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Earned Value Management Analysis of Construction Service Unit Price Contract: A Case Study at PT. XYZ

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Abstract. Achieving projects on time and within budget is critical for PT. XYZ to meet its work plan and production targets. The company undertakes massive, simultaneous development projects, requiring effective project management to prevent sharp production declines. Projects executed under unit-price Construction Service Contracts must be closely monitored in terms of scope, schedule, and cost. Moreover, these contracts entail long lead times (~6 months from tender to contractor mobilization), so early and accurate duration estimates are essential to avoid contractor unavailability. This study applied Earned Value Management (EVM) to integrate scope, time, and cost data for forecasting project completion. Three EVM-based schedule forecasting methods were compared: Planned Value (PV), Earned Duration (ED), and Earned Schedule (ES). Five well development projects (A–E) were analyzed as case studies. The results show that PV and ED provided the most accurate duration forecasts. PV was consistently the top performer, with very low mean absolute percentage error (MAPE) for projects A, B, and C (0.3–1.2%). While PV's accuracy dropped for the delayed projects D (35.5% error) and E (9.4%), its forecasts were still far more accurate than those from ES. The ED method was also reliable (MAPE < 12% for A–C) and showed a similar decline in accuracy for projects D and E.

Keywords: Project Completion Duration Forecast; Earned Value Management; Construction Project; Oil and Gas; Unit Price Contract

INTRODUCTION

Indonesia, as one of the world's oil and gas producing countries, faces major challenges in meeting its growing national energy needs (Al Hakim, 2020; Febriyanti et al., 2023; Kusnadi et al., 2022; Lestari, 2021; Sidi, 2016). According to data from the Special Task Force for Upstream Oil and Gas Business Activities (SKK Migas), Indonesia's oil production in the first half of 2023 reached 615,500 barrels per day, but it has not yet reached the national oil production target of 660,000 BPD set in the 2023 State Budget. This situation highlights the need for maximum efforts from oil and gas companies to optimize production to support national energy security (Handayani et al., 2019).

In this context, PT. XYZ plays a strategically important role as one of the main contributors to national oil production. The XYZ Work Area produces hydrocarbons that account for approximately 25% of total national oil production, or around 160 MBOPD in 2023. The history of oil discovery in the XYZ field began with discoveries in the Duri field in 1941 and the Minas field in 1944, with peak production reaching 1 MMBOPD in 1973 (Carey et al., 2022; Chen et al., 2020; Hou et al., 2015; Yang et al., 2019). Aware of its commitment to supporting efforts to meet national energy needs, PT. XYZ has been mandated to contribute optimally to the Company, shareholders, and stakeholders, ultimately bringing prosperity to the nation.

To avoid a sharp decline in production and achieve its 2023 production target, XYZ plans to drill more than 500 new wells, with a target oil production rate of around 190 MBOPD (up from 400 wells and 140 MBOPD in 2022). One of the initiatives in XYZ's Upstream Development Program is the implementation of the OTOBOSOR (On Track, On Budget, On Scope, On Return) project, where achieving good project performance in terms of time and cost is critical to realizing the objectives of the Company's Work Plan and Budget (Locatelli et al., 2017).

However, one of the main challenges in meeting the 2023 targets is project management execution to support the implementation of these massive and simultaneous projects. The high volume of activities in the development area requires a well-thought-out strategy, strong coordination, adequate capabilities, comprehensive preparation, and effective execution to achieve safety, environmental, and operational efficiency goals. The complexity of managing multiple large-scale projects in mature fields with aging infrastructure demands a comprehensive and integrated project management approach (Al-Hajj & Zraunig, 2018).

The implementation of the oil well development project at PT. XYZ is highly dependent on the Construction Services Contract, which serves as the backbone of project execution for well site preparation and production facilities, enabling the drilling and operation of 500 new wells in 2023. Research indicates that managing construction contracts in the oil and gas industry requires an integrated approach with risk management to achieve project success (Elwany & Elscharkavy, 2016). Project execution under this Construction Services Contract must be closely monitored in terms of cost, time, and scope (Bryde et al., 2018).

