Benchmarking Indonesia's Downstream Oil & Gas Construction: Evaluating Project Scheduling and Cost Estimating Processes Against Global "Best-Tested and Proven" Practices [1, 2]

By Muhammad Fadhli Zilikram

ABSTRACT

Project overruns, affecting both time and budget, are widespread, with no exception in Indonesia's downstream oil & gas industry. Poor estimation during scheduling and cost-estimating processes contributes significantly to the failure of projects. The Company has a goal for the projects, which is on time and within budget, but the current condition is still far from expectations. This study aims to find references that companies can use to improve the performance of scheduling and cost-estimating processes. Benchmarking is done by identifying several standards worldwide used, selecting a basis for comparison, assessing each other, and selecting the best reference as the "Best-Tested and Proven" Practice using Multi-Attribute Decision Making (MADM). The result of the analysis found that GAO is the best in the scheduling process and the cost-estimating process. Using the Pareto principle, a priority order has been obtained from the most significant gaps between GAO vs. Company Standards that the Company can refer to minimize work.

Keywords: Scheduling Process, Cost-Estimating Process, Downstream Oil & Gas, Infrastructure Project, Best-Tested and Proven, GAO Schedule Assessment Guide, GAO Cost Estimating & Assessment Guide

INTRODUCTION

Indonesia oil & gas experiences "56 percent of projects experience a 10 percent cost and overrun schedule, and around 36 percent experience cost and overrun schedule up to 25 percent at 45 projects"[3]. Similarly, Shah notes that "in India, from 1635 government projects, about 35 percent delayed by a large margin and responsible for 65 percent cost overrun"[4]. Likewise, Kearney report that "60 percent of capital projects on oil & gas, chemicals, utilities, metal, and mining, have more than 10 percent overrun on cost and

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[2] This paper was originally prepared during a 6-month long Graduate-Level Competency Development/Capacity Building Program developed by PT Mitrata Citragraha and led by Dr. Paul D. Giammalvo to prepare candidates for AACE CCP or other Certifications. https://build-project-management-competency.com/our-faqs/

[3] Wisnugroho, J. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study; PM World Journal, Vol. IX, Issue II, February.

[4] Shah, V. A. (2021). Cost and Time Overrun in Various Construction Projects: A Review; Psychology And Education.

schedules, and nearly a third have more than 25 percent overrun on cost"[5]. The most recent data, KPMG & AIPM found it was getting worse as "in 2022, only around 36 percent of their project on budget and 32 percent on time. Compared in 2020, 40 percent of their project delivered on budget and 42 percent on time"[6]. Therefore, this is challenging for project management to develop credible cost estimates and reliable schedules.

Figure 1 - Project Deliver Performance on KPMG & Australian Institute of Project Management[7]

"The problem of project overruns in the construction industry is a global phenomenon"[8]. Project overrun refers to both schedule and cost overrun. "Schedule overrun means late completion or delivery from the time specified and agreed by all parties of the construction project, while cost overrun means the project completed at a cost higher than what was budgeted"[9]. These two things influence one another and are usually analyzed to obtain the optimum point of both things, as shown in Figure 2.

Project overruns happen for various reasons, which makes the problem complicated and involves many different aspects. In general, Abdulaziz confirms that "major causes of time overrun in Indonesia are design changes, poor labor productivity, inadequate planning, and resource shortages, whereas for cost overrun are material cost increases due to inflation, inaccurate material estimating, and degree of project complexity"[10].

[5] Excellence in capital projects: A goal yet to be achieved - Article - Kearney. (2017, February 27). Kearney. Retrieved from: https://www.kearney.com/industry/energy/article/-/insights/excellence-in-capital-projects-a-goal-yet-to-be-achieved.
[6] KPMG & AIPM. (2022, November). The state of project management in Australia 2022.
[7] Ibid
[8] Sambasivan, M., & Soon, Y. W. (2007). Causes and effects of delays in Malaysian construction industry. International Journal of Project Management, 25(5), 517-526. Retrieved from: https://doi.org/10.1016/j.ijproman.2006.11.007.
[9] Mukuka, M., Aigbavboa, C., & Thwala, W. (2015). Effects of construction projects schedule overruns: A case of the Gauteng province, South Africa. Procedia Manufacturing, 3, 1690-1695. Retrieved from: https://doi.org/10.1016/j.promfg.2015.07.989
[10] Seddeeq, A. B., Assaf, S., Abdallah, A., & Hassanain, M. A. (2019). Time and cost overrun in the Saudi Arabian oil and gas construction industry. Buildings, 9(2), 41. Retrieved from: https://doi.org/10.3390/buildings9020041.

Kamaruddeen has categorized these factors and divided them into three main groups, namely "contractor related, client-related, and external-related factors"[11]. Because the author is on the client's side, this study will only focus on client-related factors, and it will be divided based on phases, namely, the planning and construction phases. In the planning phase, the five elements are "omit probable scope, omit possible risks or underestimated, unrealistic or optimistic assumptions, not enough time to prepare, and not prepared by a bona fide personnel"[12]. Meanwhile, in the construction phase, the most common five causes[13] are slowness in the decision-making process, change in design, poor project coordination by the client to the construction team, late revising and approval, and delay in progress payments.

