

Evaluating Cost Performance and Unit Rate Optimization in Surface Maintenance Operation (SMO) Earthwork Service Contracts

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ABSTRACT

The Surface Maintenance Operation (SMO) Construction Services Work Unit Rate Earthwork (WUR EW) project in the Rokan Block, Indonesia, utilizes a unit price contract model with hypothetical volumes. This contractual model transfers the risk of uncertain work quantities from the project owner to the contractor. This study aims to analyze the characteristics of this contract and formulate a secure strategy for preparing bidding prices and managing construction costs. The research employed a quantitative analysis of historical data from two work packages (Package 3 and Mitigation Package 3). The analysis was conducted through the calculation of Key Performance Indicators (KPIs) such as the Cost Performance Index (CPI) and Budget Variance (BV), as well as Cost and Quantity Variance Analysis per work item. The results indicate that both projects achieved excellent cost performance, exceeding the planned profit targets (Realized CPI > Planned CPI). The most effective strategy was to set a high profit percentage on the top 10 Earthwork & Civil items (the Pareto items), which experienced significant volume increases and were the main drivers of the total profit growth.

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1. INTRODUCTION

The oil and gas (O&G) sector plays a vital role as one of the main contributors to Indonesia's Non-Tax State Revenue (PNBP) [1, 2]. Maintaining the stability of energy supply and state revenue hinges on the smooth and effective operations across all O&G blocks. The Surface Maintenance Operation (SMO) Construction Services Work Unit Rate Earthwork (WUR EW) project is an integral part of facility surface maintenance and operation efforts in the Rokan Block, one of the nation's largest, specifically encompassing earthwork and civil construction. The execution of this project operates under a unique and complex contractual mechanism [3].

The SMO Construction Services WUR EW contract employs a unit price model that is initially based on hypothetical volumes [4]. In this model, payment to the contractor is fully adjusted according to the actual work volume measured on-site after execution, which can differ significantly from the initial quantities listed in the tender documents. This mechanism effectively transfers the risk of quantity uncertainty from the project

owner to the contractor [5]. This condition demands that the contractor possesses highly accurate cost estimation capabilities and formulates a robust risk mitigation strategy, particularly against volume fluctuations that could lead to heavy equipment underutilization and threaten profit margins.

Given the complexity of this contract model and the potential for high financial risk, this research is crucial for analyzing the contract characteristics and the cost performance achieved [6, 7]. Therefore, this study aims to address two primary research questions:

1. What are the characteristics of the Surface Maintenance Operation (SMO) Construction Services Work Unit Rate Earthwork contract?
2. What is the most effective strategy for preparing bidding prices and construction costs to secure and optimize profit under the Surface Maintenance Operation (SMO) Construction Services Work Unit Rate Earthwork contract?

2. LITERATURE REVIEW

2.1. Tendering in Construction Projects

Tendering, or bidding, is a process of selecting qualified service providers while maintaining fairness and transparency. According to [8], tender strategy plays a crucial role in ensuring cost competitiveness and financial stability during project execution. In Indonesia, tendering in the oil and gas sector adheres to stringent efficiency and accountability principles [9, 10]. The tendering mechanism includes various methods such as open tenders, restricted tenders, and direct procurement, each tailored to project scope and risk levels. An effective tender process not only ensures fair competition but also establishes a framework for contractual clarity, financial accountability, and performance monitoring [11].

Moreover, tender strategies have evolved with the integration of digital procurement systems, enabling data transparency and minimizing corruption risks [12, 13]. Advanced evaluation methods such as multi-criteria decision analysis (MCDA) are increasingly used to assess bidders based on financial, technical, and safety performance [14, 15]. This shift underscores the importance of aligning procurement strategy with risk management principles to ensure that contractors can adapt to fluctuating market and project conditions.

2.2. Unit Rate Contract (WUR) Characteristics

A Unit Rate Contract (WUR) involves fixed prices per work item but variable total costs depending on actual volumes [16, 17]. This model suits projects with uncertain scopes, such as maintenance or operational works. Hypothetical volume contracts serve as preliminary estimates for bidding but often deviate from actual site quantities. The payment mechanism is thus determined post-construction, emphasizing performance accountability. The WUR system is advantageous because it offers flexibility in scope adjustment while maintaining cost transparency through detailed itemized billing [18].

