has the ability to hire extra resources in case of eventualities (such as a delay in the work). In this area, it can be assessed how affordable are the extra resources for each company, thus measuring their management capacity.

Finally, an analysis of the work plan and implementation schedule of the work should be done. Again, as in the study of resources allocation, the tendering company can make an estimate for the number of hours required for the execution of each task, and assess how optimistic the contestant companies are being in terms of productivity and ability to execute the works accordingly.

robustness relates to whether the most convenient contract (in terms of costs, deadlines and technical characteristics) is still the best when taking into account the materialization of relevant risks. It is important to note that robustness of each offeror can be measured in regard to a referent (i.e., estimates done by the company that is tendering the construction work), or in regard to its own planning.

On the other hand, flexibility seeks to measure each offeror's capability to react when the main uncertainties are materialized. Flexibility is mainly related to the management capability that companies have when the scheduled plan shows delays or failures in meeting deadlines, which in turn, goes hand in hand with the ability the companies have to access extra resources to offset delays or other imbalance in the plan. This way, flexibility can measure how offerors will be able to implement management actions that lower the effects of uncertainties materializing.

The risk evaluation methodology has three steps, all of which are described below.

### 1. UNCERTAINTY IDENTIFICATION

It consists on the identification of those uncertainties that could be relevant for the decision-making process. In practice, there are multiple sources of uncertainty, so the study of them should be limited to only those with the greatest impact. The main uncertainties considered in tender evaluations can be divided in two groups: technical and economical.

Some of the relevant technical uncertainties are those linked to the project productivities. In the case of underground mining, it is important to consider the uncertainty of air availability (ventilation), which is conditioned to the development of the ventilation tunnels that allow progress on several fronts. In the same way, critical equipment availability may be a relevant uncertainty if their maintenance and usage times are not properly controlled. Finally, the ramp-up has shown to be a relevant source of uncertainty. The vast majority of the works considers a ramp-up period where the project's development rate is variable, mainly because it takes some time to reach max productivity or capacity. For this very reason, this stage may be longer than expected, or even present delays in its starting date.

Regarding economic uncertainties, only those that have a high impact on a project's costs should be considered. Some of the most common economic uncertainties are:

## ECONOMIC EVALUATION

Once the group of tenderers that meet the technical conditions have been selected, an economic evaluation must be done. This assessment is based on calculating the cost associated with hiring each company. It should evaluate the final amount that will be charged for the project, payment terms and penalties.

Moreover, it is common for the bidders to seek to protect themselves from the risks associated with changes in macroeconomic variables with the potential to influence their costs. That is why many of them use a polynomial that includes the main variables that may affect their costs. Some of the most common variables used in these polynomials costs are the exchange rate, variables associated with the cost of labor (as wage index), variables related to the cost of relevant inputs such as diesel, and consumer price index (CPI).

Regarding payment terms, these may become decisive in a tender. Given the current market conditions, in which many of the mining companies are operating with tighter margins, payment facilities could become a major factor to choose among contractors.

Finally, the definition of the system of penalties may have a leading role when choosing the contractor. Bidding companies should generate fines high enough to create incentives for the company to comply with the deadline, without jeopardizing the financial health of the contractor. It is relevant that the penalties are in line with the assessment that the company has on meeting deadlines. There may be occasions where the urgency for a work to be done is not that high, and therefore client companies may benefit from the tenders' delays (in cases where the values of the fines are sufficiently high).

the consumer price index (CPI), the remuneration index (RI), the observed dollar (DO) and the value of critical inputs. These economic uncertainties are generally part of the polynomial adjustment of the costs defined by each contractor and presented within the tender process.
In addition, there are probably many other uncertainties that affect the development of a tendered work, depending on the features of each project. However, the ones mentioned above are the most common for mining projects.

### 2. QUANTIFICATION OF UNCERTAINTIES

It allows for the inclusion of variability in the analysis. An uncertainty becomes a risk when it is quantifiable, thus becoming possible to measure its impact. The process of quantifying uncertainties generally requires, in addition to data search and the use of statistical tools, an expert component as well as the vision of the key participants in the tender.
There are three ways to quantify uncertainties: objectively, subjectively and mixed (objectively and subjectively). The objective quantification involves the use of historical data to measure the variability of the relevant uncertainties identified. Thus, it is considered that the past is a good estimate of the future. Such quantification can be performed through probability distributions or stochastic processes. Subjective quantification is used mainly in two scenarios: when historical data available for the variable to study does not represent its future behavior, or when there is no historical data of the variable. In these cases, expert judgment is used to estimate probability distributions or stochastic processes. The mixed quantification is a combination of objective and subjective probabilities. This type of quantification is used mainly when the historical data available partially represent the future behavior of the variable that is going to be studied.

### 3. RISKS EVALUATION

At this stage, the impact of the quantified risks on a variable of interest for the client company (typically deadlines and total cost) is assessed. This is done through the development of a model, which then is simulated through Monte Carlo simulations. The model must contain and link the most important uncertainties (which are called independent variables) to the variables to be studied (or dependent variables). Regarding the simulation, it allows

## RISKS EVALUATION

The focus of the risk evaluation in biddings is to understand how technical and economic uncertainties could affect the total cost of bids, and the project deadline. This evaluation helps to choose between the different offers considering the expected value of variables such as cost, deadline, or any other critical parameter; in addition to the level of risk associated with them. Thus, the client company can make a robust decision that fits its risk profile.

The risk analysis methodology used in tenders developed by GEM has three stages. The first is the identification of uncertainties, a process which seeks to identify the main sources of uncertainties or variability. At this stage, only those uncertainties, both technical and economic, that have a significant impact on the deadline, cost or others should be considered. Then, the quantification of relevant uncertainties is done, assigning a probability distribution or stochastic process to each of them. This quantification can be objective (historical data), subjective (based on expert judgment) or mixed.

Finally, the methodology considers the evaluation of the most significant risks. The cost and time of execution of the work are evaluated through a model that incorporates risks to the original plan. This model is simulated through the Monte Carlo simulation methodology. Through the latter, it is possible to obtain relevant information when assessing the risks of each proposal, as the likelihood of meeting deadlines, the probability that delays or eventualities in the project are generated, and more.