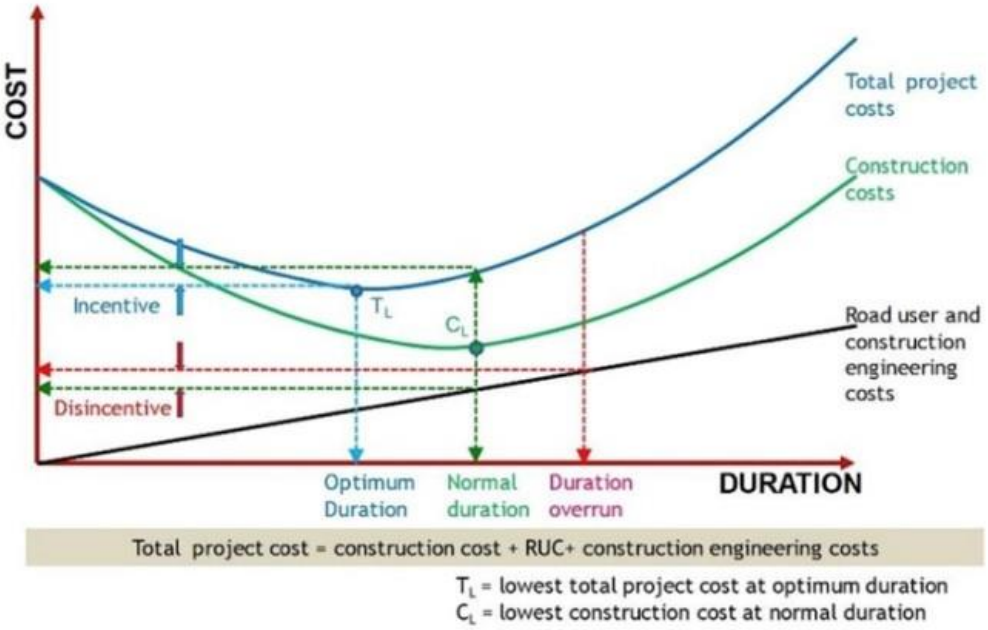

Figure 2 - Trade-Off Between Cost vs. Duration[14]

If the project is not managed correctly, the project overruns will impact the project team or Company. Referring to Mukuka, "the effect is time overrun, cost overrun, dispute and claim, arbitration, litigation, and total project abandonment"[15]. It also reveals that all those

[11] Kamaruddeen, A. M., Sung, C. F., & Wahi, W. (2020). A study on factors causing cost overrun of construction projects in Sarawak, Malaysia. *Civil Engineering and Architecture*, *8*(3), 191-199. Retrieved from: https://doi.org/10.13189/cea.2020.080301.
[12] Wisnugroho, J. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study.
[13] Mukuka, M., Aigbavboa, C., & Thwala, W. (2015). Understanding construction projects' schedule overruns in South Africa. *ICCREM 2015*. Retrieved from: https://doi.org/10.1061/9780784479377.068.
[14] Peterson, S. (2017). Incentivizing Early Completion of Major Oil and Gas Projects; PM World Journal, Vol. VI, Issue XI – November.
[15] Mukuka, M., Aigbavboa, C., & Thwala, W. (2015). Effects of construction projects schedule overruns: A case of the Gauteng province, South Africa.

things are identified as the effect of schedule overrun. Therefore, it shows that schedule overruns need to be fixed and implement better scheduling methods.

The author aims to investigate the most effective method for creating a reliable schedule in order to avoid project delays, minimize cost overrun and achieve Company management expectations which are OTOBOSOR (on time, on budget, on specification, on return), particularly in the planning phase of the project. The relationship between the level of influence, cumulative project costs, and project time is described in Figure 3. As the project progresses, costs increase while the ability to influence outcomes decreases. Hence, maximizing the planning process is essential to reduce the probability of schedule overruns. Therefore, looking for the best method in the scheduling process is necessary. The author will identify every best practice and compare it with one another to find the best one.

