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An Activity-Based Costing Approach to Calculate Unit Cost Under Dumping Area Relocation in Coal Mining Operations

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Abstract

This study examines the unit cost of overburden removal under a planned dumping-area relocation in an open-pit coal mining operation. The study addresses a practical issue faced by PT XYZ, where the planned relocation of dumping activities is expected to alter haul distances and cycle times during the 2027–2029 planning period. In current practice, the cost implications of such changes are assessed primarily through aggregated budget figures and truck requirement estimates. Although these indicators are useful for high-level planning, they provide limited visibility into how costs are generated across individual overburden removal activities. As a result, operational changes may be reflected in planning assumptions, but their cost implications remain difficult to interpret at the activity level and are therefore less informative for managerial decision-making. The results show that Plan B consistently generates a lower overburden removal unit cost than Plan A throughout the planning period. This difference is driven primarily by the overburden hauling component, while the other cost components remain broadly unchanged. Thus, Plan B is not more efficient because all activities become less costly, but because its hauling configuration is more efficient and directly reduces the most influential cost component in the comparison. The same pattern is reflected in the projected business results. Because revenue assumptions remain unchanged across both scenarios, the lower cost structure under Plan B results in a more favorable projected margin and profit outcome. The threshold-based assessment further indicates that Plan B can absorb a limited additional cost penalty before its total overburden removal cost converges with that of Plan A.

INTRODUCTION

Open-pit coal mining operations are highly dependent on the efficiency of material movement activities, particularly overburden removal (Ding et al., 2022; Jiangnan, 2026; Mishra et al., 2023; Wang et al., 2024). In many surface mining operations, overburden removal represents a major component of operating costs because it involves a series of resource-intensive activities, including drilling and blasting, loading, hauling, dozing, dumping, and supporting operations. Consequently, even minor changes in operational parameters within these activities can lead to substantial shifts in cost structure and overall operational performance (Allioui & Mourdi, 2023; Kanbach et al., 2024; Perifanis & Kitsios, 2023; Sjödin et al., 2023). The cost structure of overburden removal is inherently complex because of the interdependence among these activities, whereby adjustments in one activity may generate consequential effects on others. This interdependence requires a detailed understanding of how each activity contributes to total cost, particularly when operational changes are being considered. The significance of overburden removal in the overall cost profile of mining operations has been well documented, with previous studies identifying it as one of the largest cost components in open-pit mining (Lind, 2001; Cremonese et al., 2016). This prominence makes overburden removal a critical area for cost management and operational improvement.

One of the most influential operational factors affecting the performance and cost of overburden removal is the availability and configuration of dumping areas (Kumar et al., 2023; Sobko et al., 2026). Haul distance, equipment cycle time, and equipment utilization are directly influenced by the location of dumping areas. As mining progresses, existing dumping areas gradually reach their capacity limits, requiring operations to identify and utilize alternative dumping locations. This condition may result in planned dumping area relocation, which alters key operational parameters such as haul distance and cycle time and consequently affects resource consumption. The relocation decision is therefore not merely a logistical adjustment but also a strategic planning decision with significant cost implications. Understanding these implications requires a systematic cost analysis capable of capturing the relationship between operational parameters and cost outcomes. The relationship between haul distance and operating cost has been widely examined in the mining engineering literature, with studies indicating that hauling costs can account for approximately 50–60% of total overburden removal costs (PT XYZ, 2026; Lind, 2001). This substantial proportion underscores the importance of analyzing hauling-related cost components when evaluating alternative operational scenarios.

In current operational practice, initiatives related to cycle-time improvement or dumping area relocation are commonly evaluated using aggregate operational indicators, such as truck requirements, fleet productivity, or overall material movement capacity. Although these indicators are useful for operational planning, they provide only a high-level view of performance and do not explicitly explain how changes in operational parameters affect costs at the activity level (Mansour & Al-hamdani, 2024; Mehdiyev et al., 2025; Rathnayake et al., 2024). As a result, the cost implications of operational decisions are often assessed indirectly rather than through a detailed and structured cost analysis. This limitation creates a risk that cost consequences may be underestimated or overlooked during the planning stage. The absence of detailed activity-level cost visibility also limits management's ability to identify which specific operations are most sensitive to changes in hauling configuration, thereby reducing the effectiveness of subsequent cost-control efforts. Previous research has highlighted the limitations of traditional costing approaches in providing sufficiently accurate cost information for decision-making in complex operational environments (Kaplan & Cooper, 1998; Turney, 2008). These limitations are particularly relevant in mining operations, where diverse activities and variable operating conditions complicate cost allocation.

For the 2027–2029 planning period, the mining operation under study is expected to face constraints in existing dumping capacity, with the available dumping area projected to reach full utilization by the end of 2028. In response, a dumping area relocation plan has been incorporated into the company's operational planning process. The relocation remains a planned initiative, while key operational parameters, including haul distance and estimated cycle time, have been established based on preliminary operational planning and budgeting assumptions. These parameters represent the best available planning estimates and provide the basis for comparing alternative operational scenarios. However, reliance on these estimates also highlights the need for an analytical framework capable of evaluating how variations in operational parameters translate into activity-level cost differences. The 2027–2029 planning horizon therefore represents a critical transition period because the relocation of dumping activities is expected to alter the hauling configuration and potentially reshape the cost structure of overburden removal. This transition provides an opportunity to evaluate alternative hauling configurations and identify the most cost-efficient option before implementation.

Although these planning parameters provide a basis for estimating operational requirements, they do not necessarily provide sufficient insight into how the unit cost of overburden removal is generated and distributed across individual activities. Because overburden removal consists of multiple activities with different cost drivers, reliance solely on aggregated indicators may obscure the contribution of specific activities to the overall unit cost, particularly those that are sensitive to changes in haul distance and cycle time. Furthermore, without activity-level cost visibility, management may have difficulty determining whether a cost advantage under one scenario results from genuine operational efficiency or differences in cost allocation. This limitation is particularly relevant when evaluating dumping area relocation because the primary operational change is concentrated in the hauling activity. The need for more detailed activity-level cost analysis in mining has been recognized in previous research, which has called for cost-modeling approaches capable of capturing the complexity of mining cost structures (Cremonese et al., 2016; Duran & Afonso, 2019). However, a gap remains between the theoretical emphasis on activity-based approaches and their practical application in mining operational planning.