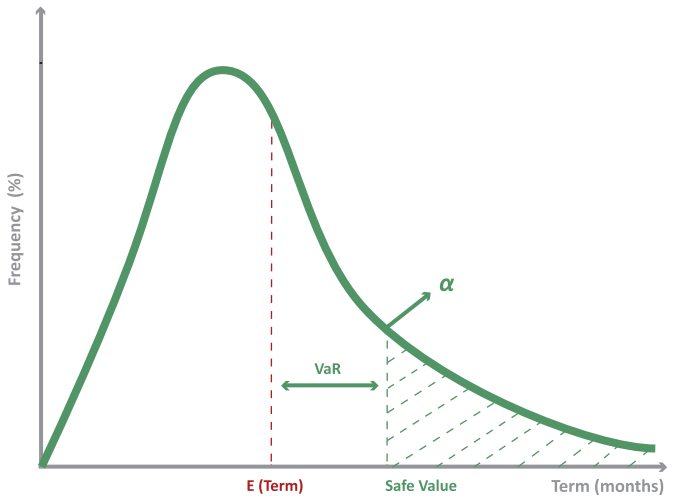
Moreover, as part of the risk analysis, results can be compared between the tender participants, and with some reference or benchmark. In this case, the plan information from the benchmark is required.

for the generation of a series of statistics that measure the robustness and flexibility of each offeror.

For example, the value at risk or VaR is the most commonly used risk indicator in this methodology. In this context, it is defined as the difference between the expected value of the cost, deadline, or some other relevant variable (which should also be defined as a compromise), and an α percentile (or insured value α) considering a confidence level (1-α). Typically the value used for α is 5%.

The VaR allows the client company to understand the magnitude of the potential loss of value that each contractor could cause (this indicator is shown in ***FIGURE 1***).

**FIGURE 1. VALUE AT RISK (VaR)**




For example, offers of two companies may have the same expected value of project completion date, but have very different reactions to risk (i.e., a different VaR).

In ***FIGURE 2***, this concept is exemplified by showing the distribution of the project's execution time for three companies and how they can be compared to theoretical expected value of the deadline and their VaR. Curve 1 and 2 show that even though they have the same expected deadline, the VaR can be very different, where the curve with the lower VaR represents a more robust scenario. The expected deadline and VaR for different distributions may also be compared to identify which company has a better relationship between deadline and project risk.

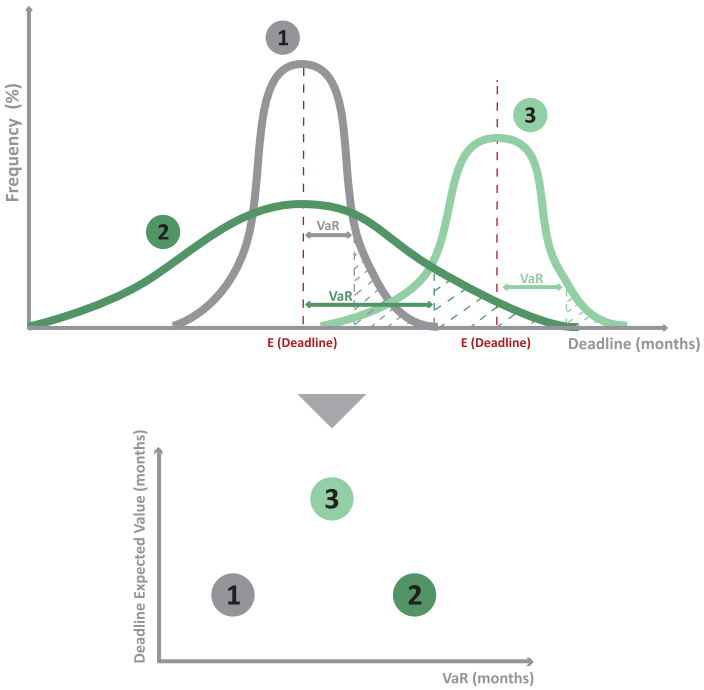
## STRATEGIC EVALUATION

Although through the technical evaluation the most prepared companies have been selected, through economic evaluation the ones with lower cost have been selected, and by assessing risks the more robust ones have been selected, there may be external variables, related to the client company or participating, that can favor the decision to choose one bidder over another. The strategic analysis seeks to complement the previous analyzes with more qualitative considerations, regarding elements that are difficult to see quantitatively. Therefore, its objective is to support the decision-making process of the client company, responding to certain strategic questions based on a holistic analysis that considers all the edges related to the project.

GEM's methodology has four strategic elements: strategic objectives, strategic levels, strategic approaches and strategic questions. First the strategic objective, which typically relates to meeting the projected plan of the project, is defined. Then, the different strategic levels that may be affected by decisions made in tenders are defined. In mining projects there are typically three: the global level (corresponding to the entire market), a more specific level (corresponding to the company that is bidding for the project) and the most detailed level (corresponding to the operation in which it will run). For the strategic approaches, generally they are related to deadlines, costs of bidding, technology, care for the environment and safety criteria.

Finally, the three main questions to be answered should be whether it is strategically wise to hire an outside company. Then, it must be questioned to whom the contract should be assigned. And finally, once the contract is assigned, a possible renegotiation of the contract must be assessed.

**FIGURE 2. COMPARISON USING VALUE AT RISK (VaR)**




In addition to evaluating different risk indicators, it is also possible to perform a sensitivity analysis of the risks in order to further assess its effect. One way to do this is through the tornado chart, explained in the next section.

## APPLIED CASE STUDY

In order to show the effects that risk assessment may have in decision-making in tenders, an applied case study was conducted. The characteristics of the proposal of each of the tender participants were established so that both were competitive and met the technical and economic conditions to carry out the tendered project, and thus giving realistic results.