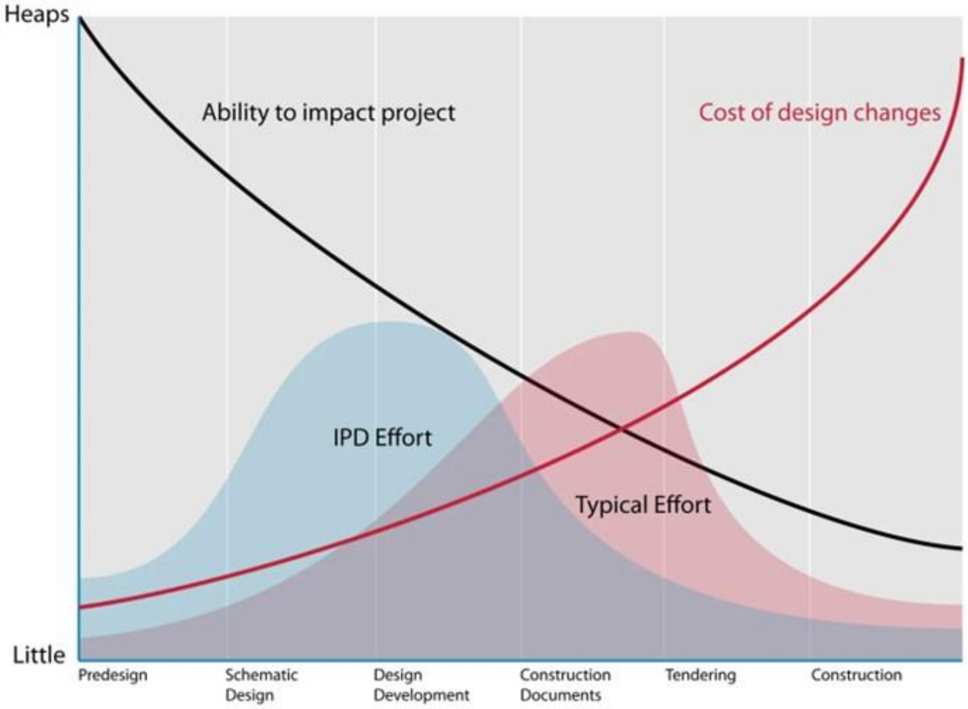

Figure 3 - MacLeamy Curve: Level of Influence and Project Costs on Project Phase[16]

The Best-Tested and Proven Practice must be followed if it produces good results. It will help to develop and maintain a reliable, high-quality schedule. So, the Best-Tested and Proven Practices will also be compared to the Company's scheduling process. It will highlight the gaps that must be filled and improve the Company's scheduling process. The comparison will be using Multi-Attributes Decision Making (MADM) compensatory model

[16] Davis, D. (2011, October 15). The MacLeamy curve. Daniel Davis. Retrieved from: https://www.danieldavis.com/macleamy/

and weighting technique. Sullivan notes that "Single-dimensional, or compensatory, models help make a final choice among alternatives. The additive weighting technique allows superb performance in some attributes to compensate for poor performance in others"[17]. The GAO will be the basis where the checklist, qualitative assessment in Appendix II, or quantitative assessment in Appendix VI will be used in this analysis because it appears to be one of the most complete references for telling people how to create and maintain a reliable schedule, as shown in Figure 4.

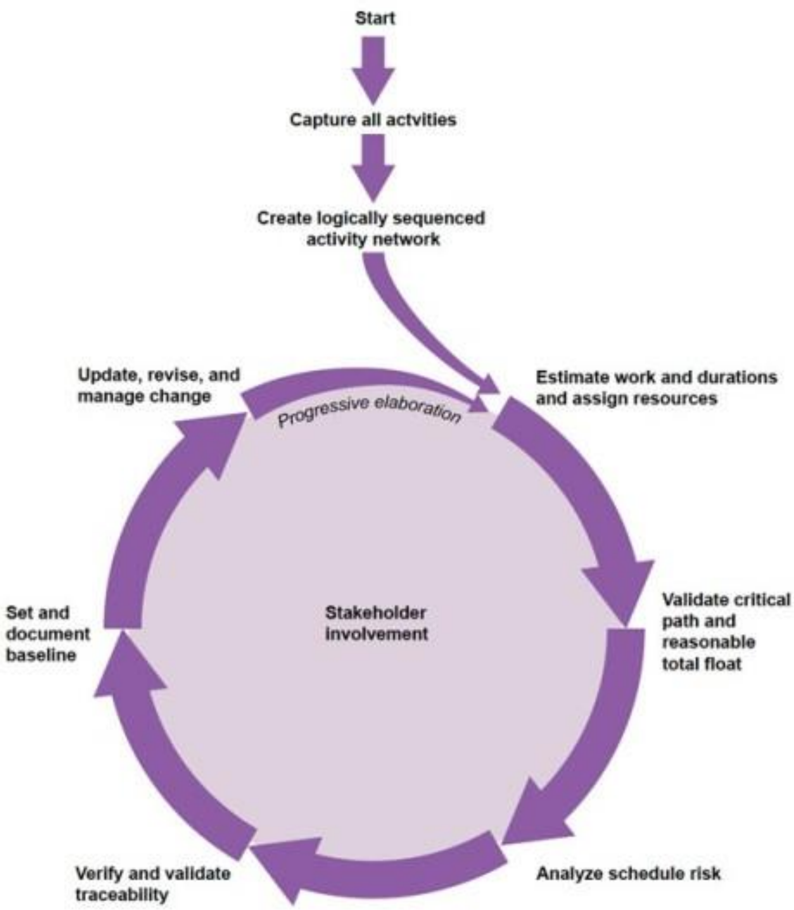

Figure 4 - GAO's Process for Creating and Maintaining Reliable Schedule[18]

The scheduling process is essential and cannot be separated from the cost-estimating process. "A cost estimate cannot be considered credible if it does not account for the cost effect of schedule slippage"[19]. Thus, creating a reliable, high-quality schedule is a must to

[17] Sullivan, W., Wicks, E., & Koelling, C. (2023). Engineering Economy (17th ed.). Pearson.
[18] U.S. Government Accountability Office. (2015). Schedule Assessment Guide: Best Practices for Project Schedules.
[19] Ibid

give the best results of the cost estimate. According to Wisnugroho[20] and Pratama[21], "GAO Cost Estimating & Assessment Guide and The NASA Cost Estimating Handbook are found to be the best practice for cost estimating." Furthermore, this paper will complement the previous research to obtain the best reference for scheduling and cost estimating.