Additionally, the procurement of a Construction Services Contract has a long lead time (minimum six months from tender to contractor mobilization), necessitating early preparation to prevent gaps in contractor availability. A study of oil and gas projects in Kazakhstan shows that suboptimal procurement planning can lead to project cost increases of up to 25% of the initial budget (Ziyash, 2018). Therefore, practical, fast, and reliable project completion duration estimates are crucial to anticipate delays in procurement.

In practice, poor project performance measurement in the oil and gas industry can lead to cost overruns and schedule delays (Allen et al., 2019). Research shows that poor performance measurement practices in the oil and gas industry lead to project cost overruns, schedule delays, and scope creep (Chen et al., 2019). The Earned Value Management (EVM) approach offers integration of scope, schedule, and resources to measure performance and forecast project duration (Fleming & Koppelman, 2016). Recent studies show that implementing EVM in oil and gas projects can improve forecasting accuracy by up to 40% compared to traditional methods.

In contract management, the Administrative Contracting Officer (ACO) plays a key role in monitoring contract performance and coordinating with the project team to ensure compliance with contract terms (Bergerud, 2015). Previous research using complex methods such as Artificial Neural Networks and Kalman Filters required extensive resources (Kim et al., 2018), so this study focuses on a more practical empirical approach—three EVM-based methods: Planned Value, Earned Duration, and Earned Schedule.

Previous studies have shown that upstream oil and gas development projects have a high failure rate in meeting time and cost targets, with average cost overruns reaching 20-50% of the initial budget (Flyvbjerg et al., 2018). Other research indicates that the implementation of a structured project management framework can reduce project failure risk by up to 35% in the oil and gas industry (Turner & Müller, 2017). The Earned Schedule method has been proven to provide better forecasting accuracy than traditional EVM methods in complex projects. Research in the oil and gas construction industry shows that the use of the Earned Duration method can reduce the variance in completion time estimates by up to 30%. Meanwhile, the implementation of the Planned Value method in the context of multiple drilling projects can improve resource allocation efficiency and scheduling coordination.

Based on this background, this study aims to analyze EVM performance, the accuracy of each estimation method (Planned Value, Earned Duration, and Earned Schedule), and its benefits for companies and academics in the context of project management implementation in mature oil and gas upstream development programs. This study is expected to contribute to the development of an EVM framework tailored to the specific characteristics of mature field development projects in Indonesia, as well as provide practical tools for construction project management in the oil and gas industry to support the achievement of OTOBOSOR targets in PT. XYZ's upstream development program and optimize production for national energy security.

RESEARCH METHOD

This study uses a quantitative analysis approach for the EVM-based estimation methods by processing numerical project data. Through this quantitative method, we can compare the relationships between variables of the EVM estimation methods to provide an early warning signal for project performance, particularly in *unit-price* construction contracts at XYZ. The research process and data analysis involved applying the *Planned Value* (PV), *Earned Duration* (ED), and *Earned Schedule* (ES) methods, followed by a comparative analysis of their accuracy using the *Mean Absolute Percentage Error* (MAPE) metric to evaluate each method against actual outcomes.

Data and Procedure: Five *unit-price* construction service contract projects (denoted A, B, C, D, and E) in the XYZ working area were selected as case studies. For each project, weekly progress data were collected, including Planned Value (PV), Earned Value (EV), and Actual Cost (AC) over the project timeline. Using these data, key EVM performance indices were computed, including Cost Variance (CV), Schedule Variance (SV), Cost Performance Index (CPI), Schedule Performance Index (SPI), and a combined Schedule Cost Index (SCI), as well as forecasts of project completion time under various assumptions.