In this context, Activity-Based Costing (ABC) provides an appropriate analytical framework for examining the cost structure of overburden removal. ABC assigns resource costs to activities based on relevant cost drivers and subsequently traces those activity costs to cost objects according to their consumption of activities. This approach enables the contribution of individual activities to unit cost to be identified and allows changes in operational parameters to be linked to activity-level cost variations. ABC can therefore provide greater cost transparency than highly aggregated costing approaches by recognizing that different operational activities consume resources in different proportions. The theoretical foundations of ABC have been extensively developed in the cost-management literature, and previous studies have demonstrated its usefulness in supporting managerial decision-making across various industries (Kaplan & Anderson, 2004; Kaplan & Cooper, 1998). Despite this extensive literature, the application of ABC to the unit cost of overburden removal under planned dumping area relocation in open-pit coal mining remains limited. Previous studies have primarily focused on applications in manufacturing and service industries, with relatively few examining resource-intensive extractive industries such as mining (Akbulut et al., 2015; Guo et al., 2015). This limited application represents a gap in both the academic literature and practical cost-management frameworks, particularly given the cost intensity of mining operations and the potential value of ABC for operational planning and decision-making.

Therefore, a detailed analysis of overburden removal unit cost using an activity-based approach is needed to improve cost visibility and support informed operational decision-making. By examining the unit cost structure and the impact of planned dumping area relocation on activity-level cost components, this study seeks to clarify how operational changes translate into cost consequences. The study aims to compare two alternative hauling configurations under the same production target using the ABC framework to determine which configuration provides the more cost-efficient approach to overburden removal during the 2027–2029 planning period. Specifically, the study examines how alternative hauling configurations affect activity-level overburden removal unit costs, which activities are most sensitive to changes in hauling arrangements, and what business implications arise from selecting one configuration over another. The analysis is expected to contribute to both practical decision support in mining operations and the academic discussion of Activity-Based Costing in resource-intensive industries. It also demonstrates how ABC can be applied prospectively to evaluate planned operational changes before implementation, thereby supporting more transparent, traceable, and cost-effective planning decisions. The resulting framework may also be adaptable to similar cost evaluations in other mining operations and resource-intensive industries.

METHOD

This study employed a quantitative, case-based modeling design to compare Plan A (Baseline) and Plan B under the same overburden removal target for the 2027–2029 planning period using an Activity-Based Costing (ABC) approach. The analysis relied on secondary archival data from PT XYZ's internal planning, budgeting, and costing documents, including haul distance, cycle time, equipment and labor requirements, and associated costs. Cost drivers and resource consumption rates were selected purposively based on their relevance to the ABC activities and research objectives. Data were standardized, classified by scenario and year, and reviewed for completeness, unit consistency, cost reconciliation, and consistency of definitions across the planning period. PT XYZ was anonymized to protect proprietary information. A threshold-based assessment was also conducted to estimate the additional cost penalty that Plan B could absorb before losing its cost advantage over Plan A.

Data were analyzed using a deterministic ABC model developed in spreadsheet software. Resource costs were assigned to relevant activity pools and subsequently traced to overburden removal as the cost object. The activity pools included loading, hauling, dumping and dozing support, road maintenance, overburden support, and other related activities. The analysis was applied consistently across 2027, 2028, and 2029, with only scenario-sensitive cost drivers varied between Plan A and Plan B. The primary outputs were total overburden removal unit cost (US$/bcm) and activity-level cost breakdowns, which were used to identify the activities most sensitive to the planned dumping area relocation. The analysis followed established ABC methodology (Kaplan & Cooper, 1998; Turney, 2008). Scenario and threshold comparisons were then used to evaluate the relative cost efficiency and managerial implications of each alternative.

RESULTS AND DISCUSSION

Analysis

This section presents the main analytical results comparing Plan A and Plan B for overburden removal during 2027–2029. The analysis is structured into scenario definition, activity-based unit cost results, effect of OB hauling on total cost, downstream business implications, threshold-based assessment, and summary of findings. The focus is on how operational differences translate into activity-based unit costs, particularly the hauling component as the main source of variation between scenarios.

Scenario Definition and Basis of Comparison

Both scenarios are evaluated under the same overburden production target (29,978 kbcm in 2027, 28,267 kbcm in 2028, and 28,608 kbcm in 2029), ensuring cost differences reflect operational efficiency rather than output volume. The main difference lies in hauling configuration: Plan A has haul distances of 6.33 km, 5.33 km, and 5.11 km with cycle times of 52.01, 44.51, and 42.84 minutes across 2027–2029, while Plan B has shorter distances (4.18 km, 2.80 km, 3.66 km) and lower cycle times (35.85, 25.50, 31.95 minutes). This shorter haul distance directly reduces cycle time and hauling-related resource consumption, consistent with mining literature establishing cycle time as proportional to haul distance (Cremonese et al., 2016; Lind, 2001).

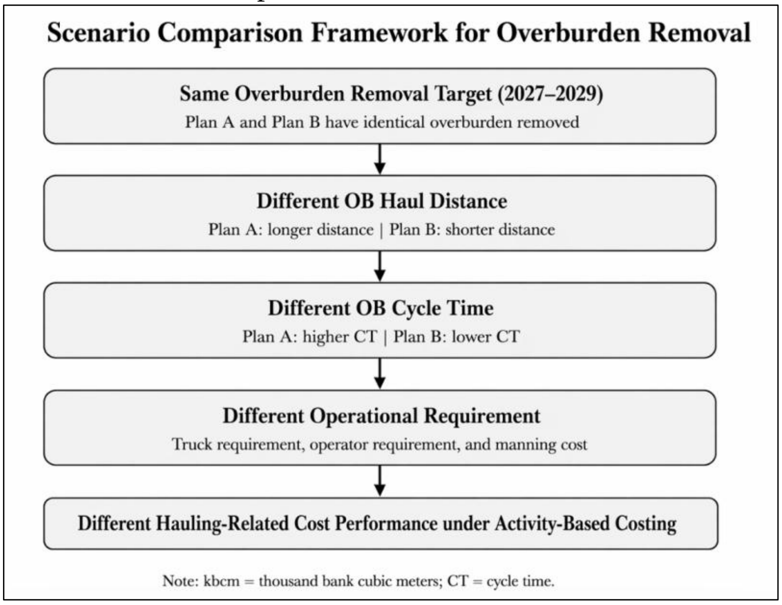
Table 1. Comparison of Key Operational Parameters Between Plan A (Baseline) and Plan B, 2027–2029

ELEMENT	UNIT	SCENARIO PLAN A (BASE)			SCENARIO B		
		2027	**2028**	**2029**	**2027**	**2028**	**2029**
Overburden Removed	kbcm	29,978	28,267	28,608	29,978	28,267	28,608
OB Cycle Time	minutes	52.01	44.51	42.84	35.85	25.5	31.95
OB Haul Distance	km	6.33	5.33	5.11	4.18	2.80	3.66
Total Digger Requirement	unit	5	5	5	5	5	5
Total Truck Requirement	unit	70	57	55	49	33	41
Total Operator per Shift	person	92	79	77	71	55	63
Total Operator (3 Crews)	person	350	300	293	270	209	239
Total Manning Cost	**US$ million**	**3.79**	**3.27**	**3.19**	**2.95**	**2.31**	**2.63**

Source: Author's analysis based on PT. XYZ internal planning and budgeting data (2026).