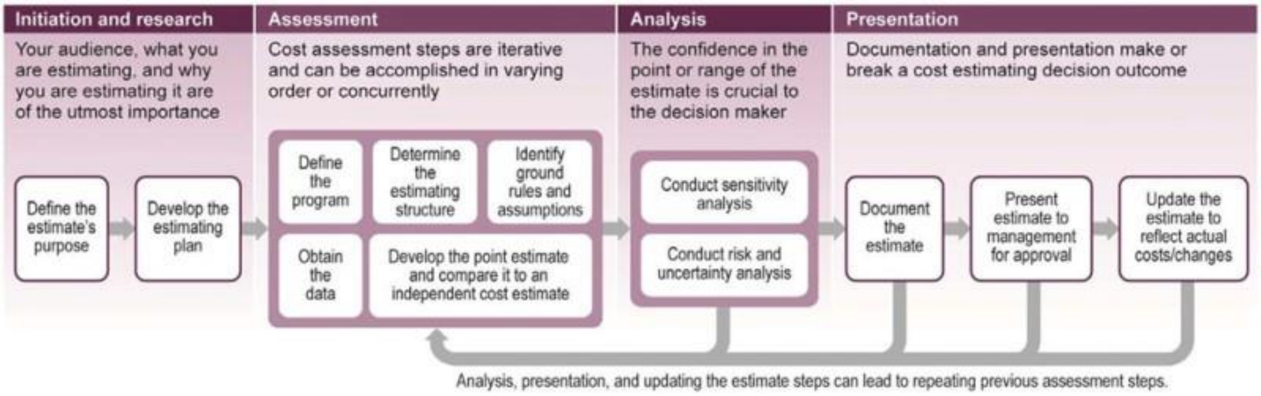

Figure 5 - GAO's Process for Cost Estimating Process[22]

In this paper, the author wants to seek the answer of the question below:

- How can we rate the scheduling process practice among other standards?
- What is the best scheduling process practice to be followed by the Company?
- What gaps must be filled and prioritized in the Company's scheduling process?
- What are the priorities for the Company to improve it?
- What are the recommended checklist and scoring models the Company must follow?
- Is there any effect between the gap in scheduling and cost-estimating processes from the previous research?

[20] Wisnugroho, J. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study.
[21] Pratama, F.N. (2020). Indonesia Aviation Fuel Facilities Project Cost Estimating Process vs the NASA Cost Estimating Process – a Process Benchmarking Study; *PM World Journal*, Vol. X, Issue I, January. https://pmworldlibrary.net/wp-content/uploads/2021/01/pmwj101-Jan2021-Pratama-Indonesia-aviation-fuel-facilities-project-cost-estimate.pdf
[22] U.S. Government Accountability Office. (2020, March). GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs.