*Offers of two companies may have the same expected value of project completion date, but have very different reactions to risk (i.e., a different VaR).*

## PROJECT DEFINITION

A company tendered a project that is characterized by the execution of 125,000 advance units (au) within 27 months. The project includes two stages, Milestone 1 and Milestone 2. For technical specifications, it is required that at least 80% of Milestone 1 must be executed to start the Milestone 2 (allowing parallel progress from this point). The technical characteristics of the works restrict the maximum monthly development to 8,500 au. The latter is mainly related to technical restrictions that prevent progress over certain limit (e.g., accesses in open pit mines or ventilation availability in underground operations).

Regarding the penalty system, the client company states that a delay in the execution of the 80% of Milestone 1, respect to the contractor's plan, triggers a compensation that depends on the monthly general expenses of the contractor and the amount of backlog. Along with this, the project status is evaluated semiannually, generating penalties if there are delays in the original plan. These penalties are also proportional to the accumulated delay at the evaluation date.

According to the client company plan, it would take nine months to run 80% of Milestone 1 (corresponding to 32,000 au), 11 to complete the Milestone 1 (40,000 au), and 27 months to complete the entire project (125,000 au). All this with a total cost of 203 million dollars (MUS $), which comprises 30% by fixed costs, and the remaining by variable costs. The fixed cost (or overhead) is prorated for the months of activity (i.e., MUS$ 2.25/month). The variable cost estimated by the client company is 1,136 US$/au.

## TENDER PARTICIPANTS

***TABLE 1*** shows the client company's estimates regarding deadlines and costs, in addition to the amounts proposed by bidders A and B.

**TABLE 1. MAIN TECHNICAL INDICATORS OF EACH COMPANY**

| | CLIENT COMPANY | COMPANY A | COMPANY B |
|---|---|---|---|
| 80% Milestone 1 | 9 months | 9 months | 7 months |
| End of the Project | 27 months | 26 months | 23 months |
| Fixed Monthly Cost | 2.25 MUS$ | 2.29 MUS$ | 2.52 MUS$ |
| Total Fixed Cost | 61 MUS$ | 59 MUS$ | 58 MUS$ |
| Variable Cost | 1,136 US$/au | 1,134 US$/au | 1,133 US$/au |
| Total Cost of the Project | 203 MUS$ | 201 MUS$ | 200 MUS$ |

From the table above it can be drawn that Company B's proposal is slightly better because it meets the deadlines required by the client company (both 80% of Milestone 1, as well as the entire project) and the costs are below the ones estimated. In ***FIGURE 3*** (below), each company's proposed production profile is shown, as well as the estimated cost for each. Along with the profile of each company, the reference profile (i.e., the one of the client company) is shown. The latter will be used to compare both companies, not only in terms of their performance with regard to their original plans, but also in terms of their performance with regard to the reference plan.

**FIGURE 3. PLANNING AND COSTS BY COMPANY**


In the case of technical risks, and for the purposes of this applied case study, three productivity-related risks were taken into account: productivity of each work crew (measured in effective hours per work crew), the number of work crews (measured in work crews per turn), and the effective progress rate (measured in advancement units per effective hour). These three variables, multiplied by the deterministic value of the number of shifts per month (90), define the effective progress of each month. Within the technical risks, the possibility that the works may not start on time was considered and therefore a risk of delays in ramp-up was established, where a probability of occurrence and a probability distribution for delay extension in months were considered. Regarding to the technical risk profile of each company, the profile of Company A is less risky than Company B's, indicating that although Company A requires a longer time for project completion with slightly higher cost, its lower risk may result in a higher probability of meeting its plan in comparison to Company B.

Regarding the economic risks, changes in the exchange rate of Chilean pesos per dollar and CPI (consumer price index) were considered. Economic risks will affect companies depending on how their cost polynomial is established. IPC weights 55% of Company A's variable cost polynomial, while it only represents 35% of Company B's polynomial (the remaining percentage ponders the exchange rate). The relevance of this is that, as changes in economic risks are the same for both companies, the only difference in the effect they have on costs is given by the weight that each company assigns to each economic variables, as well as payments realization dates.

***TABLE 2*** summarizes the monthly quantifications of each risk, showing the distribution used in each case as well as the main parameters of each distribution. It is important to note that quantifications of technical risks are made based on the planned value, (i.e., if in an iteration of the simulation the risk associated to the number of work crews was 1, then that month the materialized risk would be equivalent to the plan, while a value of 0.9 means that the number of work crews for that particular month would be 90% compared to the plan).

Moreover, although both risk profiles have a negative bias, they also consider values greater than one, which will eventually allow them to catch up with the plan.

**TABLE 2. DENSITY DISTRIBUTIONS OF THE RISKS ASSOCIATED WITH CONTRACTORS**

| RISK | UNIT | COMPANY | TYPE | DISTRIBUTION | PARAMETERS |
|---|---|---|---|---|---|
| Crews Productivity | [EfH/crew] | A | Multiplicative | Triangular | Min:0.89 Max:1.15 Mod:1.00 |
| Number of Crews | [crew/turn] | A | Multiplicative | Triangular | Min:0.85 Max:1.13 Mod:1.00 |
| Effective Advance | [au/ EfH] | A | Multiplicative | Triangular | Min:0.75 Max:1.10 Mod:1.00 |
| Start with Delay | [%] | A | Additive | Bernoulli | P: 0.95 |
| Length of the Delay Start | [month] | A | Additive | Triangular | Min:1.00 Max:3.00 Mod:1.00 |
| Crews Productivity | [EfH /crew] | B | Multiplicative | Triangular | Min:0.70 Max:1.10 Mod:1.00 |
| Number of Crews | [crew/turn] | B | Multiplicative | Triangular | Min:0.81 Max:1.08 Mod:1.00 |
| Effective Advance | [au/ EfH] | B | Multiplicative | Triangular | Min:0.78 Max:1.13 Mod:1.00 |
| Start with Delay | [%] | B | Additive | Bernoulli | P: 0.85 |
| Length of the Delay Start | [month] | B | Additive | Triangular | Min:1.00 Max:4.00 Mod:1.00 |
| Dollar | [US$] | A/B | Additive | Normal | μ:690 σ^2:15.00 |
| CPI | [%] | A/B | Additive | Normal | μ:0.003 σ^2:0.003 |

## STUDY SCENARIOS

The risk evaluation was conducted considering two scenarios. The first, called recovery scenario, is the one in which contractors do not have the ability to manage extra resources in response to delays. In this scenario, contractors must recover – hence its name – the accumulated delay at the end of the planned period, with a productivity equal to their average productivity of the last three months.