Under this comparison framework, the loading side of the operation remains broadly unchanged, as reflected in the same total digger requirement in both scenarios throughout the planning period. This consistency in loading operations is important because it isolates the effect of the hauling configuration change on cost outcomes. The stability of the loading component provides a controlled basis for evaluating the cost impact of the hauling difference. In contrast, the effect of the shorter hauling distance in Plan B is reflected in the downstream operational requirement, particularly in total truck requirement, total operators per shift, total operators for three crews, and total manning cost. Compared with Plan A, Plan B consistently requires fewer trucks and fewer operators across the planning horizon, which indicates that the main operational consequence of the scenario difference is concentrated in the hauling-related part of overburden removal. This pattern is consistent with the operational logic that shorter haul distances reduce cycle times, which in turn reduces the number of trucks needed to achieve the same production target (PT XYZ, 2026). The reduction in truck requirement also leads to a corresponding reduction in operator requirement, as fewer trucks require fewer operators to operate them. This cascading effect from operational parameter to resource requirement demonstrates the interconnectedness of the various elements in the overburden removal system.

Figure 1. Scenario Comparison Framework for Overburden Removal



Source: Author's formulation based on the study's planning scenarios.

Based on this scenario definition, the comparison in this study provides the analytical basis for examining how a difference in hauling arrangement is translated into a difference in activity-based cost results. Therefore, the next part of the analysis focuses on the operational impact of the scenario change before discussing how the hauling-related difference affects overburden cost performance under the Activity-Based Costing framework.

Activity-Based Unit Cost Results for Overburden Removal

The Activity-Based Costing model developed in this study produces unit cost outputs for the main activities involved in overburden removal. In line with the scope of the study, the discussion in this section focuses on the overburden cost structure, since the operational difference between the compared scenarios is concentrated in the hauling arrangement of overburden removal. The activity-based approach provides visibility into how costs are distributed across the various activities that constitute overburden removal, which is essential for understanding the sources of cost differences between scenarios. As a result, the activity-based unit cost output for overburden removal becomes the most relevant basis for explaining how the scenario difference is reflected in cost performance. The detailed activity-level cost breakdown allows for a more nuanced analysis than would be possible with aggregated cost data alone. Previous research has demonstrated the value of activity-based costing in providing detailed cost information for decision-making in mining operations (Cremonese et al., 2016; Duran & Afonso, 2019).

The results show that Plan B consistently generates a lower overburden unit cost than Plan A during the 2027–2029 planning period. Under Plan A, total overburden cost is recorded at US$4.33/bcm in 2027, US$4.21/bcm in 2028, and US$3.94/bcm in 2029. Under Plan B, the corresponding values are lower at US$3.40/bcm, US$3.23/bcm, and US$3.18/bcm. The magnitude of the cost difference ranges from US$0.77/bcm to US$0.98/bcm across the three-year period. Because both scenarios are evaluated under the same overburden production target, the difference in total unit cost can be interpreted as the cost consequence of the different operational arrangement rather than as the effect of a different output level. This interpretation is important because it establishes a direct causal link between the hauling configuration and the cost outcome. The consistency of the cost advantage across all three years strengthens the conclusion that Plan B is more cost-efficient than Plan A. The annual variation in the magnitude of the cost difference is related to the annual variation in haul distance and cycle time between the two scenarios, with larger differences in haul distance and cycle time corresponding to larger cost differences

Table 2. Comparison of Activity-Based Unit Cost Components of Overburden Removal Between Plan A (Baseline) and Plan B, 2027–2029

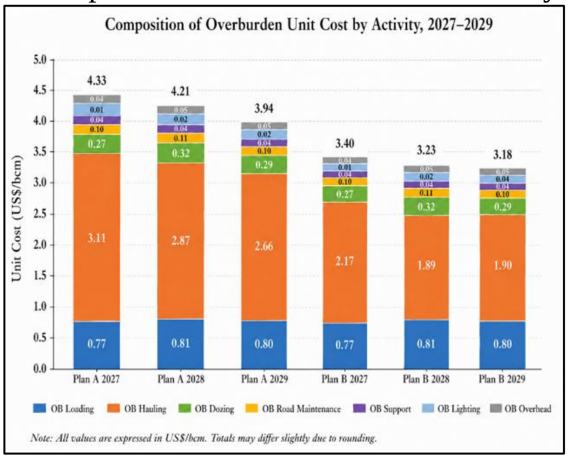
ACTIVITY	UNIT	PLAN A (BASELINE)			PLAN B			VAR (A-B)		
		2027	**2028**	**2029**	**2027**	**2028**	**2029**	**2027**	**2028**	**2029**
OB Loading	$/bcm	0.77	0.81	0.80	0.77	0.81	0.80	-	-	-
OB Hauling	$/bcm	3.11	2.87	2.66	2.17	1.89	1.90	0.93	0.98	0.77
OB Dozing	$/bcm	0.27	0.32	0.29	0.27	0.32	0.29	-	-	-
OB Road Maintanence	$/bcm	0.10	0.11	0.10	0.10	0.11	0.10	-	-	-
OB Support	$/bcm	0.04	0.04	0.04	0.04	0.04	0.04	-	-	-
OB Lighting	$/bcm	0.01	0.02	0.01	0.01	0.02	0.01	-	-	-
OB Overhead	$/bcm	0.04	0.05	0.05	0.04	0.05	0.05	-	-	-
TOTAL OB COST	**$/bcm**	**4.33**	**4.21**	**3.94**	**3.40**	**3.23**	**3.18**	**0.93**	**0.98**	**0.77**

Source: Author's analysis based on PT. XYZ internal costing data (2026) using the Activity-Based Costing (ABC) approach.