METHODOLOGY

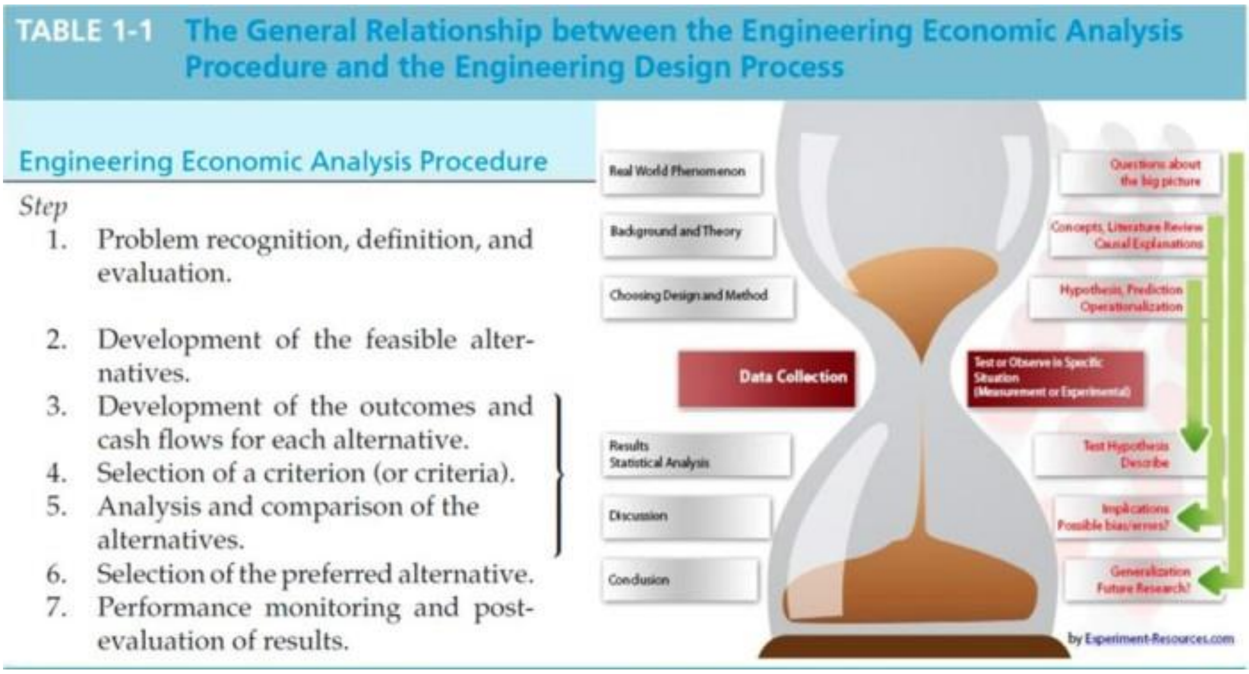

***Figure 6 - Engineering Economic Analysis Procedure & Step of the Scientific Process*[23]**

For this research to be carried out systematically, rationally, and reasonably, a methodology was chosen with the following details shown in Figure 6.

1. **Problem recognition, definition, and evaluation** means understanding the issue a project wants to solve. It identifies the current state, the desired future state, and any gaps between the two.
2. **Development of the Feasible Alternatives** is searching for potential alternatives and screening them to select a smaller group of feasible alternatives for detailed analysis.
3. **Development of the Outcomes and Cash Flows for each alternative** is developing every outcome using analytical tools.
4. **The selection of a Criterion (or Criteria)** describes what will be chosen as the standard for comparing the outcomes of each alternative.
5. **Analysis and Comparison of the Alternatives** is a thorough analysis and comparison of the feasible alternatives performed using the established criteria.
6. **Selection of the preferred alternative** is where a decision is made to choose the most suitable or preferred alternative that aligns with the project's goals and criteria.

[23] Wijoseno, T. (2023). Modifying The Lang Factor using Process Plant Project Data Cost in PERTAMINA for more Precision, Valid, & Reliable AACE Class 4 Estimation Purpose in Indonesia; *PM World Journal*, Vol. XII, Issue VI, June. https://pmworldlibrary.net/wp-content/uploads/2023/05/pmwj130-Jun2023-Wijoseno-modifying-the-lang-factor-for-better-cost-estimates.pdf

7. **Performance monitoring and post-evaluation results** are steps that will be carried out after implementation to determine the performance and understand the effectiveness of the selected alternative.

Step 1 – Problem Definition

The Company has a goal in project management, which is OTOBOSOR, but the current condition is still far from expectations, specifically **on time** and **on budget**. Out of 48 projects in the Company, only 21% did not experience project overrun, 73% experienced up to 25% project overrun, and 6% experienced above 25% project overrun. If those data are further processed and separated into schedule and cost overruns, only 23% on time and 75% experienced schedule overruns of more than 125%. Whereas in the cost overrun, there are 63% on budget and only 6% experienced cost overruns of more than 125%. So from Figure 7, the Company experienced more schedule overrun than cost overrun.

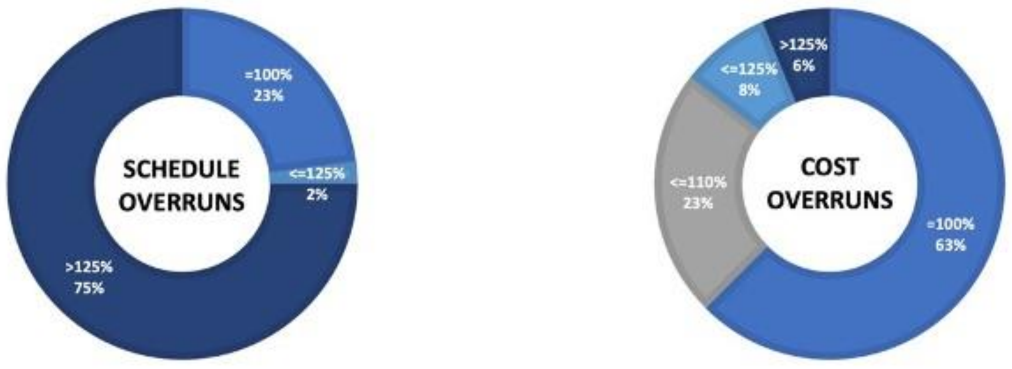

Figure 7 - The Company Schedule and Cost Overrun[24]

In addition, if it is depicted on the Bullseye Chart from the distribution of Schedule Performance Index (SPI) and Cost Performance Index (CPI) values in Figure 8, it can be seen that almost all of them are outside the green circle, which is the ±5% of the Company's SPI and CPI targets. The distribution of the Company's weighted average project performance is at SPI 0.60 and CPI 0.90, which are in the **behind-schedule and over-budget** quadrants (8.1). So, it can be concluded project performance has characteristic **low accuracy or low validity**.