However, this model also introduces substantial risk exposure to the contractor, who must accommodate cost volatility and schedule variation [19, 20]. Effective management of WUR projects requires advanced cost estimation techniques and predictive analytics to anticipate volume deviations. Contractors are encouraged to use digital quantity surveying tools and historical cost databases to refine estimates and safeguard profit margins against unexpected scope expansion or reduction [21, 22, 23].

2.3. Contractual Risks in Hypothetical Volume Projects

The WUR model shifts quantity risks to the contractor, who must handle variations in project scope, material cost fluctuations, and heavy equipment mobilization challenges. Financial risks include underutilized equipment and budget overruns, while administrative risks involve potential penalties for delays or non-compliance [24, 25]. Effective strategies to mitigate these include predictive cost modeling, real-time project tracking, and contingency allocation. Managing these risks also requires the contractor to maintain efficient communication with project owners to anticipate operational changes early [26, 27].

In addition, unforeseen environmental and regulatory conditions, such as delays in obtaining borrow pit permits or logistical bottlenecks, can impact project timelines and costs. Risk mitigation should therefore be

proactive and data-driven, utilizing scenario simulation and sensitivity analysis. The ability to adapt financial and operational planning in real time determines the project's overall resilience under uncertain conditions [28].

2.4. Cost Control and Performance Indicators

Project performance can be assessed using CPI and BV metrics. A CPI value above 1 indicates cost efficiency, while BV measures deviation from planned profit margins. Combining these indicators provides insights into operational success and highlights areas requiring corrective measures. Continuous monitoring through these indicators allows project managers to take early corrective actions and enhance project governance [29, 30].

Furthermore, integrating cost control systems with digital dashboards or AI-based predictive analytics can enhance transparency and precision [31, 32]. These tools enable contractors to forecast financial deviations and identify performance bottlenecks in near-real time [33]. The synergy between quantitative indicators and technology-driven monitoring provides a foundation for data-informed decision-making, ultimately leading to improved project sustainability and profitability [34, 35].

3. RESEARCH METHODS

This study adopts a quantitative research approach using variance analysis to assess the performance, risk, and financial efficiency of the Surface Maintenance Operation (SMO) Construction Services Work Unit Rate Earthwork (WUR EW) project. The approach was selected because it enables systematic comparison between planned and actual project outcomes, providing measurable insights into cost deviations, profitability, and risk management effectiveness [36, 37, 38].

3.1. Research Design and Approach

The quantitative approach was applied through a descriptive-analytical design, focusing on the relationship between project variables such as contract type, cost performance, and quantity fluctuation [39, 40, 41]. The study measured cost performance using Key Performance Indicators (KPIs), specifically the Cost Performance Index (CPI) and Budget Variance (BV), supported by detailed Cost and Quantity Variance Analysis.

This approach was chosen to objectively quantify financial outcomes and minimize subjectivity in performance evaluation. The design also allows replication for future research on similar projects with hypothetical volume contracts in the oil and gas sector [42, 43, 44].

3.2. Data Collection

Data were collected through document analysis and field validation. Primary data sources include:

1. Procurement and Contract Documents, outlining initial unit rates, tender specifications, and contractual conditions.
2. Work Orders (SPK) and Call-Out Records, reflecting the dynamic execution of tasks under the WUR system.
3. Initial and Final Bills of Quantities (BoQ) and Budget Implementation Plans (RAPP), providing the baseline and realized cost and quantity data.

Secondary data such as internal reports, site logs, and monitoring dashboards were used to verify accuracy. The research was conducted at the Rokan Block O&G operational area, focusing on Package 3 and Mitigation Package 3, which represent large-scale and risk-intensive segments of the project.