In the second scenario, contractors can take management actions to catch up with the accumulated delays during the execution of the project by managing extra resources, and therefore is called management scenario. In this case, the minimum cumulative delay that triggers the management of extra capacity is 3,000 au. Once this happens, the contractor makes a request by the amount delayed up to date, which becomes effective three months later. However, if in three months after the request, the contractor is wholly or partially updated with the delay, then the extra capacity would help to advance production.

Since in both scenarios, the one with recovery as well as the one with management, contractors require additional effort than planned to meet all the advance units stipulated in the tender, the costs of these productions are higher. In the recovery scenario, contractors A and B have an increase in variable cost per advance units recovered of 5% and 10%, respectively. On the management scenario, these numbers go up to 10% and 20%, respectively.

Finally, note that when evaluating the results, both a comparison of the proposals with themselves (the original plan versus the plan at risk) and a comparison with the values of reference (what the client company estimates should be the deadline and cost) are made.

## RESULTS

Once the model that links the technical and economic risks with the deadline and cost has been developed, using

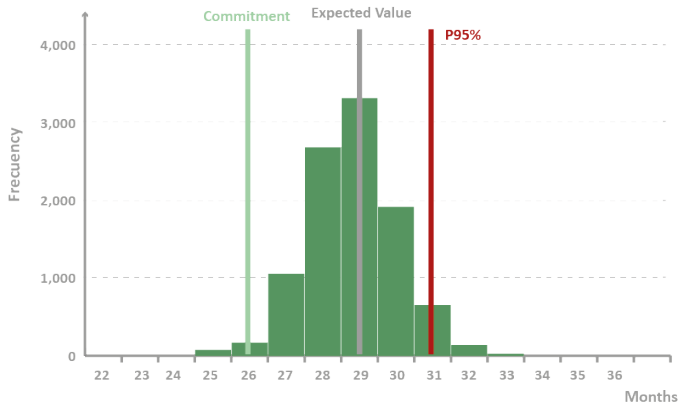
the above configurations, a Monte Carlo simulation with 10,000 iterations was performed. Through this simulation, it was possible to find the expected values, the 5th and 95th percentiles of the time that companies would take to implement the project and the cost considering the penalties generated during the project. Furthermore, it was possible to evaluate the development plan of each contractor in the recovery scenario (without management) and management scenario. First, the variability of the deadline of each company was evaluated. ***FIGURE 4*** shows the probability distribution of the deadline of Company A for each scenario.

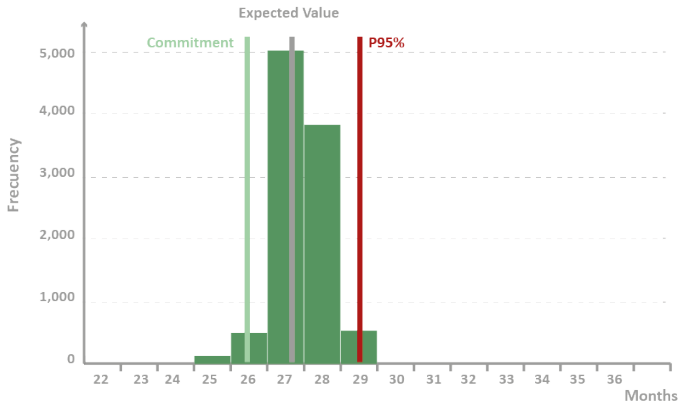
In the illustration above it can be seen that, in both cases, the expected value is above the committed value of 26 months (i.e., the odds of compliance are low in both cases: 2.4% with recovery and 6.1% with management). However, when comparing these deadlines with the value of 27 months established by the client company, the chances of compliance notoriously grow to 13% in the recovery scenario and 56% in the management scenario. Regarding the deadlines for the worst possible scenarios, it can be said that the work will take 31 months at the most to be

**FIGURE 4. COMPANY A DISTRIBUTION OF DEADLINES WITH RECOVERY AND WITH MANAGEMEN**

| TERMS WITH RECOVERY | |
|---|---|
| Expected Deadline | 29 Months |
| Worst Case Scenario | 31 Months |
| Months at Risk | 2 Months |
| Compliance Prob. (Regarding Commitment) | 2.4% |
| Compliance Prob. (Regarding Client Company) | 13% |

| TERMS WITH MANAGEMENT | |
|---|---|
| Expected Term | 28 Months |
| Worst Case Scenario | 29 Months |
| Months at Risk | 1 Month |
| Compliance Prob. (Regarding Commitment) | 6.1% |
| Compliance Prob. (Regarding Client Company) | 56.3% |




completed in the recovery scenario, and 29 months in the management scenario. Overall, the ability of Company A to manage resources does not generate significant benefit regarding its commitment (results with and without management are similar), but when comparing it to the client company reference, the ability to manage becomes more important.

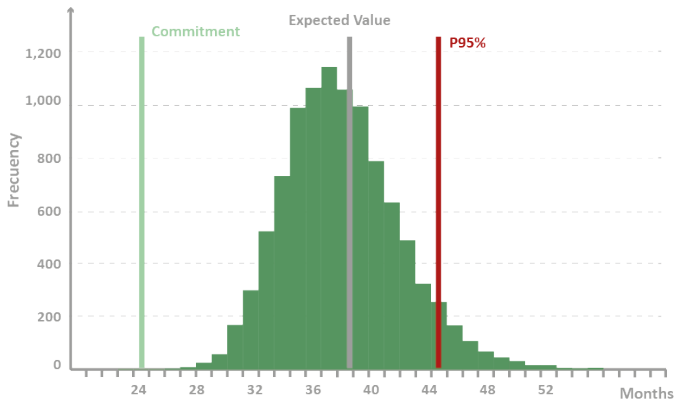
As in the previous case, ***FIGURE 5*** shows the results regarding the deadline for Company B.

