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Indirect cost estimation and deviations from different closure plans

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Abstract

In accordance with the International Council on Mining and Metals (ICMM) guidelines, closure cost estimates are classified into 3 principal components: direct costs, indirect and additional costs, and contingencies.

Direct costs correspond to activities explicitly associated with the implementation of the closure plan (ICMM 2025), and their estimation can be carried out using parametric, historical, probabilistic or deterministic methods, depending on the level of engineering development (Association for the Advancement of Cost Engineering International [AACEI] 2012).

Meanwhile, indirect costs are costs that cannot be assigned directly to a specific activity. These include, among others, human resources, support services, social programs, engineering and construction management, safety, quality, supervision, and temporary maintenance (ICMM 2025). Indirect costs may be estimated as a percentage of direct costs or using a deterministic approach (AACEI 2012), itemising each cost category. The choice of method depends on the engineering (class) level achieved in the project.

Through the review of closure plans from different countries, this study evaluates the consistency between percentage-based and deterministic approaches for estimating indirect costs. The analysis is based on the ratio between indirect and direct costs (IC/DC), which was compared against reference ranges defined in the Alaska Mine Closure Cost Estimation Guidelines (Alaska Department of Natural Resources [ADNR] & Alaska Department of Environmental Conservation [ADEC] 2015).

Results show that, although several sites fall within the commonly referenced range (approximately 25–47%), significant deviations occur above and below this interval. These deviations are not explained by a single variable, but rather by the interaction between cost definition, timeline distribution of closure and post-closure activities, and site-specific operational conditions. In particular, extended closure and post-closure activities can significantly increase indirect cost ratios. The analysis indicates that approximately 70% of the data lie between the 10th percentile (P10 = 15%) and 80th percentile (P80 = 69%).

Keywords: *mine closure cost, indirect costs, cost estimation, direct costs, deterministic approach, percentage-based estimation, cost structure*

1 Introduction

In accordance with the guidelines of the ICMM (2025), mine closure cost estimates are classified into 3 main components: direct costs, indirect costs, and contingencies. While direct costs correspond to activities explicitly associated with the implementation of closure measures, indirect costs are costs that cannot be directly assigned to a specific activity, according to the Association for the Advancement of Cost Engineering International (AACEI) (AACEI 2012), such as administration, supervision, support services, permitting and temporary maintenance.

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According to AACEI (2012), cost estimation definition is related to the level of engineering, according to the different estimation classes and use of different methodologies. In this context, indirect costs may be estimated using a percentage of direct costs or by applying a deterministic approach that breaks down each cost component.

Although reference percentage ranges are commonly used as guidance in indirect cost estimation, empirical evidence obtained from the review of case studies shows values derived from deterministic approaches that fall outside these ranges, indicating deviations from those theoretical ranges.

The objective of this study is to compare deterministic estimates of indirect costs from different mining sites with reference ranges derived from the good practices or guidelines. This study considered the criteria described in the *Mine Closure and Reclamation Cost Estimation Guidelines: Indirect Cost Categories* (ADNR & ADEC 2015). In addition, deviations between cases were assessed to identify main factors influencing the structure of indirect costs.

A comparative analysis of different mine closure cost estimates was therefore conducted by estimating the ratio between indirect and direct costs (IC/DC) and contrasting the results with reference ranges. The observed deviations were analysed by giving consideration to type of mine, geographic conditions, level of engineering, and the closure and post-closure timeline.

2 Methodology

The indirect cost analysis was carried out through a review of cost estimations from multiple mine closure plans. The methodology considers 4 main phases: data review, closure cost classification, analytical metrics definition, and comparative analysis against guidelines.

Cost information was collected from mine closure plans and subsequently classified, focusing on ensuring consistency in cost criteria and definition across all cases. Specific analytical metrics were then defined to quantify the impact ratio between indirect and direct costs, enabling a consistent cross-comparison among the different estimates.

To assess their consistency and to identify any deviations, the resulting values were then compared and analysed against reference percentage ranges reported in ADRN & ADEC (2015) guideline.

2.1 Data review

Cost information was gathered from mine closure plan cost estimates from several mines around the world. The selection of cases sought to represent a range of mine operation, site location, and regulatory aspects.