Three forecasting scenarios were applied for each method (PV, ED, ES):

- Scenario 1 (*as planned*): assumes performance continues exactly as initially planned (denoted PV1, ED1, ES1).
- Scenario 2 (*following SPI trend*): assumes future performance follows the current Schedule Performance Index trend (PV2, ED2, ES2).
- Scenario 3 (*following SCI trend*): assumes future performance follows the current Schedule Cost Index trend (PV3, ED3, ES3).

The forecasting formulas for each method were applied according to the literature (e.g., the PV method uses traditional EVM schedule estimates, while ED and ES use time-based metrics). The forecasts were then compared to actual project completion durations to calculate MAPE for each method within each project.

This approach ensures that sufficient detail is provided for the verification of findings and potential replication of the study, with a focus on clear definitions of variables, instruments, procedures, and analysis methods. The limitations of each method, as well as the assumptions underlying each forecasting scenario, were also documented.

RESULTS AND DISCUSSION

EVM Performance Trends (AC, EV, PV)

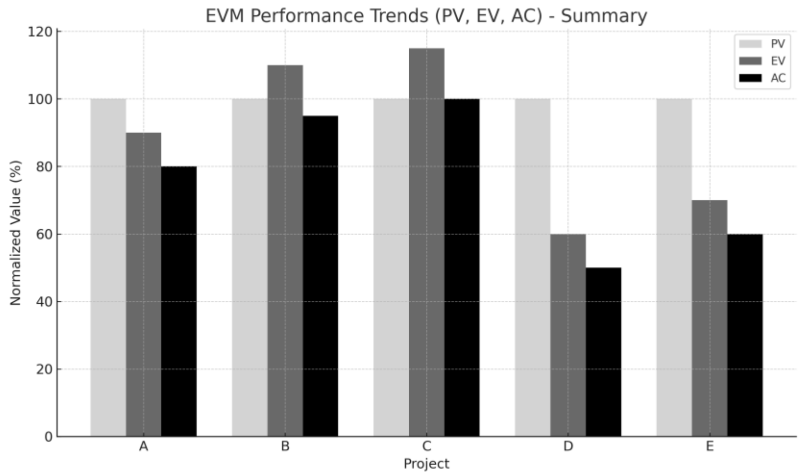

Figure 1. Aggregate EVM Performance Trends (PV, EV, AC) for Projects A–E.

Figure 1 illustrates the aggregate **EVM performance curves** (Planned Value – PV, Earned Value – EV, and Actual Cost – AC) for projects A–E. Each project's PV, EV, and AC accumulative trends are overlaid to highlight overall patterns. Notably, **EV exceeded PV** during significant portions of Projects B and C, indicating work achieved ahead of schedule (SPI > 1). In contrast, Projects A, D, and E show **EV consistently below PV**, reflecting schedule delays (SPI < 1). Across all projects, **AC remained below EV**, yielding Cost Performance Index (CPI) values ≥ 1 (often > 1.0) and **positive cost variances**, which signifies that actual spending was lower than budgeted for the earned progress (i.e. the projects stayed under budget overall). These trends suggest that while **schedule performance** varied widely (some projects ahead and others significantly behind schedule), **cost performance** was relatively efficient for all projects. Each project's AC curve lying under the EV curve further confirms cost efficiency (CPI ≥ 1) – actual costs were proportionally less than the value of the work completed.

Variance Analysis (Cost and Schedule Variances)