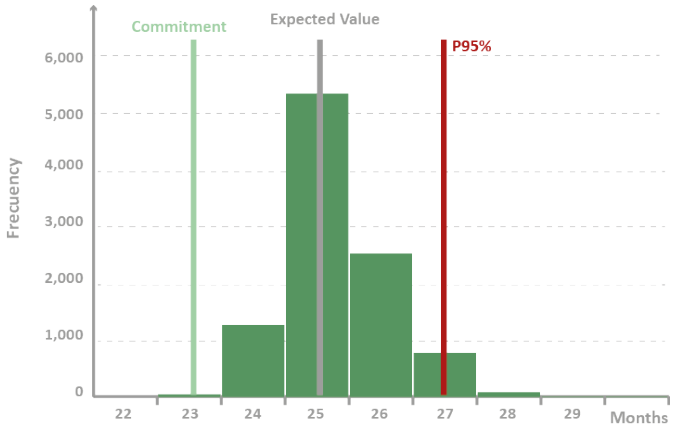
Here, the expected values for deadlines in both scenarios are higher than the commitment, with virtually no chance of meeting the plan (0% in the case with recovery and 0.3% in the case with management). Nonetheless, when comparing these values to the deadlines stablished by the client company, there is a high probability of meeting it in the management scenario (99.3% probability). Therefore, the possibility of managing resources for Company B has a significant impact, allowing it to go from an expected value

## FIGURE 5. COMPANY B DISTRIBUTION OF DEADLINES WITH RECOVERY AND WITH MANAGEMENT

| TERMS WITH RECOVERY | |
|---|---|
| Expected Deadline | 39 Months |
| Worst Case Scenario | 45 Months |
| Months at Risk | 6 Months |
| Compliance Prob. (Regarding Commitment) | 0% |
| Compliance Prob. (Regarding Client Company) | 0% |

| TERMS WITH MANAGEMENT | |
|---|---|
| Expected Deadline | 26 Months |
| Worst Case Scenario | 27 Months |
| Months at Risk | 1 Month |
| Compliance Prob. (Regarding Commitment) | 0.3% |
| Compliance Prob. (Regarding Client Company) | 99.3% |

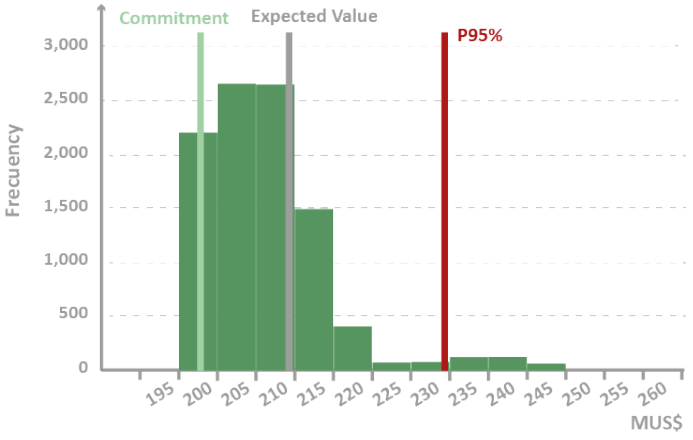


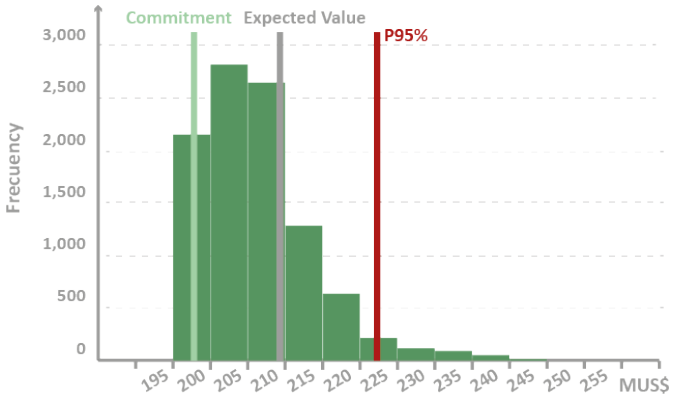




## FIGURE 6. COMPANY A DISTRIBUTION OF COSTS WITH RECOVERY AND WITH MANAGEMENT

| COSTS WITH RECOVERY | |
|---|---|
| Expected Term | 212 MUS$ |
| Worst Case Scenario | 232 MUS$ |
| Costs at Risk | 20 MUS$ |
| Compliance Prob. (Regarding Commitment) | 0% |
| Compliance Prob. (Regarding Client Company) | 9.1% |

| COSTS WITH MANAGEMENT | |
|---|---|
| Expected Cost | 211 MUS$ |
| Worst Case Scenario | 224 MUS$ |
| Term at Risk | 13 MUS$ |
| Compliance Prob. (Regarding Commitment) | 0% |
| Compliance Prob. (Regarding Client Company) | 7.8% |



of 39 to 26 months. Along with this, the expected value for the deadline in the case with management for Company B is the only one who manages to meet the deadline of 27 months proposed by the client company.

It is important to mention that the reason why the expected deadline of Company B with management is lower than the one of Company A is because Company B's plan considers a greater margin between its planned deadline (23 months) and the deadline requested by the client company (27 months). Thus, although Company B tends to lag further behind, because of their higher risk profile, this is offset by the ability to manage (identical to Company A's) and the highest margin mentioned above.

Having analyzed the deadlines of the companies in each scenario, variations in materialized costs were evaluated in relation to the ones planned by each company and the ones estimated by the client company. It is important to note that the costs assessed correspond to the real cost of doing the project for each company (i.e., the cost at risk plus the triggered penalties).

In ***FIGURE 6***, the costs distribution of Company A for the recovery and the management scenarios are shown, as well as a comparison of the values regarding the planned cost and the cost of reference proposed by the client company. There is no big difference between the observed cost for the recovery scenario and the management one (in both cases there is a low probability to meet the planned cost and the cost stablished by the client company). The cost at risk, which corresponds to the difference between the reliable cost and committed cost (MUS$ 201), is equal to 9% and 6% of the latter for the recovery and management scenarios respectively. These variations are mainly attributable to penalties that are paid as results of delays, since, as noted in the analysis of deadlines, the likelihood of accomplishing them is low, and therefore the probability of incurring in penalty fees is high.