At the activity level, the most material difference between the two scenarios appears in the hauling component. Under Plan A, OB hauling cost is US$3.11/bcm in 2027, US$2.87/bcm in 2028, and US$2.66/bcm in 2029. Under Plan B, the corresponding values are lower at US$2.17/bcm, US$1.89/bcm, and US$1.90/bcm. The hauling component represents the largest individual cost element in both scenarios, accounting for 62-72% of total overburden cost. By contrast, the loading component remains the same in both scenarios at US$0.77/bcm in 2027, US$0.81/bcm in 2028, and US$0.80/bcm in 2029, while the dozing, lighting, and support-related components remain relatively stable. This indicates that the cost difference between Plan A and Plan B is not broadly distributed across all overburden activities but is concentrated mainly in the hauling-related component. This concentration of the cost difference is consistent with the operational logic that the primary difference between the two scenarios lies in the hauling configuration. The stability of the non-hauling cost components across scenarios provides further evidence that the cost advantage of Plan B is specifically related to hauling efficiency rather than to broader operational differences. This finding also validates the design of the scenario comparison, which successfully isolated the effect of hauling configuration on cost outcomes.

This result is consistent with the scenario comparison presented earlier. Since the main operational difference between Plan A and Plan B lies in OB haul distance and OB cycle time, the largest cost effect also appears in the hauling-related activity. The alignment between operational parameters and cost outcomes demonstrates the internal consistency of the analysis. In this case, the ABC result provides a clear explanation of how the operational change is translated into cost performance: a shorter hauling arrangement leads to a lower hauling unit cost, and this lower hauling cost becomes the main reason why Plan B produces a lower total overburden cost. This traceability between operational change and cost outcome is one of the key advantages of the activity-based costing approach, as it allows management to understand not just that a scenario is cheaper, but why it is cheaper. The ability to explain cost differences at the activity level enhances the credibility of the analysis and improves its usefulness for decision-making (Kaplan & Cooper, 1998; Turney, 2008).

Figure 2. Composition of Overburden Unit Cost by Activity



Source: Author's analysis based on the Activity-Based Costing (ABC) results.

Figure 2 further shows that hauling is the dominant component in the overburden cost structure and also the main source of variation between the two scenarios. The graphical representation of the cost composition provides a visual confirmation of the numerical results, showing that the hauling component consistently accounts for the largest share of total overburden cost. This dominance of hauling in the cost structure is consistent with findings from previous mining cost studies, which have identified hauling as the single largest cost element in overburden removal operations (Lind, 2001; Cremonese et al., 2016). This makes the result more meaningful from a managerial perspective, since it shows not only that Plan B is more cost-efficient, but also where the advantage comes from within the activity structure. The identification of hauling as the key cost driver provides management with a clear target for cost improvement initiatives. The next section therefore focuses more specifically on the effect of the hauling difference on OB hauling cost and total overburden cost.Effect of OB Hauling on Total Overburden Cost

Effect of OB Hauling on Total Overburden Cost

The results presented in the previous section show that the cost difference between Plan A and Plan B is concentrated in the hauling component of overburden removal. This is an important finding because it indicates that the scenario effect is not spread across the entire cost structure. Instead, the difference is highly specific and is associated with the activity that is directly affected by the change in hauling configuration. Since the non-hauling cost components remain unchanged between the two scenarios, the variation in total overburden cost can be interpreted as a direct consequence of the difference in OB hauling cost. This specificity strengthens the causal interpretation of the results, as it establishes a clear and direct link between the operational change and the cost outcome. The ability to attribute the cost difference to a specific activity is a key advantage of the activity-based costing approach over traditional costing methods (Kaplan & Cooper, 1998; Turney, 2008).

This pattern strengthens the analytical link between the operational comparison in Section IV.1.1 and the cost results in Section IV.1.2. Earlier findings showed that Plan B applies a shorter hauling arrangement, which leads to lower cycle time and lower hauling-related resource requirements. The cascading effect from shorter haul distance to lower cycle time to lower resource requirement is reflected in the operational parameters presented in Table 1. In the ABC result, this operational improvement is translated into a lower hauling unit cost. The translation of operational improvement into cost reduction follows a clear and logical path, which enhances the credibility of the findings. As a result, the cost advantage of Plan B is not produced by a broad reduction across all overburden activities, but by a more efficient hauling configuration. This finding has important implications for cost management, as it suggests that cost improvement efforts should focus on the hauling activity rather than on attempting to reduce costs across all activities indiscriminately.

A closer comparison between the two scenarios confirms this relationship. Under Plan A, OB hauling cost is higher than under Plan B in all three years of analysis. The difference amounts to US$0.93/bcm in 2027, US$0.98/bcm in 2028, and US$0.77/bcm in 2029. Interestingly, the difference in total OB cost is identical in each corresponding year. This indicates that the reduction in total overburden cost under Plan B is fully explained by the reduction in the hauling component, while the remaining activity costs stay constant. This perfect correspondence between the hauling cost difference and the total cost difference is a strong validation of the ABC model, as it demonstrates that the model is internally consistent and that the cost allocation logic is sound. The consistency between the hauling cost difference and the total cost difference also simplifies the interpretation of the results, as management can focus on the hauling component to understand the cost advantage of Plan B.

Table 3. Difference in OB Hauling Cost and Total Overburden Cost

ITEM	UNIT	2027	2028	2029
Difference in OB Hauling Cost (A–B)	US$/bcm	0.93	0.98	0.77
Difference in Total OB Cost (A–B)	US$/bcm	0.93	0.98	0.77

Source: Author's calculation based on PT. XYZ internal costing data (2026).

The result is analytically strong because it isolates the source of the cost difference with a high degree of clarity. In many scenario comparisons, a lower total cost is observed without a clear explanation of which activity drives the change. This lack of clarity can undermine confidence in the results and reduce their usefulness for decision-making. In this study, however, the activity-based structure shows that the entire reduction in total OB cost comes from hauling. This means that the scenario comparison does not simply identify the lower cost option but also explains why that option becomes less costly. The explanatory power of the ABC model is one of its key strengths, as it provides management with not just a recommendation but also a rationale for that recommendation (Kaplan & Anderson, 2004; Kaplan & Cooper, 1998). The ability to explain cost differences enhances the credibility of the analysis and improves its acceptance by decision-makers.