If the standard deviation is calculated, three red circles will be produced. Theoretically, the third red circle represents 99.73% of the data from the normal distribution / bell-shaped curve, which is formed by the weighted average ± 3 δ. The red circle coincides with the green circle in the SPI +3 δ area (8.2). It means, so far, the **scheduling process has**

[24] By Author

been underestimated. Then it has been identified that only 8% of the projects are within the ±1 δ, around 60% within the ±2 δ, and 92% within the ±3 δ so it can be concluded that this data has **moderate precision or moderate reliability** characteristics (8.3).

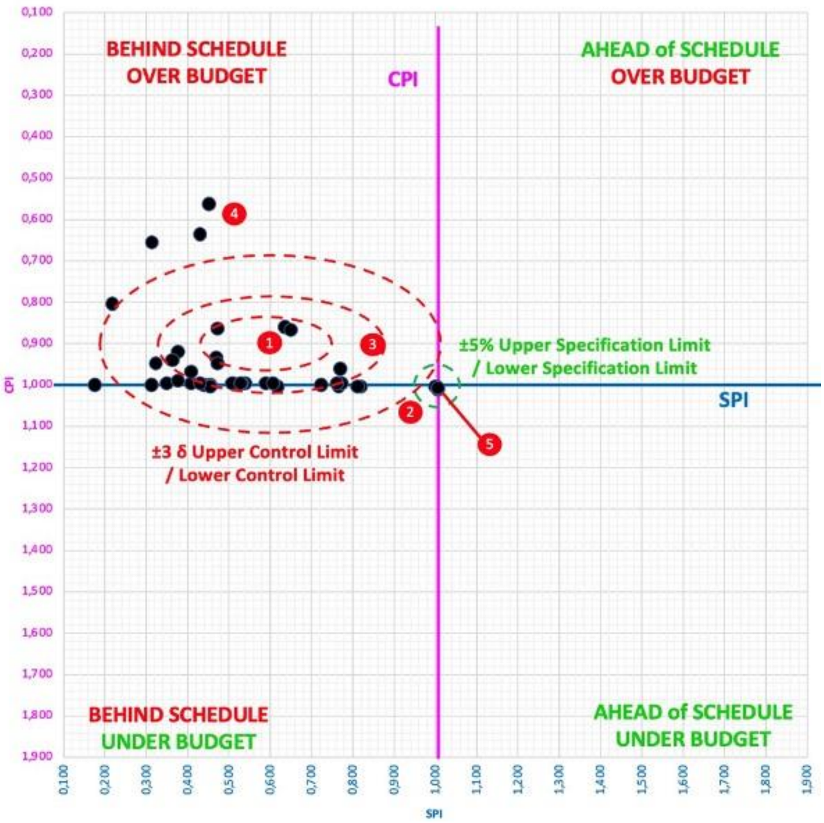

Figure 8 - The Company Bullseye Chart[25]

There are eight outliers where it is outside the red circle (8.4). This means that there is a project performance that does not match the existing distribution patterns. For this case, the outlier should be removed so the Company can decide what adjustments to return the SPI and CPI values to the target.

All those data describe that there has been a **systematic error** in the scheduling process because it continues to produce almost the same results (**moderate precision**) but does not reach the desired target (**low accuracy**). Even the data in the green circle is considered an outlier (8.5). Many things can cause this, but the author wants to mitigate it by improving schedule processing at the planning stage due to high impacts and low costs[26]. The Company needs to improve schedule planning from this research's findings.

[25] By Author
[26] Davis, D. (2011, October 15). The MacLeamy curve. Daniel Davis. Retrieved from: https://www.danieldavis.com/macleamy/

Step 2 – Development of Alternatives

The best practices related scheduling process has been identified and selected to be assessed further against Company standard, namely:

- Schedule Assessment Guide from GAO

  Schedule Assessment Guidelines were developed by GAO for the effective use of public funds by implementing effective management practices and processes, including measuring the performance of government programs. This guide is a companion to the cost guide and is expected to be used together[27].

  "The GAO Schedule Assessment Guide develops the scheduling concepts introduced in the Cost Estimating and Assessment Guide and presents them as ten best practices associated with developing and maintaining a reliable, high-quality schedule"[28].

  GAO is complete as a guide because it has a checklist for implementing each activity, key questions to assist the auditor in evaluating projects, and measurement standards for quantitative benchmarks. Due to the many options available and their ease of use, GAO's ten best practices checklist was chosen as the basis for analysis in this study to develop a good schedule.

- Schedule Management Handbook from NASA.

  There are four handbooks related to project management that NASA has developed; one of them is Schedule Management. This handbook provides the basis of practice for Schedule Management across the Agency. Schedule Management Handbook aims to provide the framework for coordinating, communicating, time phasing, and resource planning the necessary tasks within a work effort to manage and optimize the available resources and deliver products on time and within budget.