In ***FIGURE 7***, cost distributions associated with Company B's scenarios (with recovery and with management), along with their statistics, are displayed.

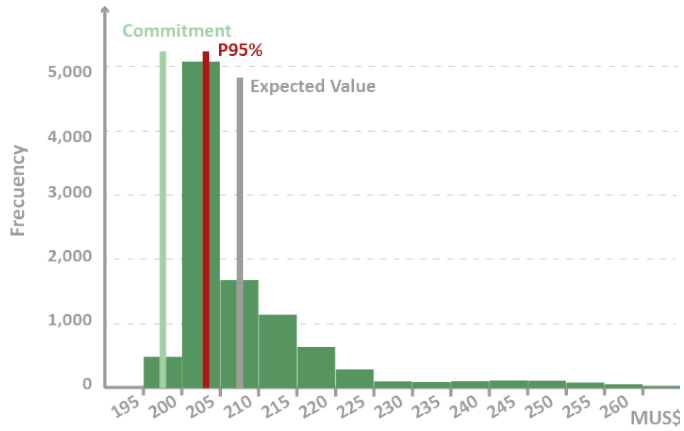
Here, even if the differences in the expected costs with respect to the planned ones are higher than for Company A, these are still not relevant. In the case of the value at risk, values are around 4% and 3% of the committed costs, for cases with recovery and management respectively.

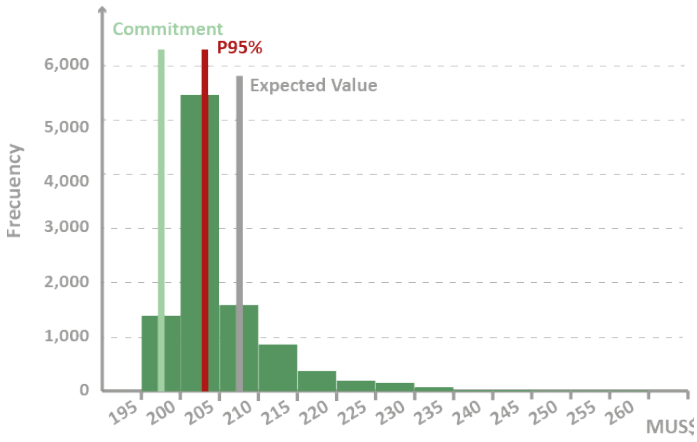
Although observed differences between expected costs in the case with recovery and with management are not

**FIGURE 7. COMPANY B DISTRIBUTION OF COSTS WITH RECOVERY AND WITH MANAGEMENT**

| COSTS WITH RECOVERY | |
|---|---|
| Expected Cost | 214 MUS$ |
| Worst Case Scenario | 205 MUS$ |
| Costs at Risk | 9 MUS$ |
| Compliance Prob. (Regarding Commitment) | 0% |
| Compliance Prob. (Regarding Client Company) | 0.2% |

| COSTS WITH MANAGEMENT | |
|---|---|
| Expected Cost | 210 MUS$ |
| Worst Case Scenario | 204 MUS$ |
| Costs at Risk | 6 MUS$ |
| Compliance Prob. (Regarding Commitment) | 0% |
| Compliance Prob. (Regarding Client Company) | 0.1 % |