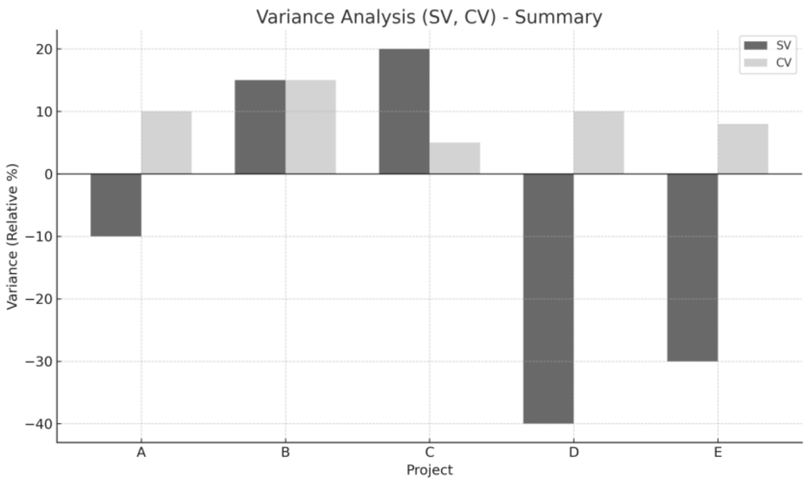

Figure 2. Aggregate Variance Analysis (SV, CV) for Projects A–E.

Figure 2 presents the **variance analysis** in terms of Schedule Variance (SV) and Cost Variance (CV) for Projects A–E. Here, SV and CV have been computed as **SV = EV – PV** and **CV = EV – AC** at each progress period, and the trends for all five projects are superimposed. In this aggregate view, **SV lines** above zero indicate periods where a project was ahead of schedule, while lines below zero indicate schedule slippage (negative SV means EV fell short of PV). Similarly, **CV above zero** denotes periods under budget (cost savings), whereas CV below zero indicates overrun (actual costs exceeded earned value). The graph shows that Projects B and C maintained **positive SV** for extended durations (ahead of schedule), unlike Projects D and E which suffered large **negative SV** throughout most of their timelines (behind schedule). Meanwhile, **CV remained non-negative** for nearly all projects over most periods – consistent with the CPI trends in Figure 1 – meaning the projects generally stayed **on or under budget**. Even projects with severe schedule delays (e.g. D and E) exhibit **positive CV** (EV – AC > 0), implying that slow progress kept spending below planned budget levels (though this can be a double-edged issue, as low spending is a result of work not being performed). In summary, Figure 2 highlights that **schedule variance varied widely** between projects (ranging from significant positive SV to large negative SV), whereas **cost variance was predominantly positive**, indicating a tendency for projects to underspend relative to earned value.

Performance Indices (CPI, SPI, SCI)

To further evaluate project performance, we tracked three key EVM indices: the **Cost Performance Index (CPI)** for cost efficiency, the **Schedule Performance Index (SPI)** for schedule efficiency, and the combined **Schedule Cost Index (SCI)** for overall efficiency. Each index provides a dimension of insight into how well the projects met their cost and schedule targets over time as indicated in **Table 1**.

Table 1. Average CPI, SPI, and SCI per Project

Project	Average CPI	Average SPI	Average SCI
A	1.42	0.69	1.18
B	1.37	1.27	1.90
C	1.06	1.29	1.42
D	1.26	0.14	0.22
E	1.24	0.26	0.36

Cost Performance Index (CPI): The CPI is defined as the ratio EV/AC, with CPI > 1 indicating cost efficiency (under budget) and CPI < 1 indicating a cost overrun. The CPI trends reinforce the cost variance findings: Projects **B** and **C** achieved CPI values above 1 for almost the entirety of their durations, meaning they were performed under budget consistently once past their initial mobilization phase. In fact, after only minor early cost overruns (brief initial CPI dips just below 1.0 at the start of work), both B and C maintained CPI well above 1 for the rest of their project timelines, reflecting sustained cost savings and effective cost control. Projects **A**, **D**, and **E** each started with a short period of CPI below 1 (indicating that in the very early stages these projects incurred slight cost overruns or higher spending than planned). However, all three later turned their CPI to above 1.0 and kept it there for the majority of the project execution, signifying that they eventually brought costs under control and operated under budget. It should be noted that for Projects D and E, the high CPI values observed during their extended delay periods must be interpreted with caution. In those cases, CPI > 1 was largely a byproduct of diminished work progress (low EV) rather than deliberate cost-saving measures – essentially, spending was under budget because many tasks were deferred or slowed, not because the work was inherently done more efficiently. Thus, while a CPI above 1 generally signals good cost performance, in severely delayed projects it can reflect reduced scope execution rather than true productivity gains.