  NASA has divided the book into five main sub-functions: scheduling management planning, schedule development, schedule assessment & analysis, schedule maintenance and control, and schedule documentation & communication. Every sub-function has best practices that can be followed.

[27] U.S. Government Accountability Office. (2020). Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs.
[28] U.S. Government Accountability Office. (2015). Schedule Assessment Guide: Best Practices for Project Schedules.

Similar to the Schedule Management Handbook, NASA also has a separate Cost Estimating Handbook. This handbook is designed to help readers understand how to estimate costs based on the experiences and practices of the spacecraft industry. Cost estimation is a critical aspect of project management to ensure that resources are allocated appropriately, and budget constraints are met.

- Total Cost Management from AACE.

  "Total cost management (TCM) effectively applies professional and technical expertise to plan and control resources, costs, profitability, and risk. The TCM Framework is a structured, annotated process map that explains each practice area of the cost engineering field in the context of its relationship to the other practice areas, including allied professions"[29].

  There are three process management principles in TFM: Total Cost Management Process, Strategic Asset Management Process, and Project Control Process. The scheduling process is in the project control process.

- Project Management Body of Knowledge (PMBOK) from PMI.

  The Project Management Institute (PMI) publishes the PMBOK guide and is the premier reference for internationally recognized project management practices. This guide provides the framework, processes, and knowledge to manage projects effectively. PMBOK covers a wide range of processes and knowledge related to project management, including scope, time, cost, risk, quality, human resources, communications, procurement, and stakeholder management[30].

  This guide is comprehensive in scope, so each explanation is general and does not explain the specifics of scheduling processing. However, a little explanation can be found in the planning performance domain.

- Project Controls/PMO Handbook of "Best Tested and PROVEN Practices" from PTMC Team and Dr. Paul D. Giammalvo

[29] Stephenson, H. (2015). AACE international total cost management framework: An integrated approach to portfolio, program, and project management.
[30] Project Management Institute Project Management Institute**.** (2021). A guide to the project management body of knowledge (PMBOK® guide) – and the standard for project management (7th ed.). Project Management Institute.

"This book is designed to be a How-To-Do-It or Cookbook of best tested and proven recipes derived or based on 90+ years of experience and solid research"[31]. This book is handy as it provides detailed explanations for each step of some well-known guides that are commonly referred to.

"The Aims or Role of the Planner or Scheduler: creating, managing, and utilizing one of the project's most valuable tools, the Project Schedule (frequently referred to as the program). In addition, the purpose of the Managing Planning and Scheduling is to introduce the tools, techniques, and methodologies deemed appropriate to take the Scope of Work defined through progressive elaboration, producing a Level 3 (minimum) or, preferably, a Level 4 WBS and merge it with the resources. This integrated process combines the outputs of Managing Risk & Opportunity, Managing Resources, Managing Planning, Scheduling, and Managing Cost Estimating and Budgeting to produce what is known as the Performance Measurement Baseline (PMB), which is the classic S Curve"[32].

Adapted to GAO, PMO also develops nine best practices checklist to guide the scheduling process, namely Capture Schedule Activities, Create The Logical Relationship & Sequence Activities, Assigning Resources To All Activities, Calculate The Duration Of Each Activity, Validate Horizontal And Vertical Integration, Calculating Float And The Critical Path, The Critical Path & Completion Dates, Conducting A Schedule Risk Analysis, and Baselining And Communicating The Schedule.

- Company Standard

  The Company has an internal project management guideline that explains in general terms the needs and requirements for creating a master schedule for each project. For analysis purposes, this guideline will be complemented with usual practices that are carried out in the planning phase.

Step 3 – Development of Prospective Outcomes

All the guidelines mentioned in Step 2 will be benchmarked with GAO's ten best practices checklist. Every checklist will be evaluated using non-dimensional scaling with a score from 0 to 1 (0 = Dissatisfied; 1 = Satisfied) based on compliance with GAO.

[31] Giammalvo, P. D., & PTMC. (2021). Unit 9 – Managing Planning and Scheduling. Retrieved from https://build-project-management-competency.com/1-4-1-9-unit-9/
[32] Giammalvo, P. D., & PTMC. (2021). Unit 9 – Managing Planning and Scheduling. Retrieved from https://build-project-management-competency.com/1-4-1-9-unit-9/

MADM, which has two models, Non-compensatory and Compensatory, will be used to assess their non-monetary value. Multidimensional, or non-compensatory, models are most useful for the initial screening of alternatives. Sometimes, they can be used to make a final selection, but this usually involves high subjectivity. For non-compensatory model has four methods: Dominance, Satisficing, Disjunctive Reasoning, and Lexicography. Among those methods, dominance is the least selective, while satisficing is the most selective[33].

Meanwhile, Single-dimensional or compensatory models help make a final choice among alternatives. This model has two methods, Non-dimensional scaling, and Additive Weighting Technique. The additive weighting technique allows superb performance in some attributes to compensate for poor performance in others. For this research, a combination of non-compensatory and compensatory will be used. Initially, satisficing will eliminate some alternatives, and Additive Weighting Technique will be conducted for final decision-making.