For each case, the closure cost was identified and classified to ensure analytical consistency and facilitate comparison across data sources.

In addition, relevant information was also evaluated for each site. This includes type of mining activity (open pit mines, underground mines, tailings storage facilities or other associated infrastructure), general geographic conditions and altitude.

2.2 Closure cost classification

To undertake a comparative analysis, the costs from each mine closure plan were organised and classified. During this process, direct and indirect costs were identified and segregated in accordance with the conceptual guidelines established by the ICMM (2025).

Subsequently, the direct costs corresponded to the closure activities directly associated with the implementation of the actions defined in the closure plans, such as remediation, decommissioning, waste and water management, and closure activities focused on physical and chemical stability, as well as risks to human health and the environment. In contrast, indirect costs correspond to the activities associated with

support, management or planning activities that are not explicitly linked to the direct execution of closure activities but are necessary for their effective implementation.

Based on ICMM guidance (2025), the direct and indirect costs are outlined below.

- Direct costs:
  - decommissioning and demolition of structures, and clean-up of contaminated sites
  - earthworks, including re-sloping, channel construction/expansion, placement of erosion protection material, relocating waste materials, cover construction and borrow source development
  - implementation of rehabilitation measures, including seeding, planting, fertiliser placement, maintenance and other related activities
  - water management, including surface and groundwater management
  - treatment of water, including water treatment plant construction and operation
  - liner installation or removal
  - construction of seals on underground mine openings to surface
  - post-closure monitoring and maintenance
  - access control and signage
  - disposal cost
  - costs of funding the management of future or long-term activities related to residual risks
  - closure planning and decommissioning investigations and studies to inform and assist in development of the closure designs.
- Indirect costs:
  - mobilisation/demobilisation of contractors, consultants and other support services
  - retrenchment of staff
  - socio-economic programs
  - engineering, procurement and construction management (EPCM) costs
  - health and safety plans, construction monitoring and QA/QC
  - costs for management of closure activities, including management and supervision, power, water and sewage services, fuel and supplies
  - closure planning activities
  - interim care and maintenance costs (sometimes needed while closure designs are being finalised)
  - ongoing dam safety inspections and reviews.

Regarding contingency costs, the ICMM guidance and some jurisdictions (SERNAGEOMIN 2025) define these as a percentage applied to the sum of direct and indirect costs. In contrast, the *Alaska Mine Closure Cost Estimation Guidelines* incorporate contingencies as part of indirect costs (ADNR & ADEC 2015). Given that these approaches differ in their treatment of contingencies, and to maintain consistency and comparability of the results presented in this study, contingencies were excluded from the analysis.

2.3 Comparative analysis

As the primary analytical metric, the percentage correlation between indirect and direct costs (IC/DC) was defined for the study. For example, if a mine site has direct costs of USD33 million and indirect costs of USD 23 million, the resulting IC/DC ratio would be 23/33 × 100 = 70%.

Based on this percentage ratio, calculated values were compared against a percentage range defined in *Mine Closure and Reclamation Cost Estimation Guidelines: Indirect Cost Categories* (ADNR & ADEC 2015).

Finally, values were analysed incorporating different variables such as class of the cost estimate defined by (AACEI 2020), geographic location, site conditions, proximity to nearby city, and the closure and post-closure periods and activities considered, in order to identify deviations between sites.

3 Results

This section presents the results of the analysis between indirect costs and direct costs for all the mine sites considered in this study. First, baseline information for each site is presented by the IC/DC ratio defined and a breakdown of indirect costs according to their main components.

A statistical analysis of the results is then developed and benchmarked against reference ranges commonly used. Finally, the observed deviations are analysed to identify the factors explaining differences in the structure of indirect costs among the evaluated mine sites.

3.1 Characterisation of mine sites

The set of mine sites analysed are all in America. These sites were identified using alphanumeric codes.

In terms of mining method, most of the analysed sites correspond to open pit operations, with a limited number combining open pit and underground mining methods.

From a geographical perspective, the sites are located in mountain ranges and arid regions, including high-altitude environments, Arctic tundra conditions, semi-arid climates and humid subtropical regions. This-heterogeneity captures a broad range of conditions that influence cost structures, particularly with respect to logistics, site accessibility, and services or support requirements.