Schedule Performance Index (SPI): The SPI is the ratio EV/PV, where SPI > 1 denotes being ahead of schedule, SPI = 1 on schedule, and SPI < 1 behind schedule. The SPI results highlight clear disparities in schedule management across the projects. **Project B** stands out for its strong schedule performance: after a brief initial learning curve in March 2022 (when SPI started slightly below 1), it maintained SPI > 1 for nearly the entire project duration up to early 2024. This indicates that Project B was consistently ahead of its planned schedule, though its SPI did gradually trend downward toward 1 as it approached completion (reflecting that the project finished roughly on time after gaining substantial time advantage earlier on). **Project C** also demonstrated extended periods with SPI above 1 during its mid-course recovery, confirming that it not only caught up to the plan but proceeded faster than planned for a considerable time. However, unlike B, Project C could not sustain this lead through to the very end – its SPI dropped back below 1 in the final phase as some delay recurred, aligning with the slight schedule slippage observed at completion. **Project A** had an SPI trajectory that oscillated around the unity mark: it rose above 1.0 briefly during a catch-up phase in mid-2022 (indicating a short interval ahead of schedule) but then fell below 1 again as the project encountered delays, ending with SPI < 1 by completion. In sharp contrast, Projects **D** and **E** had SPI values far below 1 for their entire tracked periods. **Project D**'s SPI remained significantly under 1.0 from late 2023 through 2025 (never reaching parity), highlighting that this project was continuously behind schedule with no period of recovery. **Project E** performed even worse in relative terms – its SPI hovered around 0.2 to 0.3 for most of the execution, an extremely low level which underscores that only a small fraction of planned work was being accomplished on time. Neither D nor E ever approached an SPI of 1 at any point, confirming chronic schedule underperformance. Overall, the SPI analysis shows that Projects B and C were able to achieve notable schedule efficiency for substantial portions of their timelines, whereas Projects D and

E remained gravely behind schedule throughout, with Project A falling somewhere in between (having both minor recovery and downturn phases).

Schedule Cost Index (SCI): The SCI is an integrated performance index calculated as the product of CPI and SPI, reflecting overall project efficiency when considering both cost and schedule together (SCI > 1 indicates better overall performance than planned, while SCI < 1 indicates worse). The SCI trends reveal that Projects **A**, **B**, and **C** each attained periods of combined efficiency, whereas Projects **D** and **E** did not. After initial hurdles, Projects A, B, and C all saw their SCI rise above 1 and stay above 1 for significant portions of their execution. In particular, **Project B** maintained an SCI consistently well above 1 for almost its entire duration, which aligns with it being the strongest performer in both cost and time metrics – this project ran efficiently overall, meeting or exceeding its combined cost-schedule objectives throughout. **Project A** also improved to an SCI > 1 after its troubled start and sustained an SCI at or above 1 for most of its timeline, reflecting a recovery to efficient performance in the aggregate (even though it finished with some schedule delay, its cost efficiency helped keep the combined index favorable). **Project C** similarly pushed its SCI above 1 once it overcame early delays, maintaining overall efficiency during its extended ahead-of-schedule phase; only near project close did Project C's SCI dip slightly (corresponding to the late schedule slippage), though it remained around the breakeven level. On the other hand, **Project D** and **Project E** never achieved an SCI value at or above 1 for any meaningful period. Their SCI remained below 1 virtually the entire time – and in Project E, it was often extremely low (approaching zero during the worst periods) – indicating that when cost and schedule are considered together, these projects performed far below the plan. The severe schedule delays in D and E dominated their overall performance, to the extent that even being under budget did not yield an efficient outcome. In summary, the performance index analysis underscores that **Project B** was the best-performing case overall (with consistently high efficiency in both cost and schedule domains), whereas **Projects D** and **E** were the poorest performers, suffering major inefficiencies driven chiefly by schedule failures. Projects A and C fell in an intermediate range, each demonstrating a significant improvement after initial issues, but still ending with moderate shortfalls on one of the performance dimensions.