From a managerial perspective, this finding has an important implication. Since OB hauling is both the largest cost component and the only component that materially changes between the scenarios, it becomes the key lever for improving overburden cost performance within the planning scope of this study. This insight provides management with a clear focus for cost improvement efforts, as it identifies hauling as the activity with the greatest potential for cost reduction. In other words, the economic advantage of Plan B is derived from a more efficient hauling arrangement rather than from a general reduction in all overburden activities. The concentration of the cost advantage in a single activity also makes the cost improvement easier to achieve, as it requires changes in only one part of the operation rather than in multiple parts simultaneously. This makes the result easier to interpret and more relevant for planning decisions, because the source of the cost advantage can be traced directly to a specific operational driver. The traceability of the cost advantage enhances the practical usefulness of the findings for planning and decision-making.

Overall, the analysis in this section confirms that the lower total overburden cost under Plan B is fully attributable to the lower OB hauling cost. This conclusion is important because it establishes a direct connection between operational design and cost outcome. The direct connection between operational design and cost outcome is a key requirement for effective operational planning, as it allows management to anticipate the cost consequences of operational decisions. It also provides the basis for the next subsection, which extends the analysis from unit cost difference to its downstream business implication under the planning assumptions. The extension of the analysis to business implications demonstrates the practical relevance of the cost findings and connects them to the company's overall financial performance.

Downstream Business Implication

The difference in overburden cost identified in the previous section does not remain isolated at the activity level. Since overburden removal forms a significant part of the overall mining cost structure, a lower OB cost under Plan B also affects the broader business result under the planning assumptions. The significance of overburden removal in the total cost structure means that changes in OB cost have a material impact on overall profitability. In this study, the activity-based unit cost difference between the two scenarios is therefore extended into its downstream business implication in order to show how the operational cost advantage of Plan B is reflected at a more aggregated financial level. This extension is not intended to create a new research objective, but to provide a managerial interpretation of the cost result derived from the scenario comparison. The downstream business implication connects the operational analysis to the financial performance of the company, which is ultimately the primary concern for management decision-makers. The connection between operational efficiency and financial performance is a fundamental principle of management accounting, and this analysis demonstrates that principle in a practical context (Kaplan & Cooper, 1998).

Under the planning assumptions used in this study, the lower OB hauling cost and lower total OB cost in Plan B contribute to a lower total operating cost than in Plan A. When this lower cost structure is carried forward into the financial projection, the impact can be observed in the resulting margin and profit indicators. The transmission from cost reduction to profit improvement follows a direct path, as lower costs translate directly into higher margins when revenue remains constant. In other words, the scenario comparison shows not only that Plan B is operationally more cost-efficient, but also that the cost advantage has a measurable consequence for projected business performance. This makes the cost result more meaningful from a managerial point of view, because it connects operational design with its broader economic implication. The ability to demonstrate the financial impact of operational decisions is essential for securing management support for those decisions (Cokins, 2001).

Table 4. Downstream Business Implication for Pit X Between Plan A (Baseline) and Plan B, 2027–2029

Indicator	Unit	Plan A (baseline) 2027	Plan A (baseline) 2028	Plan A (baseline) 2029	Plan B 2027	Plan B 2028	Plan B 2029	VARIANCE (B-A) 2027	VARIANCE (B-A) 2028	VARIANCE (B-A) 2029
Total Cost	US$ million	$158.69	$132.88	$129.36	$133.86	$105.54	$113.45	$(24.83)	$(27.34)	$(15.91)
Total Cost	$/ton	$25.31	$26.60	$27.88	$21.35	$21.13	$24.45	$(3.96)	$(5.47)	$(3.43)
Total Revenue	US$ million	$300.61	$274.24	$288.30	$300.61	$274.24	$288.30	$-	$-	$-
Margin Before Tax	$/ton	$22.63	$28.30	$34.25	$26.59	$33.77	$37.68	$3.96	$5.47	$3.43
Margin After Tax	$/ton	$17.65	$22.07	$26.72	$20.74	$26.34	$29.39	$3.09	$4.27	$2.67

Indicator	Unit	Plan A (baseline) 2027	Plan A (baseline) 2028	Plan A (baseline) 2029	Plan B 2027	Plan B 2028	Plan B 2029	VARIANCE (B-A) 2027	VARIANCE (B-A) 2028	VARIANCE (B-A) 2029
Margin after Profit Sharing	$/ton	$15.89	$18.97	$24.05	$18.67	$23.71	$26.45	$2.78	$3.84	$2.41
Profit Before Tax	US$ million	$141.92	$141.36	$158.94	$166.75	$168.70	$174.85	$24.83	$27.34	$15.91
Profit After Tax	US$ million	$110.70	$110.26	$123.97	$130.06	$131.59	$136.39	$19.37	$21.33	$12.41
Profit after Profit Sharing	US$ million	$99.63	$99.24	$111.58	$117.06	$118.43	$122.75	$17.43	$19.20	$11.17

Source: Author's analysis based on PT. XYZ internal planning, costing, and financial projection data (2026).

As shown in Table IV.4, Plan B consistently results in a lower total cost than Plan A over the 2027–2029 planning period, while revenue remains unchanged between the compared scenarios. The consistency of the cost advantage across all three years strengthens the conclusion that Plan B is the more cost-efficient planning alternative. The stability of revenue across scenarios is an important feature of the comparison, as it ensures that any differences in profit are attributable to cost differences rather than revenue differences. In monetary terms, the total cost advantage of Plan B reaches US$24.83 million in 2027, US$27.34 million in 2028, and US$15.91 million in 2029. **These are substantial amounts that would have a significant impact on the company's financial performance.** On a unit basis, this is equivalent to a cost reduction of US$3.96/ton, US$5.47/ton, and US$3.43/ton, respectively. The unit cost reduction represents a meaningful improvement in the cost competitiveness of the operation. Since the revenue assumptions remain the same in both scenarios, this lower cost position is carried directly into the downstream profitability indicators. Profit before tax under Plan B is higher by US$24.83 million, US$27.34 million, and US$15.91 million, while profit after profit sharing is higher by US$17.43 million, US$19.20 million, and US$11.17 million over the same period. The profit improvement is directly proportional to the cost reduction, which is consistent with the logic that lower costs lead to higher profits when revenue is unchanged.

The importance of this result lies not only in the size of the difference, but also in the consistency of the transmission path. The economic advantage begins with the operational arrangement, is reflected in overburden cost, then in total cost, and finally in the projected margin and profit indicators. The clear transmission path from operational parameters to financial outcomes demonstrates the interconnectedness of operational and financial performance. This makes the downstream business implication analytically important, because the financial result is not presented as a separate conclusion, but as an extension of the earlier cost analysis. The integration of cost analysis and financial projection provides a comprehensive view of the implications of the scenario choice. In other words, the better financial outcome under Plan B is supported by the same operational logic established in the previous subsections. The consistency of the analysis across multiple levels—operational, cost, and financial—enhances its credibility and usefulness for decision-making (Cokins, 2001; Kaplan & Cooper, 1998).