3.3. Analytical Framework

The analytical process consisted of three stages:

1. Descriptive Statistical Analysis, to summarize financial and operational variables (unit cost, total volume, and CPI trends).
 2. Variance Analysis, to measure differences between planned and realized values for cost and quantity indicators.
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3. Comparative Evaluation, applying the Pareto principle (80/20 rule) to identify the most profitable work items driving cost performance.

The formulas applied include:

$$CPI = \frac{EV}{AC} \quad (1)$$

Where:

- EV = Earned Value (value of completed work)
- AC = Actual Cost (total realized project expenditure)

$$BV = RP - PP \quad (2)$$

Where:

- RP = Realized Profit
- PP = Planned Profit

$$QV = \frac{Q_a - Q_p}{Q_p} \times 100\% \quad (3)$$

Where:

- Q_a = Actual Quantity
- Q_p = Planned Quantity

These calculations provided a clear quantitative assessment of the degree of cost efficiency and risk exposure.

3.4. Validity and Reliability

Data validity was ensured through triangulation between three main sources: contract documents, site implementation reports, and final audit summaries. Consistency of financial data was tested by cross-verifying BoQ quantities against SPK-issued call-outs.

Reliability was maintained by repeating variance analysis calculations with two independent analysts to minimize human error and confirm reproducibility of results.

3.5. Model of Analysis

The conceptual model used in this research, illustrated in Figure 1, outlines the relationship between contract mechanism, variance dynamics, and profit outcome.

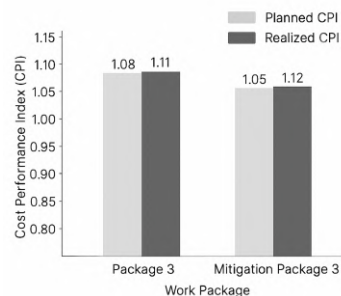


Figure 1. Cost Performance Index Trends for Selected Work Packages

The model begins with the input phase of contract data and cost planning, proceeds through the variance measurement stage, and concludes with performance interpretation using KPI indicators. This model ensures a closed feedback loop for future tender strategy refinement and continuous cost optimization [45, 46].

4. RESULT AND DISCUSSION

This section presents the findings derived from the analysis of two project packages Package 3 and Mitigation Package 3 within the Surface Maintenance Operation (SMO) Construction Services Work Unit Rate Earthwork (WUR EW) project. The analysis focuses on evaluating project performance through Cost Performance Index (CPI), Budget Variance (BV), and Variance Analysis to identify cost and quantity deviations between the planned and realized values. The discussion further elaborates on how these indicators reflect the effectiveness of the applied tender and cost management strategies under the hypothetical volume based contract system.

4.1. Overview of Project Performance

Both project packages demonstrated excellent performance in terms of cost efficiency and profitability. The evaluation showed that the realized CPI values exceeded the planned CPI targets, indicating that both projects achieved cost savings relative to their original estimates. The performance metrics are summarized in the Table 1 below.

Table 1. Key Performance Indicators (KPI) for SMO WUR EW Project

Work Package	Planned CPI	Realized CPI	Planned Profit (Rp Billion)	Realized Profit (Rp Billion)	Budget Variance (BV)
Package 3	1.08	1.11	9.18	11.75	+2.57
Mitigation Package 3	1.05	1.12	4.32	10.83	+6.51

A CPI greater than 1.0 indicates cost efficiency, implying that the project spent less than the earned value of work performed. The positive BV for both projects confirms that realized profit margins surpassed the initial projections by 28.0% for Package 3 (from 9.18 billion to 11.75 billion) and 150.2% for Mitigation Package 3 (from 4.32 billion to 10.83 billion), respectively. These results validate that effective tender preparation and execution strategies led to superior financial outcomes despite high contractual risks.

The superior cost performance can be attributed to three primary factors:

1. Strategic allocation of profit margins on work items with higher likelihood of volume increase.
2. Effective monitoring and adjustment of non-performing or low-margin items.
3. Strong coordination between field operations and cost control units to ensure alignment between volume execution and financial planning.