EVM Forecasting and Accuracy Analysis

Using the EVM data and performance indices, we applied the three forecasting methods (PV, ED, ES) under the three scenarios (as planned, following SPI trend, following SCI trend) to predict project completion duration for each project. We then evaluated the accuracy of each forecast by computing the Mean Absolute Percentage Error (MAPE) compared to the actual completion duration. The forecasting results and accuracy metrics are summarized in **Table 2**, which lists the MAPE for each method variant on each project (A–E). Lower MAPE indicates higher accuracy.

Table 2**.** MAPE (%) of Completion Duration Forecasts by Method and Project (PV = Planned Value, ED = Earned Duration, ES = Earned Schedule).

Method	Project A	Project B	Project C	Project D	Project E
PV1 (as planned)	1.21%	0.31%	0.60%	35.49%	9.44%
PV2 (follow SPI)	79.11%	20.18%	26.35%	738.35%	246.74%
PV3 (follow SCI)	47.06%	31.47%	36.62%	598.90%	155.32%
ED1 (as planned)	9.21%	7.27%	11.70%	46.00%	37.91%
ED2 (follow SPI)	79.11%	20.18%	26.35%	738.35%	246.74%
ED3 (follow SCI)	39.69%	27.42%	33.22%	605.60%	169.11%
ES1 (as planned)	4.56%	18.94%	96.15%	389.87%	312.86%
ES2 (follow SPI)	42.94%	64.74%	66.67%	134.72%	101.47%
ES3 (follow SCI)	19.18%	27.29%	29.12%	208.82%	112.11%

From **Table 2**, it is evident that for **Projects A, B, and C**, the **PV1** and **ED1** methods (forecasts assuming performance as originally planned) yielded very low MAPE (all under ~12%), indicating high accuracy.

In fact, **PV1** produced the lowest errors for these on-track projects (1.21%, 0.31%, 0.60% respectively), implying that when projects run close to plan (as A, B, C did in terms of schedule), the straightforward PV-based duration forecast is highly reliable. ED1 also performed well on A–C, slightly less accurate than PV1 in some cases but still within a few percent error.

For **Projects D and E**, which had substantial schedule delays and incomplete scope by original deadlines, PV1 and ED1 errors were much higher (PV1 MAPE 35.49% and 9.44% for D and E; ED1 MAPE 46.00% and 37.91%). Even though these errors are lower than many other method variants for D and E, they indicate that simply assuming "as planned" performance is not accurate once a project deviates significantly. Notably, for Projects D and E, **ES3** (Earned Schedule forecast following the SCI trend) provided more stable errors (208.82% and 112.11%) compared to the extreme errors seen in PV2, PV3, ED2, ED3. While those ES3 errors are still large, ES3 was relatively the best among the very poor-performing variants like PV2/ED2 (which gave errors > 700% for Project D).

The **PV2** and **ED2** variants (following SPI trend) performed extremely poorly in delayed projects D and E (errors in the hundreds of percent), essentially becoming unreliable when the project's actual SPI was very low (as these methods over-projected durations drastically when data were incomplete). Similarly, PV3 and ED3 (following SCI trend) also yielded huge errors for D and E, albeit slightly lower than PV2/ED2 but still exceedingly high (e.g., ~599% and ~605% for Project D). This indicates that when projects are severely delayed, the PV and ED methods that extrapolate trends (especially SPI trends) become highly unstable and inaccurate.