With respect to relative location, most sites are situated considerable distances from urban centres, particularly those located in high-altitude or extreme climatic environments. A smaller set of sites, primarily in the United States, is located in closer proximity to cities. This variable is relevant for interpreting indirect costs, given its influence on transportation, workforce accommodation and service availability.

Regarding the level of estimate definition, most sites correspond to Class 3 estimates (2 are Class 1 estimates). Under AACEI (2020), the definitions of level estimate are as follows:

- Class 5: conceptual estimate based on parametric methods, historical databases, scaling factors and industry benchmarks. Indirect costs are typically applied as percentages of direct costs using benchmark ratios.
- Class 4: preliminary estimate based on budget quotations, approximate quantities and unit-cost factors. Indirect costs are generally estimated as factored percentages of direct costs.
- Class 3: budget estimate developed from detailed quantity take-offs for major cost items, supplier quotations and measured construction quantities. Indirect costs are estimated using a combination of detailed evaluations and factored approaches.
- Class 2: control estimate based on detailed deterministic methods, firm quotations and definitive quantity take-offs. Indirect costs are developed from detailed estimates with limited reliance on allowances.

- Class 1: definitive estimate based on completed engineering and actual design quantities. Direct and indirect costs are both estimated as detailed line items, with minimal use of factors or assumptions.

Table 1 presents a summary of the mine sites considered in the analysis.

Table 1 Characterisation of analysed mine sites

Mine site	Mining method	Distance to city or town (km)[†]	Closure period (years)	Post-closure period (years)	Class level (Class 5 to 1)
MS1	Open pit	0–50	1–3	1–10	C1
MS2	Open pit	100–200	1–3	1–10	C3
MS3	Open pit	100–200	1–3	>30	C3
MS4	Open pit	100–200	1–3	11–30	C1
MS5	Open pit	100–200	1–3	1–10	C3
MS6	Open pit	>200	1–3	>30	C3
MS7	Open pit	0-50	5–10	11–30	C3
MS8	Open pit & underground	0–50	5–10	11–30	C3
MS9	Open pit	50–100	5–10	1–10	C3
MS10	Open pit	0-50	5–10	>30	C3
MS11	Open pit	>200	5–10	11–30	C3

3.2 Indirect cost by mine sites

Table 2 presents the results between indirect and direct costs (IC/DC) ratio for each mine site, and the percentage breakdown of indirect costs by category defined by the ICMM (2025). The categories were redistributed or group according to the existing data for each of the closure costs, resulting in the following classification:

- General administration: includes mobilisation and demobilisation; consultants and support services; workforce retrenchment; human resources management, and costs associated with management and supervision for complementary services for closure activities, such as power supply, water and waste water services, fuel and other consumables.
- Closure planning: includes studies associated with closure plan development, including engineering activities and permitting processes.
- Engineering and construction management: includes engineering, procurement and construction management costs, as well as health and safety plans, construction monitoring, and quality assurance/quality control (QA/QC).
- Care and maintenance: covers interim care and maintenance costs during the transition to closure, including road maintenance and other activities required while closure designs are finalised.

Table 2 shows that while there is a general tendency for general administration costs to dominate indirect costs, the composition of indirect costs might vary among mine sites.

[†] A city greater than 20,000 people.

Table 2 Breakdown of indirect costs for selected mine sites

Mine site	Class level	IC/DC	Indirect cost distribution			
			General administration	Closure planning	Engineering & construction management	Care and maintenance
MS1	C1	85%	95%	–	5%	–
MS2	C3	47%	72%	15%	13%	–
MS3	C3	149%	77%	23%	–	–
MS4	C1	42%	83%	–	13%	4%
MS5	C3	69%	75%	2%	20%	4%
MS6	C3	27%	25%	1%	2%	74%
MS7	C3	17%	66%	17%	1%	16%
MS8	C3	15%	41%	6%	26%	27%
MS9	C3	14%	55%	–	14%	31%
MS10	C3	38%	86%	8%	–	5%
MS11	C3	66%	60%	13%	0%	26%

3.3 Comparison analysis

The calculated IC/DC values were compared against reference percentage ranges presented in *Alaskan Mine Closure and Reclamation Cost Estimation Guidelines: Indirect Cost Categories* (ADNR & ADEC 2015), which define commonly used ranges in the industry for the closure cost estimate.