4.2. Cost and Quantity Variance Analysis

Table 2. Work Item Composition: Package 3 and Mitigation Package 3

No	No. Item	Work Items	Package 3		Mitigation Package 3	
			% Initial	% Final	% Initial	% Final
1	EW22003	Earthworks Fill from Company Designated Location, Haul & Compacted, Additional Cost per KM Above 15 KM Hauling Distance	21,78	48,00	23,74	45,86
2	EW22002	Earthworks Fill from Company Designated Location, Haul & Compacted (with hauling distance from 0.5 KM to 15 KM)	21,88	32,94	33,81	26,81
3	EW22015	Soil/Dirt Hauling, distance 0–10 KM (without compaction)	5,88	5,19	2,09	6,10
4	EW22008	Land Clearing and Grubbing	2,08	4,97	4,18	5,91
5	EW22001	Earthworks Fill from Company Designated Location, Haul & Compacted, Balanced Cut/Fill (with hauling distance < 0.5 KM)	0,66	2,31	0,57	5,73
6	EW22012	Mud Pit Excavation/Construction	2,33	1,22	2,03	2,72
7	EW22137	Fabricate and Install Structural Steel	2,06	0,68	0,36	1,29
8	EW21003	Install Steel Pipe Pile 8"	4,24	0,58	0,78	0,98
9	EW22007	Land Clearing	1,21	0,53	0,47	0,64
10	EW22017	Soil/Dirt Hauling, Additional Cost per KM Above 15 KM Hauling Distance (without compaction)	0,64	0,49	0,35	0,60
Total Pareto Work			62,74	96,90	68,38	96,65
11	–	<i>Other Work Categories</i>	37,26	3,10	31,62	3,35
Total			100,00	100,00	100,00	100,00

Variance analysis was conducted to evaluate how changes in quantities and costs per item influenced overall project performance. The comparison between initial and final BoQ and RAPP revealed that several work items exhibited significant variances in quantity and cost distribution.

The top 10 work items, predominantly within the Earthwork and Civil category, were identified as Pareto items contributing the most to the project's overall profit. These items experienced substantial volume increases, with several items exceeding 100% of the initial plan. For example, Earthworks Fill in Package 3 (Item 1) saw an increase from 21.78% to 48.00%, and Mitigation Package 3 (Item 5) went from 0.66% to 2.31%, demonstrating the profitability potential of strategically selected high-variance items.

These high-variance items played a key role in the project's profitability, allowing project management to prioritize resource allocation and maximize efficiency in high-impact areas.

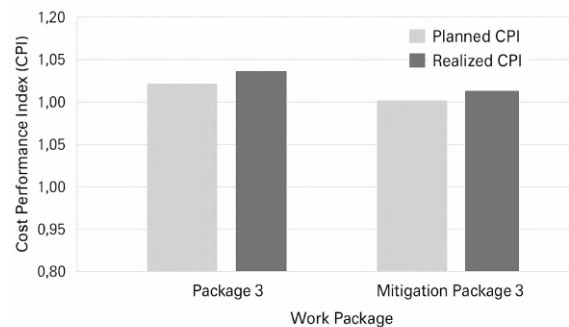


Figure 2. Contribution of Top 10 Pareto Items to Total Profit

Figure 2 illustrates the contribution of Pareto items to total project profit, highlighting how targeted cost management generated disproportionate financial gains.

4.3. Cost Shifting and Strategic Reduction

The analysis also revealed intentional cost shifting, where budget savings from non-essential or low-profit items were redirected toward high-performing categories. For instance, piling, canal works, and concrete works were either reduced or eliminated entirely, freeing up financial and logistical resources for earthwork operations with greater return potential. This reallocation strategy aligns with adaptive project management principles that emphasize flexibility under uncertainty.

The ability to eliminate redundant activities without compromising project deliverables reflects effective collaboration between the project control unit, engineering team, and procurement management. Furthermore, the use of a continuous feedback mechanism between cost tracking and execution allowed for timely decision-making, minimizing idle costs related to heavy equipment mobilization and material storage.

4.4. Comparison Between Packages

While both Package 3 and Mitigation Package 3 demonstrated positive performance, differences in cost dynamics were observed.