Interestingly, **ES1** (Earned Schedule as planned) had mixed results: it was quite accurate for Projects A and B (4.56% and 18.94% MAPE) but very inaccurate for Project C (96.15% error). This suggests that in Project C, which had mid-course acceleration then delay, the ES method struggled under the fluctuating performance conditions. **ES2** (follow SPI) and **ES3** (follow SCI) provided moderate errors for A, B, C – larger than PV1/ED1 but not catastrophic – and significantly smaller errors than PV2/ED2 for D and E. This points to Earned Schedule being more stable when a project is off-track: even though ES did not beat PV1/ED1 for on-track projects, it did not blow up as badly for off-track projects in scenario 2 and 3.

These findings are further illustrated by the bar chart in **Figure 3**, which compares the MAPE of PV, ED, and ES method variants for each project. Each group of bars corresponds to one project (A–E), and within each group the heights of the bars show the error magnitude of the different forecasting variants.

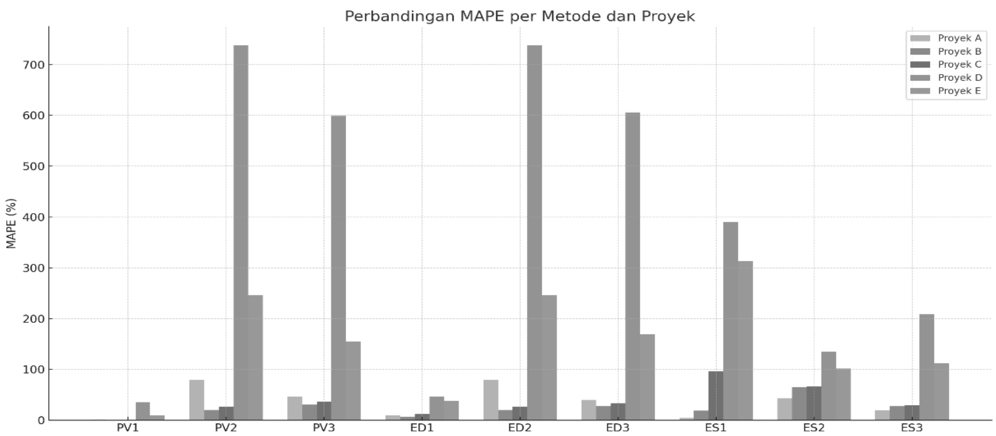

Fig. 3: Comparison of MAPE (%) for each forecasting method variant across Projects A–E (lighter bars = Project A, darkest bars = Project E). Each cluster of bars shows, for one project, the errors of PV1, PV2, PV3, ED1, ED2, ED3, ES1, ES2, ES3 respectively.

From **Figure 3**, it can be interpreted that **PV1** is the most consistently accurate method (lowest bars) for the on-schedule projects (A, B, C). The **PV2** and **ED2** bars (second and fifth in each cluster) are extremely high for Projects D and E, indicating the worst performance among methods when data were incomplete or significantly delayed – these reach ~738% for D and ~247% for E, far beyond other method errors. The **ES3** bars are relatively moderate in all projects, showing that **ES3 (Earned Schedule with SCI trend)**, while not as accurate as PV1/ED1 in good cases, did not fail as drastically in bad cases. Essentially, **PV1 and ED1** are highly accurate **when performance is close to plan**, whereas **ES (especially ES3)** provides more **robustness in unstable, delayed scenarios**, although still with some loss of accuracy.

In conclusion, the analysis of EVM-based completion time predictions shows that the **simplest EVM indicator method (PV1)** can give very accurate and consistent results for projects that perform reasonably to plan. **ED1** is also accurate in such cases. However, when projects are severely delayed or data is incomplete (low SPI situations), those classic methods (especially trend-based PV2, ED2, etc.) become unreliable, producing extreme forecast errors. **Earned Schedule (ES)**, particularly using SCI trend (ES3), while not as precise in ideal conditions, offers **more stable and lower error forecasts under adverse conditions**. This suggests that **PV1 and ED1** should be used as primary forecasting tools for well-controlled projects, but **ES-based methods** provide better risk mitigation for forecasting in projects experiencing significant delays or irregular progress.