This result should be interpreted within the study's boundaries. The business implication is based on planning assumptions and model outputs, not realized field performance. The planning-based nature of the analysis means that the results represent projections rather than actual outcomes. Therefore, it should be viewed as a planning-based managerial implication rather than evidence of actual savings or profit improvement during execution. The distinction between planning-based projections and actual performance is important for managing expectations and for interpreting the results appropriately. Even with this limitation, the result remains meaningful: Plan B offers a lower overburden-related cost structure and a more favorable projected business outcome under the same planning basis. The consistency of the advantage across all three years provides confidence that the results are not merely artifacts of a single year's data. This strengthens the managerial case for prioritizing Plan B for the 2027–2029 planning horizon. The managerial case for Plan B is further strengthened by the clarity of the analysis and the traceability of the cost advantage to a specific operational driver.

Threshold-Based Assessment of Plan B Under Additional Penalty

The lower overburden cost of Plan B under the base-case scenario indicates that it is the preferred planning alternative relative to Plan A (Baseline). However, for planning purposes, it is also important to assess how much additional burden Plan B can absorb before this advantage disappears. This assessment is important because operational conditions may change between the planning phase and the execution phase, potentially introducing additional costs that are not captured in the base-case comparison. For that reason, this study extends the analysis through a threshold-based assessment. This assessment serves as a sensitivity check that quantifies the margin of cost advantage and provides management with a practical reference for evaluating the robustness of the preferred scenario. The threshold-based assessment addresses the question of how much uncertainty or additional cost Plan B can tolerate before it becomes less attractive than Plan A. This is a practical question that management would need to consider when making the final decision on which scenario to implement.

In this subsection, the threshold value is defined as the cost gap between Plan A and Plan B in total overburden unit cost. Based on the calculation results, Plan B can absorb an additional penalty of up to US$0.93/bcm in 2027, US$0.98/bcm in 2028, and US$0.77/bcm in 2029 before its total overburden cost converges with Plan A. These values represent the maximum additional burden that may be imposed on Plan B while still preserving its cost advantage over the baseline scenario. The threshold values provide management with a clear reference point for evaluating whether Plan B remains the preferred alternative under different operational conditions. The threshold values vary across years, reflecting the variation in the cost gap between the two scenarios. The highest threshold is in 2028, which corresponds to the year with the largest cost gap between Plan A and Plan B. The variation in threshold values across years highlights the importance of year-specific analysis in planning decisions.

Table 5. Threshold Value of Plan B Relative to Plan A

Year	OB Cost Gap (US$/bcm)	Overburden Volume (kbcm)	Equivalent Annual Threshold (US$ million)	Interpretation
2027	**0.93**	**29,978**	**27.88**	**Plan B remains preferable as long as additional penalty does not exceed the threshold**
2028	**0.98**	**28,267**	**27.70**	**—**
2029	**0.77**	**28,608**	**22.03**	**—**

Source: Author’s calculation based on the cost difference and overburden volume under the 2027–2029 planning scenarios.

In practical terms, the additional penalty may take the form of higher road maintenance requirement, additional support cost, extra delay, traffic interaction, dump sequence inefficiency, or other scenario-specific operational burdens that are not fully reflected in the base-case comparison. These potential additional burdens represent the types of operational complexities that may arise during execution and that could affect the actual cost performance of Plan B. The identification of these potential additional burdens helps management anticipate and plan for operational challenges. If such additional burdens remain below the estimated threshold, Plan B remains the preferred planning alternative from a cost perspective. The threshold analysis thus provides management with a practical decision rule for evaluating Plan B under uncertainty. The availability of threshold values enhances the usefulness of the analysis for planning purposes, as it allows management to assess the robustness of the recommendation under different assumptions.

This threshold-based assessment does not constitute a full quantitative risk analysis. Rather, it serves as a limited analytical check on the persistence of Plan B's economic advantage under additional scenario-specific penalties. The limited nature of the assessment means that it does not cover all possible sources of risk or uncertainty. Within that boundary, the results show that the recommendation to prioritize Plan B is not only valid under the base-case assumptions but also retains a measurable margin before its cost advantage is eliminated. The existence of a measurable margin provides some assurance that the recommendation is robust to reasonable variations in operational conditions. This strengthens the analytical basis for selecting Plan B as the preferred planning scenario and provides a clearer foundation for the summary of findings presented in the next subsection. The threshold analysis adds a layer of practical insight that enhances the value of the study for decision-makers.

Summary of Findings

The analysis in this chapter leads to one main conclusion: Plan B is the more efficient planning alternative for overburden removal during the 2027–2029 period. This conclusion is not driven by a difference in production target, because both scenarios are assessed under the same overburden removal volume. The equal production basis ensures that the comparison is fair and that the results are attributable to differences in operational efficiency rather than to differences in output volume. The difference lies in the hauling arrangement. Plan B uses a shorter haul distance, which lowers cycle time and reduces truck requirement, operator requirement, and manning cost compared with Plan A (Baseline). The operational advantage of Plan B is clear and consistent across all three years of the planning period.

The cost result follows the same pattern. Under the Activity-Based Costing approach, Plan B consistently produces a lower overburden unit cost than Plan A. The gap comes mainly from the OB hauling component, while the other cost components remain relatively unchanged. This specificity of the cost difference is an important finding, as it identifies hauling as the key driver of the cost advantage. In other words, Plan B is not better because every part of the operation becomes cheaper, but because the most influential cost driver in this comparison, namely hauling, becomes more efficient. This finding provides management with a clear focus for cost improvement efforts and enhances the credibility of the recommendation.

The downstream business implication confirms that the cost advantage of Plan B translates into a more favorable projected financial outcome. The lower cost structure under Plan B leads to higher margins and higher profits, as revenue assumptions remain the same across scenarios. The consistency of the financial advantage with the operational and cost advantages provides a comprehensive and coherent picture of the benefits of Plan B. The threshold-based assessment further indicates that Plan B retains a measurable margin of advantage, suggesting that the recommendation remains robust under a range of additional operational burdens. The threshold analysis provides management with a practical tool for evaluating the robustness of the recommendation under uncertainty. These findings collectively support the adoption of Plan B as the preferred planning basis for overburden removal during the 2027–2029 planning period. The comprehensive nature of the analysis, covering operational, cost, and financial dimensions, provides a strong foundation for the business solution presented in the next section.