As shown in Figure 1, comparison of the IC/DC values against the reference band defined by ADNR (approximately 25–47%) reveals significant deviations. The highest percentage and only data that significantly exceed the reference range correspond to site MS3, with value of 149%.

Additional sites exceeding the upper reference limit while showing a trend distribution between 66% and 85% include MS1 (85%), MS5 (69%) and MS11 (66%). In contrast, sites MS7 (17%), MS8 (15%) and MS9 (14%) exhibit IC/DC ratios below the lower bound of the reference range.

Conversely, sites MS2 (47%), MS4 (42%) and MS10 (38%) fall within or close to the reference interval, displaying behaviours that are broadly consistent with values reported in the reference range.

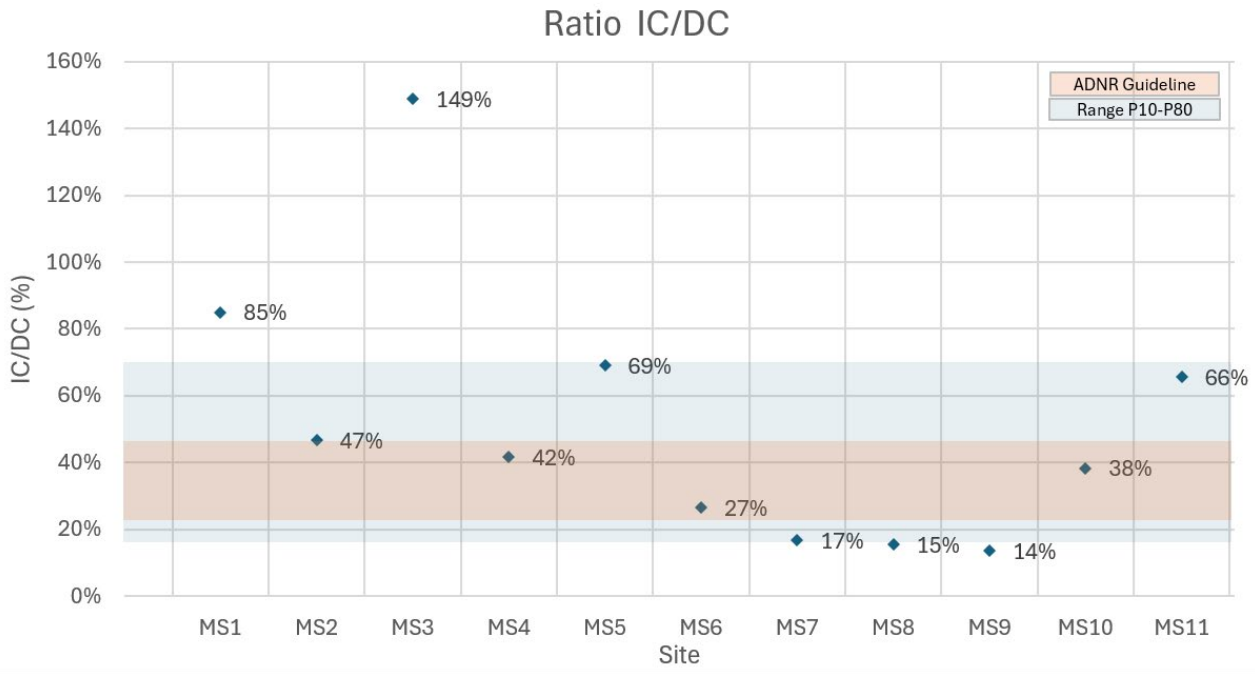

Figure 1 Indirect and direct cost ratio (IC/DC) of the sites

Figure 1 shows that the most relevant portion of the CI/CD ratio (%) data lies between the 10th percentile (P10 = 15%) and the 80th percentile (P80 = 69%). This range represents the core behaviour of the dataset, containing approximately the central 70%, while excluding both the lowest and the most extreme values.