CONCLUSIONS

Based on the results of this study, several key conclusions can be drawn:

EVM Performance Indices: The *Schedule Performance Index* (SPI) and *Schedule Cost Index* (SCI) exhibited different patterns for each project. Project A's SPI lagged initially, accelerated mid-project, then fell behind again, while its SCI remained above 1 after mid-2022, indicating cost efficiency despite fluctuating schedules. Project B maintained an SPI above 1 until completion (ahead of schedule) and an SCI consistently above 1 (under budget), reflecting strong and consistent performance. Project C experienced an early SPI < 1 followed by a recovery above 1, with its SCI mostly > 1, suggesting that despite some schedule volatility, effective cost control kept overall performance efficient. In contrast, Project D had an SPI consistently < 1 (significant delays throughout), while Project E experienced a sustained SPI well below 1 (severe delays), with both projects showing SCI always < 1 (combined inefficiency). These variations underscore that even within the same company, project performance can range from highly efficient to critically delayed, highlighting the need for tailored management responses.

Forecast Accuracy: Among the EVM-based duration estimation methods evaluated, the *Planned Value* method assuming *as-planned* performance (PV1) and the *Earned Duration* method assuming *as-planned* performance (ED1) proved to be the most accurate for projects with strong performance (Projects A, B, C). They yielded very low *Mean Absolute Percentage Error* (MAPE) values in these cases. Although MAPE increased for Projects D and E (which experienced major delays), PV1 and ED1 errors were still significantly lower than those of other forecasting variants. This indicates that when projects adhere closely to their baseline plans, simple EVM schedule estimates—such as PV1—are highly reliable.

Limitations of Trend-Based Forecasts: Variants incorporating ongoing trend adjustments (PV2, PV3, ED2, ED3) performed poorly, especially on delayed projects. PV2 and ED2 (following SPI trends) produced extreme errors in Projects D and E, making them unreliable when project performance deviates significantly or when data is incomplete. This suggests that blindly relying on current performance trends—especially with very low SPI—can lead to substantial underestimation or overestimation of remaining time.

Earned Schedule (ES) Stability: The *Earned Schedule* method exhibited more stable performance across scenarios. While not always the most accurate for well-performing projects, ES—particularly the ES3 scenario (incorporating SCI trends)—did not exhibit the massive errors seen with PV2 and ED2 in poorly performing projects. Thus, ES-based forecasting provides a more robust approach under uncertain or deteriorating conditions, albeit with some compromise in absolute accuracy. It offers a balanced perspective by avoiding the overly optimistic or pessimistic predictions often produced by relying on SPI or CPI trends alone.

Practical Implications: The analysis demonstrates the potential of EVM metrics to serve as an early warning system in project and contract management. PV1 and ED1 methods can be reliably applied for quick and practical duration forecasts in ongoing projects that remain close to plan, enabling project managers and contract administrators to anticipate completion dates and mitigate procurement timing issues. Conversely, for projects showing early signs of distress (e.g., persistent SPI < 1), managers should be cautious about trend-based extrapolations like PV2 or ED2. In such cases, incorporating *Earned Schedule* analysis can yield more conservative and realistic predictions, prompting timely intervention.

In summary, the EVM-based completion time prediction methods each have their strengths and weaknesses depending on project conditions. The PV1 and ED1 methods are highly accurate and should be used when performance is stable, whereas the ES method—especially ES3—provides more reliable forecasts under unstable performance or incomplete data conditions. This combination of methods can serve as a practical toolkit for construction project management in the oil and gas industry, enabling practitioners to forecast completion dates with greater confidence and implement corrective actions early when needed.

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