- Package 3 emphasized volume expansion in earthworks, benefiting primarily from increased fill quantities and material handling efficiency.
- Mitigation Package 3, however, showed higher overall profitability due to superior cost absorption efficiency and reduction in overhead costs, partly driven by improved scheduling and resource utilization.

The mitigation project applied a more refined Pareto-Focused Bidding Strategy, enabling even greater alignment between projected and actual high-margin work items. Lessons from Package 3 were used to recalibrate profit assumptions in Mitigation Package 3, demonstrating a learning-based cost optimization loop across successive projects.

4.5. Summary of Findings

To summarize, the empirical results from both project packages confirm that:

- The WUR EW contractual mechanism, despite transferring quantity risk to the contractor, can yield high profitability if managed with data-driven strategies and continuous variance monitoring.
- The Pareto-focused approach proved highly effective in optimizing cost and mitigating volume uncertainty by prioritizing high-impact work items and reducing non-essential activities.
- Active monitoring, cost shifting, and elimination of low-margin or redundant items played pivotal roles in maintaining positive CPI and BV outcomes throughout project implementation.
- These findings support the conclusion that proper alignment between tender strategy, operational flexibility, and real-time financial monitoring is essential to achieving sustainable performance in high-risk, volume-variable construction contracts.

5. MANAGERIAL IMPLICATIONS

The findings of this study highlight that effective tender management in unit rate contracts requires a shift toward data-driven and risk-oriented decision-making. Contractors should adopt strategic pricing mechanisms that incorporate predictive analytics to forecast quantity variances, enabling the allocation of higher profit margins on high-impact items with greater volume uncertainty. This proactive approach not only enhances cost efficiency but also minimizes exposure to financial risk during project execution. Additionally, continuous variance monitoring using digital tools allows project managers to detect deviations early, optimize resource allocation, and apply corrective measures in real time, ensuring sustained profitability despite dynamic project conditions.

From a broader managerial perspective, the Pareto-Focused Bidding Strategy validated in this research demonstrates that profitability in high-risk construction environments can be achieved through selective investment and adaptive cost control. Contractors and project owners are encouraged to integrate flexible contractual clauses to accommodate price escalation and material fluctuations, fostering a more sustainable partnership. Furthermore, embedding post-project variance analysis into organizational learning systems will enable continuous refinement of tender strategies, reinforcing long-term competitiveness and operational excellence in future construction projects.

6. CONCLUSION

The SMO WUR EW project is characterized by a high-risk unit price contract that utilizes hypothetical volumes and operates via a call-out mechanism, effectively placing the primary risk of quantity uncertainty onto the contractor. Despite this inherent contractual risk, the projects successfully demonstrated robust financial performance, as evidenced by realized CPI values significantly above the planned targets, translating into a substantial over-achievement of expected profit margins.

The key finding of this research is the validation of the Pareto-Focused Bidding Strategy as the most effective method for this contract type. This strategy involves the contractor strategically front-loading the bid with a high-profit margin on a specific, small subset of Earthwork & Civil items that are predicted to have the highest likelihood of volume increase during execution. The actual financial success and the surplus profit were not derived from consistent project volume but from the massive, unpredictable increase in the executed quantities of these few, high-margin Pareto items, which successfully neutralized the non-executed volumes of other work items.

Based on this analysis, it is highly recommended that contractors refine their forecasting models to more accurately project the potential volume changes for these critical Pareto items before submitting the bid. Future research should focus on developing advanced simulation models that can integrate probabilistic risk factors (such as the likelihood of borrow pit delays or administrative penalties) with the projected volume variance for the high-impact Pareto items to create a truly optimized bidding and execution strategy specifically tailored for hypothetical volume-based unit price contracts in the O&G sector.

7. DECLARATIONS

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7.2. Author Contributions

Conceptualization: AL; Methodology: DP, EA, and LS; Software: EA and LS; Validation: AL and DP; Formal Analysis: EA and LS; Investigation: AL, EA, and LS; Resources: DP; Data Curation: AL; Writing Original Draft Preparation: AL and DP; Writing Review and Editing: EA and LS; Visualization: EA; All authors, AL, DP, EA and LS have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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