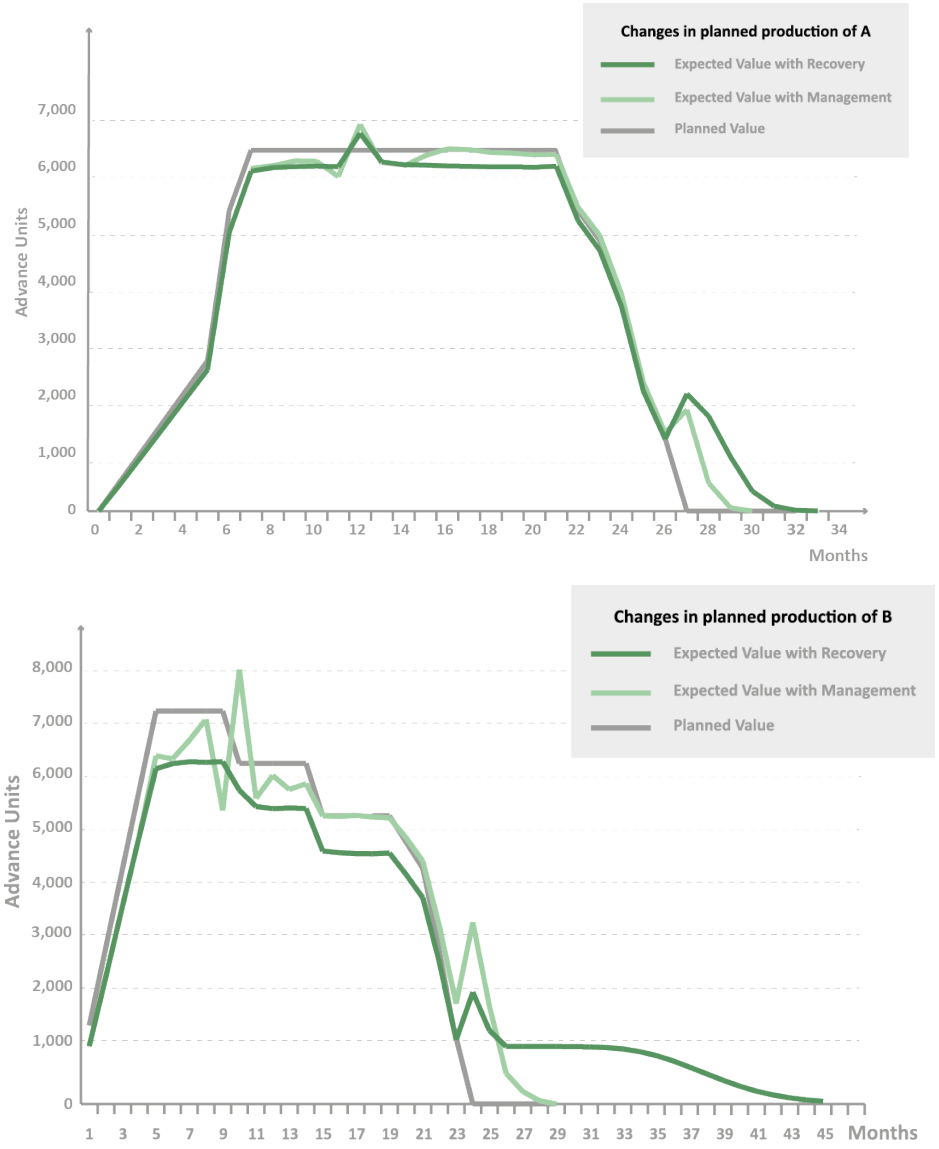


relevant, it is worth noting that, although the variable cost of each managed unit is higher than the variable cost of recovered advance units, the scenarios with management achieve lower total costs. This is attributable to two reasons. First, the ability to manage the delays (advance units do not accumulate) translates into a lower probability of paying semi-annual penalties. In the case without management, delays are accumulated until the end of the work, and only then the total accumulated delay can be recovered. Therefore, the semi-annual penalties increase and so does the total cost. On the other hand, the costs associated with managed advance units are sticking as they are requested, and therefore the polynomial cost fits the value of economic variables in these periods. In the case of recovered advance units, they are paid at the end of the scheduled time, and therefore they are subject to higher values of economic variables (taking into account that the CPI is a variable that tends to rise).

In ***FIGURE 8***, the expected development profiles of both companies in both scenarios are analyzed. In Company A, there is not a big difference between scenarios, while in Company B, the ability to manage resources becomes critical to get closer to the deadlines proposed by the client company.

**FIGURE 8. CHANGES IN PLANNED PRODUCTION PROFILE OF COMPANIES A AND B**



A sensitivity analysis for the technical and economic risks' impact in the most important performance variables was done. To perform this analysis tornado charts were used, where the idea was to evaluate the sensitivity of deadlines and costs to the assessed risks. For this, the values of each risk were fixed one by one at their extreme values (P5% and P95%), while other risks remained active. Then, the model was simulated (these simulations were performed with 1,000 iterations). Thus, through tornado charts it is possible to see the impact of each risk separately, in addition to showing the intervals in which deadlines and costs may vary. In Figure 9 the tornado charts obtained for management scenarios are shown. It is important to clarify that in the case of cost, the cost that the client company would have to pay considering penalties was was taken into account (i.e., the cost of each contractor minus penalties charged).

From Figure 9, it can be concluded that for Company A, the risk that has a greater negative impact in deadlines is the Effective Advance (i.e., the realization of low values of this risk leads to a further deadline increase within the project). Regarding to the costs for the client company, and if it chooses Company A, the risk related to the Effective Advance is the one that reduces its cost the most. In other words, the Effective Advance is responsible for bulkier penalties, reducing the amount payed by the client company.

In the case of Company B, it can be said that the risk related with the productivity of the crews is the one that has the most negative impact on deadlines. The risk associated with a low level of productivity has a greater impact on increases in deadlines compared to other technical risks. Regarding the contractor's costs, this risk (crew's productivity) is also leading to increased generation of fines, reducing the total amount paid by the client company. It is important to note that although the risks have the potential to reduce the

**FIGURE 9. SENSITIVITY ANALYSIS**

amounts paid by the client company due to penalties, the main objective is that the contractor complete the project within the deadline established. In other words, the system of penalties needs to have as a main objective to encourage the contractor to finish the work as planned, and not to generate profits.

Through this risk evaluation of bids, it can be inferred, first, that in the recovery scenarios both companies would not achieve – in expected value – the planned objectives in terms of deadline or cost. However, in this scenario, Company A is closer to the client company's reference deadline than Company B, who is quite far from it because of its riskier profile.

However, when companies have management capacity, Company B is capable of finishing the project within the client company's reference deadline, mainly because it can gradually react to the generated delays. Company B has in its favor that the extra capacity runs with no risk and that its planned deadline had a differential in favor with respect to the client company's reference deadline. Finally, it was found that in the case of Company A, the technical risk with the most impact on the development of the plan was the Effective Advance, while for Company B it was the productivity of the crews. This would allow the client company to ask for the chosen company to add mitigation measures to offset the impact of its critical risks.

## CONCLUSIONS

The illustrated case exemplified the importance of performing a risk evaluation when analyzing the options in a tender. A priori, certain offers may be attractive in terms of deadlines and costs. However, this figure may change drastically if the risk profile of each bidder is considered. In this case, it was concluded that, in cases where companies do not have management measures to alleviate the delays (case with recovery), both offerors were incapable – in expected value – to perform the work neither within their planned deadline nor in the way the client company required. However, in the case with management, at least Company B is able to develop the project in the time required by the client company.

*A priori, certain offers may be attractive in terms of deadlines and costs. However, this figure may change drastically if the risk profile of each bidder is considered.*

*Risk evaluation allows the client company to choose the right contractor, considering its risk profile, and providing valuable information to assist the client company during the negotiation of the contract terms.*

Risk evaluation in tenders also provides the benefit of detecting the risks of greater impact for each offeror. This can be very useful as it increases the information that can be used to negotiate once a contractor has been chosen. For example, the client company could ask the contractor to include some prevention and/or mitigation measures to offset the potential impact of a certain risk. In addition, different penalties strategies could be studied using this tool with the final objective of finding the best penalties strategies. To define these strategies, it should always be taken into account that penalties should encourage the contractor to complete the project as programmed without affecting the financial health of the company, and not to reduce the cost for the client company as a result of charging exorbitant penalties.

Finally, the traditional view of tender evaluation only considers the technical and economic analysis. Nevertheless, and given the current situation, the idea of adding a risk evaluation to the traditional evaluation process gets more relevant each day. This allows for each offer to be studied in detail, considering the risks affecting the performance of contractors, and thus providing a share of realism to the conclusions of the technical and economic evaluations. Risk evaluation allows the client company to choose the right contractor, considering its risk profile, and providing valuable information to assist the client company during the negotiation of the contract terms.