3.4 Deviation and variables analysis

3.4.1 Data above range

The sites with IC/DC values above the reference range include MS1, MS3, MS5 and MS11. These elevated ratios are associated with specific cost structure configurations and site conditions rather than a single explanatory variable. In general terms, these sites are located at relatively large distances from nearby cities (150–350 km), except MS1, which is located approximately 50 km from a city.

The most notable case is MS3, with an IC/DC ratio of 149%, which lies well outside the observed range. A detailed review of the cost structure indicates that this behaviour is primarily explained by the temporal distribution of the indirect costs. In this case, the direct costs are concentrated over a relatively brief period associated with the execution of closure activities of approximately 3 years, whereas indirect costs – mainly administrative – extend over a much longer period due to the operation of post-closure activities exceeding 30 years. This imbalance increases the IC/DC ratio.

For sites MS1, MS5 and MS11, although deviations are less pronounced, a common pattern is observed in the high proportion of general administration costs within indirect costs. This condition is associated with remote locations, requiring more robust logistical, operational and administrative support structures, thereby increasing indirect cost burdens.

3.4.2 Data below range

Sites with IC/DC values below the reference range include MS7, MS8 and MS9. These operations are located near a city, a 50–100 km distance away.

In contrast to sites above the reference range, these operations benefit from more favourable access conditions and exhibit more moderate indirect cost structures. This behaviour is mainly explained by the greater availability of local suppliers and support services for mining operations.

4 Discussion and conclusion

In the context of mine closure cost estimation, indirect costs may be estimated using either percentage-based approaches or deterministic approaches, depending on the level of engineering definition. However, empirical evidence derived from the review of case studies shows that, under certain conditions, values obtained using deterministic approaches fall outside commonly used reference ranges. This raises questions regarding the ability of such reference ranges to adequately represent the variability analysed in this study.

4.1 Conclusions

This study assessed the IC/DC ratios of 11 mine closure plans against commonly used reference ranges. The main findings are as follows:

- Most analysed sites exhibit IC/DC ratios outside the reference range established by ADNR & ADEC (2015), indicating that percentage-based approaches may not adequately capture site-specific variability.
- The temporal distribution of closure and post-closure activities is an important factor in indirect cost estimation, as evidenced by MS3.
- Geographic remoteness contributes to higher indirect costs, though it does not act as a standalone explanatory variable.
- The observed deviations reinforce the need to complement percentage-based reference ranges with deterministic approaches that reflect the actual cost structure of each site.

4.2 Discussion

The results indicate that most of the analysed mine sites exhibit IC/DC ratios outside the ranges reported in the ADNR & ADEC (2015) guidelines (approximately 25–47%). These deviations are not attributable to a single explanatory variable, but rather to the interaction between cost structure, the temporal distribution of closure and post-closure activities, and site-specific operational conditions.

MS3 is the most illustrative case, where direct costs concentrate over 3 years of closure execution while indirect costs extend over 30 years of post-closure activities, generating a significant temporal imbalance that percentage-based ranges fail to capture. In addition, geographic remoteness increases indirect costs through higher logistical and administrative burdens, though it alone is not sufficient to explain the observed deviations.

The observed deviations should be interpreted as the result of multiple site-specific variables. This reinforces the need to complement the use of reference percentage ranges with detailed analyses that reflect the site reality, particularly with a more detailed class of estimate. As noted by Byrne (2024), percentage-based methods represent a crude measure of uncertainty that does not directly relate to each specific cost line item, further supporting the adoption of deterministic approaches that better capture the variability inherent in closure cost structures.

4.3 Recommendations

Based on these results, complementing the use of percentage-based reference ranges with a deterministic approach is recommended, particularly at advanced stages of engineering definition, in accordance with AACEI (2020).

Another recommendation is to explicitly consider the timeline required for closure and post-closure activities when estimating indirect costs, as evidenced in cases such as MS3.

In addition, an evaluation of the general administration cost component is recommended, particularly in relation to site geographic conditions and accessibility. The proximity of the site to nearby cities can have a significant impact on the indirect cost.

Finally, developing progressive closure activities is recommended, as this provides insight into actual costs and enables calibration of closure cost estimates. Furthermore, as the level of engineering definition increases, indirect costs should be estimated with the same level of detail using a deterministic approach.

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