Business Solution

This section presents the business solution formulated from the findings of the analysis. The results indicate that the economic advantage of Plan B over Plan A is derived from a more efficient hauling arrangement under the same overburden removal target. The clear and consistent nature of the advantage provides a strong basis for a business recommendation. On that basis, the proposed business solution in this study is focused on adopting the more efficient planning alternative for overburden removal during the 2027–2029 planning period. The proposed solution is grounded in the analytical findings and is designed to be practical and implementable. The next subsection sets out the proposed solution and its managerial justification.

Proposed Business Solution

Based on the findings in Section IV.1, the proposed business solution in this study is to adopt Plan B as the preferred planning basis for overburden removal during the 2027–2029 period. This recommendation is grounded in a simple but important result: Plan B achieves the same overburden removal target as Plan A (Baseline), but with a more efficient hauling arrangement. The equal production basis ensures that the comparison is fair and that the recommendation is based on operational efficiency rather than on differences in output. As demonstrated in the analysis, this operational difference reduces hauling-related cost, lowers total overburden cost, and leads to a more favorable projected business outcome under the same planning basis. The cascading benefits from operational efficiency to cost reduction to profit improvement provide a compelling case for the recommendation.

The proposed solution should therefore be understood as a planning-based cost-efficiency decision. It does not rely on a higher production target, a change in revenue assumptions, or a broad reduction across all activity categories. The simplicity and specificity of the recommendation make it easier to understand and implement. Instead, it is based on a specific operational improvement that has a clear and traceable cost consequence. In this study, that improvement lies in the hauling configuration, which becomes the main source of Plan B's economic advantage over the baseline scenario. The traceability of the cost advantage to a specific operational driver enhances the credibility of the recommendation and makes it more persuasive for decision-makers (Kaplan & Cooper, 1998).

From a practical standpoint, adopting Plan B means that the company prioritizes the hauling configuration represented in that scenario when preparing the overburden removal plan. This is important because the analytical results show that Plan B is not merely the lower-cost option in aggregate terms. More importantly, it is the alternative whose cost advantage can be explained at the activity level and linked directly to the underlying operational driver. In that sense, the proposed solution offers not only a lower cost position, but also a stronger planning basis for managerial decision-making. The ability to explain the cost advantage enhances the usefulness of the recommendation for planning and budgeting purposes. The proposed business solution in this thesis can therefore be stated as follows: Plan B should be prioritized as the preferred overburden removal planning alternative for the 2027–2029 period because it delivers the same target with a lower hauling-related cost structure and a more favorable projected economic outcome than Plan A (Baseline). The clarity of the recommendation and the strength of the supporting evidence provide a solid foundation for implementation planning. The managerial rationale for this recommendation is discussed in the next subsection.

Managerial Rationale

The recommendation to prioritize Plan B is managerially justified because it improves cost performance without changing the overburden removal target. The analysis shows that the economic advantage of Plan B does not arise from a higher output level or from different revenue assumptions, but from a more efficient hauling arrangement on the same planning basis. This means that the recommendation is consistent with the company's existing production plans and does not require changes to the overall production strategy. This makes the recommendation relevant for management, since it identifies a lower-cost planning alternative without requiring a broader change in production strategy. The alignment of the recommendation with existing plans reduces implementation complexity and increases the likelihood of management acceptance.

The recommendation is also strengthened by the clarity of its operational basis. The cost advantage of Plan B is not distributed across the entire cost structure but concentrated in the hauling-related component. The concentration of the cost advantage in a single activity simplifies the implementation of the recommendation and makes it easier to achieve. This is an important result because it links the recommendation to a specific operational driver rather than to a general cost reduction claim. From a managerial standpoint, such traceability increases the credibility of the recommendation and improves its usefulness for planning and cost evaluation. The ability to explain the source of the cost advantage is essential for gaining management support for the recommendation (Cokins, 2001).

In addition, the recommendation is consistent with the role of Activity-Based Costing as a decision-support tool. The analysis does not only show that Plan B yields a lower total overburden cost but also explains why this occurs at the activity level. This gives management a more reliable basis for selecting the preferred planning alternative, since the lower cost position of Plan B can be interpreted in relation to the underlying operational configuration. The use of ABC provides a level of analytical detail and transparency that is not available with traditional costing methods. The transparency of the analysis enhances management confidence in the recommendation.

At the same time, the recommendation remains bounded by the scope of the study. It is derived from a planning-based scenario comparison and should therefore be understood as a basis for managerial judgment rather than as evidence of realized operational savings. The planning-based nature of the recommendation highlights the importance of monitoring and review during the execution phase. Within that boundary, however, the rationale for prioritizing Plan B is clear: it provides a more efficient and analytically defensible basis for overburden removal planning during the 2027–2029 period. The strength of the rationale supports the implementation of the recommendation in the company's planning process.

Implementation Plan and Justification

This section presents the implementation plan and practical justification for the proposed business solution. Based on the previous analysis, Plan B is identified as the preferred planning alternative for overburden removal during the 2027–2029 period. The clear identification of the preferred alternative provides a foundation for implementation planning. The discussion in this section focuses on how the recommendation can be justified within the company's planning context, how it can be translated into implementation steps, and how its relevance can be maintained through review and updating. In this thesis, implementation refers to the formal adoption of Plan B within the planning and budgeting process rather than immediate operational execution in the field. The distinction between planning adoption and field execution is important, as it clarifies the scope and timing of the implementation.

Practical Justification of the Recommended Scenario

The recommendation to prioritize Plan B requires practical justification before it can be positioned as a credible planning reference. In this study, that justification is derived from the internal consistency of the analytical results and from the operational logic underlying the compared scenarios. The internal consistency of the results, demonstrated by the alignment between operational parameters and cost outcomes, provides confidence in the validity of the recommendation. Plan B is recommended not because it changes the overburden removal target or the revenue basis, but because it achieves the same target under a more efficient hauling arrangement. This makes the recommendation practically relevant, since its advantage can be linked directly to a specific operational difference. The link to a specific operational difference provides a clear rationale for the recommendation and makes it easier to understand and accept.