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**JOSEFINA CORREA**

Joined GEM in March 2015. During her time in the company she has specialized in project evaluation and in the economics area. She has participated in several projects related to the copper, lithium, potash and aluminum industries, preparing market trends studies, and developing models to estimate future prices, costs and productions trends. Also she participated in the evaluation of strategic projects of large mining companies. Josefina holds an Industrial Engineer degree, with a Mining Engineer diploma from the Pontifical Catholic University of Chile.

*jcorrea@gem-ing.cl*



**CARLOS HINRICHSEN**

Joined GEM in March 2011, and actually he is their Chief Business Development Officer. He has specialized in the Evaluation and Training areas. His experience has been focused on project valuations under uncertainty, through risk and real options methodologies. Also, he is the principal teacher of the training courses “Risk Analysis of Mine Plans” and “Real Options for the Evaluation of Mining Projects”.
Carlos holds an Industrial Engineer degree, from the Universidad de los Andes, and a Marketing and Sales diploma from the Universidad de Chile. He also is a professor of the course “Valuation Under Uncertainty” from the engineering and applied sciences faculty of the Universidad de los Andes.

*chinrichsen@gem-ing.cl*



**MATÍAS MARAÑÓN**

Joined GEM in September 2014. He has specialized in the Economics, Evaluation and R&D areas. His experience has been focused on market trends studies (for copper, iron ore, lithium and aluminum), economic models, risk evaluations, mining project evaluations and in the development of internal tools. Matías holds an Industrial Engineer degree, with a Mining Engineer diploma from the Pontifical Catholic University of Chile.

*mmaranon@gem-ing.cl*

# MINERAL ECONOMICS

Por **Christian Lichtin**

Not just people linked to the world of mining are aware of the difficulties the industry is facing, in where the price of several commodities has fallen considerably. On the contrary, given the relevance these markets have in the worldwide economy, this crude context is widely known. One could say that the situation is known, but perhaps only a few understand the reasons behind it.

There is an area of the economy focused on studying the economic fundamentals of the mining industry called Mineral Economics, which tries to look for explanations for the mineral markets' behavior. Along these lines, we are giving a brief description of a book that deals with these issues. It is called *Mineral Economics and Policy*, and was jointly written by John E.Tilton and Juan Ignacio Guzman. This book seeks to explain the fundamentals behind the forces that determine the market price of various commodities, reviewing Demand and Supply of commodities, and how the two of them interact and create different types of mineral markets. It seeks to explain why there is a high volatility in metal prices and addresses the impact of investors/speculators in the industry.

One of the attributes that makes this book different is that it includes interesting discussions related to the establishment of specific mining taxes, detailing the reasons for and against such policies. In turn, it checks how mining and the economic development of countries are related, illustrating with experiences of certain countries. Finally, it discusses sustainability issues and how the availability of raw materials is expected to evolve in future generations.
*Mineral Economics and Policy* is a book easy to read and simple to understand. It does not get into too technical definitions, but has the depth necessary for anyone interested in understanding a little more about the mineral markets to do so.

It has received good reviews from well-known scholars in the industry, such as those presented at the end of this section, so if you have time and are interested in understanding why the industry is as it is now, and how it should evolve, this book is fully recommended.

"This is a well-written concise examination of the basic economics of the mineral industry and of the various policy issues facing all its stakeholders. It is not only an ideal text for students of mineral economics but also a clear exposition of the industry's driving forces for students of mining-related disciplines, and for professionals within the industry, the financial community and governments." - Phillip Crowson, Honorary Professor and Professorial Research Fellow, Centre for Energy, Petroleum and Mineral Law and Policy, University of Dundee, UK.

"… this is a comprehensive work of encyclopedic ambitions. It is well researched by two scholars with impressive knowledge of minerals. In my judgment, the prospects are considerable for the book to become a long-lasting classic. Reading it will benefit all kinds of audiences with an interest in mining, from students and their faculty to the captains and employees in the industry, as well as the public policy makers responsible for creating a favorable climate for mineral production, not to forget the financial types that invest in the sector." - Marian Radetzki, Professor of Economics, Luleå University of Technology, Sweden, in Asian Pacific Economic Literature.

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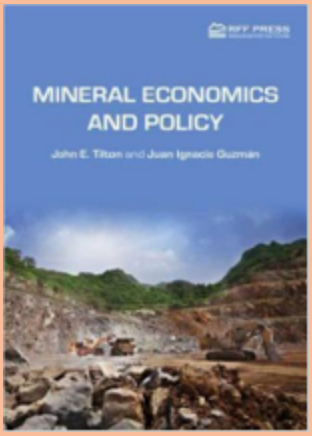


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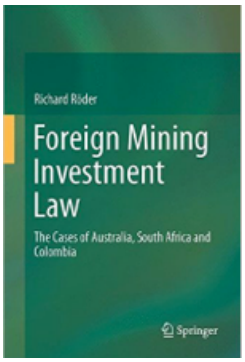


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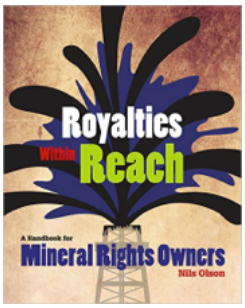


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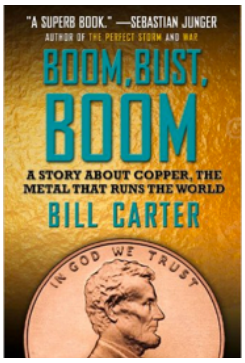


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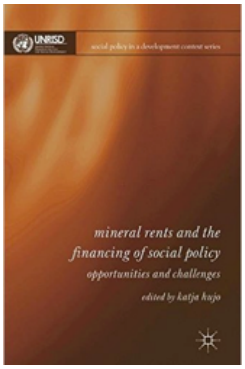


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**CARLOS HINRICHSEN**
Chief Business Development Officer
chinrichsen@gem-ing.cl
+56 22 225 3021

**www.gem-ing.cl**