From an operational perspective, the recommendation is justified because the compared scenarios remain controlled in their main planning basis. The overburden target is unchanged, the loading side remains broadly constant, and the main variation is concentrated in haul distance, cycle time, truck requirement, and the resulting hauling-related cost. The controlled nature of the comparison reduces the number of variables that could confound the interpretation of results. This shows that the lower total overburden cost under Plan B is not an isolated financial result, but the consequence of a coherent operational configuration. The coherence between operational parameters and cost outcomes is a strength of the analysis.

The recommendation is also justified because its economic advantage can be traced clearly through the cost structure. The analysis shows not only that Plan B is less costly than Plan A (Baseline), but also where the difference originates and how it is transmitted from hauling arrangement to OB hauling cost, from OB hauling cost to total overburden cost, and from total overburden cost to projected business outcome. The traceability of the cost advantage provides a transparent and persuasive rationale for the recommendation. This makes the recommendation more credible as a planning reference, since its benefit can be interpreted in relation to a clear operational driver. The clarity of the causal chain enhances the credibility of the recommendation.

At the same time, the recommendation should be applied only as long as the key technical and operational assumptions underlying the preferred scenario remain feasible within the planning horizon. These include haul route configuration, dump sequence, fleet allocation, support requirement, and other operational conditions that may materially affect the original comparison. The validity of the recommendation depends on the validity of the underlying assumptions. Within that scope, the justification for prioritizing Plan B is sufficiently strong to support its use as the preferred planning basis for overburden removal during the 2027–2029 period. The strength of the justification supports the implementation of the recommendation in practice. The next subsection therefore presents the implementation plan for translating this recommendation into planning practice.

The recommendation to prioritize Plan B applies as long as the key technical and operational assumptions underlying the scenario remain feasible within the planning horizon, including haul route configuration, dump availability, fleet allocation, and supporting operational conditions.

Implementation Plan

The implementation of the proposed solution should be positioned within the company's planning process rather than as an immediate field execution decision. Since the recommendation in this study is derived from a planning-based comparison between Plan A (Baseline) and Plan B, implementation refers to the adoption of Plan B as the preferred reference for overburden removal planning during the 2027–2029 period. The planning-based nature of the implementation means that the primary focus is on incorporating Plan B into the company's formal planning documents and processes.

The first step is to confirm the main assumptions underlying Plan B, particularly haul distance, cycle time, equipment requirement, manpower requirement, and the resulting cost structure. This step is necessary to ensure that the preferred scenario remains consistent with the most recent planning condition. Confirmation of assumptions is important because planning conditions may change between the time of the analysis and the time of implementation. The second step is to integrate Plan B into the formal planning and budgeting process, including overburden removal planning, equipment requirement planning, manpower estimation, and cost budgeting. Integration into the planning and budgeting process is the primary vehicle for implementing the recommendation. At this stage, the Activity-Based Costing result becomes practically useful because it supports not only total cost estimation, but also a clearer explanation of the activity-level drivers behind that cost structure. The ability to explain the cost structure enhances the usefulness of the ABC results for planning and budgeting.

The third step is cross-functional alignment. Because the overburden plan affects multiple planning outputs, the preferred scenario should be interpreted consistently across the relevant functions involved in mine planning, operations, and cost control. Cross-functional alignment is important to ensure that all parts of the organization are working with the same assumptions and targets. The fourth step is periodic review during the planning horizon. Once Plan B is adopted as the preferred basis, its key assumptions and expected cost implications should be reviewed against updated planning information so that the recommendation remains relevant when there are changes in haul route, mine geometry, production target, resource availability, or other material planning assumptions. Periodic review ensures that the recommendation remains valid and relevant throughout the planning period.

Overall, the implementation plan can be understood as a structured sequence consisting of assumption confirmation, integration into planning and budgeting, cross-functional alignment, and periodic review. In this study, implementation therefore refers to the institutional use of Plan B within the planning process rather than to an immediate claim of realized field execution. The structured nature of the implementation plan enhances its practicality and usability.

Table 6. Implementation Plan of the Proposed Solution

Aspect	Description
What	Adopt Plan B as the preferred planning basis for overburden removal during the 2027–2029 planning period.
Why	Plan B achieves the same overburden removal target as Plan A (Baseline), but with a lower hauling-related cost structure, lower total OB cost, and a more favorable projected business implication.
Who	Mine planning team as the primary owner, in coordination with operations, budgeting/cost control, and relevant planning decision-makers.
When	During the preparation and revision of the annual and medium-term overburden removal plan for the relevant planning cycle.
Where	Within the overburden planning, equipment planning, manpower estimation, and cost budgeting process for the relevant pit/operation.
How	Confirm the planning assumptions underlying Plan B, incorporate the preferred scenario into the formal planning and budgeting process, align the selected scenario across relevant functions, and review the key assumptions periodically during the planning horizon.

Source: Author's formulation based on the findings of the study.

Table 6 summarizes the implementation logic of the proposed solution in a structured manner. Prioritizing Plan B should be viewed not merely as an analytical conclusion, but as a planning action requiring clear ownership, appropriate timing, process integration, and regular review. This implementation framework translates the analytical recommendation into an actionable planning process and enhances the practical value of the study.

The implementation of Plan B also depends on the validity of its underlying assumptions and alignment across relevant planning functions. Therefore, implementation should be treated as a managed and continuous planning process rather than a one-time decision. The next subsection discusses how the recommendation should be reviewed and updated to maintain its relevance throughout the planning horizon.

CONCLUSION

This study concluded that Plan B was the more cost-efficient planning alternative for overburden removal during the 2027–2029 period. Because both scenarios were evaluated under the same production target, the cost difference reflected differences in operational efficiency rather than output volume. Plan B involved a shorter haul distance and lower cycle time, which reduced truck and operator requirements. Under the Activity-Based Costing (ABC) framework, these operational differences translated into lower hauling costs and a lower total overburden removal unit cost. The cost advantage was concentrated primarily in the hauling component, while the other activity costs remained broadly unchanged, confirming that Plan B's superiority was driven specifically by greater hauling efficiency. The threshold analysis further indicated that Plan B retained a measurable cost advantage before its total cost converged with that of Plan A.

This cost advantage also resulted in more favorable projected profitability because the revenue assumptions were identical across both scenarios. The findings demonstrated the usefulness of ABC as a decision-support tool for evaluating overburden removal costs and comparing alternative operational plans. Plan B was therefore identified as the preferred basis for the 2027–2029 planning period. Future research should validate these findings using realized operational data and examine additional cost drivers, including fleet composition, equipment utilization, fuel consumption, and maintenance requirements, to further strengthen the practical application of ABC in mining operations.

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