Table 1 - Summary Scoring Alternatives Based on GAO's Checklist[34]

ASSOCIATED TASK	TOTAL TASK	GAO	AACE	NASA	PMO	PMBOK	COMPANY
Best Practice 1 : Capturing All Activities (Checklist)	10	10	3	6	10	1	3
Best Practice 2 : Sequencing All Activities (Checklist)	14	14	1	8	14	1	1
Best Practice 3 : Assigning Resources to All Activities (Checklist)	17	17	4	1	16	1	0
Best Practice 4 : Establishing Duration For All Activities (Checklist)	12	12	4	3	12	1	3
Best Practice 5 : Verifying That The Schedule Is Treaceable Horizontally and Vertically (Checklist)	9	9	1	7	9	0	0
Best Practice 6 : Confirming that the critical path is valid (Checklist)	12	12	0	12	12	1	0
Best Practice 7 : Ensuring Reasonable Total Float (Checklist)	9	9	0	7	9	0	0
Best Practice 8 : Conducting a Schedule Risk Analysis (Checklist)	17	17	7	15	17	3	0
Best Practice 9 : Updating The Schedule Using Logic and Progress (Checklist)	20	20	8	10	20	0	0
Best Practice 10 : Maintaining a Baseline Schedule (Checklist)	28	28	12	13	28	6	0
Total Score	148	148	40	82	147	14	7
Total Percentage		100%	27%	55%	99%	9%	5%

Step 4 – The selection of Decision Criterion

The selection criterion of satisficing is that at least one task out limit must be rejected where the limit is 1 (satisfied). Non-dimensional scaling and Additive Weighting Techniques will be selected with the highest alternatives score. The additive weighting technique will use an ordinal ranking of GAO's Best practices, as shown below in Table 2. It is developed based on the sequence of essential activities that need to be done from the beginning to the end. The higher the ranking value, the more influential the activity is.

[33] Sullivan, W., Wicks, E., & Koelling, C. (2023). Engineering Economy (17th ed.). Pearson.
[34] By Author

Table 2 - Ordinal Ranking on GAO's Checklist[35]

ASSOCIATED TASK	ORDINAL RANGKING
Best Practice 1 : Capturing All Activities (Checklist)	9
Best Practice 2 : Sequencing All Activities (Checklist)	8
Best Practice 3 : Assigning Resources to All Activities (Checklist)	3
Best Practice 4 : Establishing Duration For All Activities (Checklist)	7
Best Practice 5 : Verifying That The Schedule Is Treaceable Horizontally and Vertically (Checklist)	6
Best Practice 6 : Confirming that the critical path is valid (Checklist)	5
Best Practice 7 : Ensuring Reasonable Total Float (Checklist)	2
Best Practice 8 : Conducting a Schedule Risk Analysis (Checklist)	4
Best Practice 9 : Updating The Schedule Using Logic and Progress (Checklist)	0
Best Practice 10 : Maintaining a Baseline Schedule (Checklist)	1

FINDINGS

Step 5 – Analysis and Comparison Alternatives

Based on the results of the non-compensatory model with satisficing, as shown in Table 3, it is clear that only GAO can pass all the limits, while the other alternatives cannot meet the criteria and are eliminated.

Furthermore, the additive weighting technique is conducted, and the result is shown in Table 4. From this model, it can be found that the ranking of every alternative where cannot be obtained from satisficing.

For further analysis, PMO produces near-perfect performance values, which is only lacking in Best Practice 3: Assigning Resources to All Activities. Although the score cannot meet all of GAO's criteria, the PMO explanation can complement the GAO content. So GAO can be considered a tool that conveys individual procedures for carrying out the scheduling process. At the same time, PMO becomes an implementation procedure that discusses how to do it more concretely, supplemented by lessons learned that have been collected.

From NASA's performance, it can be concluded that NASA can fulfill 55 percent of GAO's checklist. NASA Schedule Management Handbook is similar to GAO Schedule Assessment Guide, which includes a checklist but with a different framework. Moreover, NASA can also be used as the basis for the analysis, so it is possible to produce different

[35] By Author

benchmarking results as what Wisnugroho[36] did on GAO vs. Company and Pratama[37] on NASA vs Company.

Table 3 - Noncompensatory Model - Satisficing[38]

ASSOCIATED TASK	Minimum Acceptable Value	GAO	AACE	NASA	PMO	PMBOK	COMPANY
Best Practice 1 : Capturing All Activities (Checklist)	10	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 2 : Sequencing All Activities (Checklist)	14	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 3 : Assigning Resources to All Activities (Checklist)	17	Acceptable	Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable	Not Acceptable
Best Practice 4 : Establishing Duration For All Activities (Checklist)	12	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 5 : Verifying That The Schedule Is Treaceable Horizontally and Vertically (Checklist)	9	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 6 : Confirming that the critical path is valid (Checklist)	12	Acceptable	Not Acceptable	Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 7 : Ensuring Reasonable Total Float (Checklist)	9	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 8 : Conducting a Schedule Risk Analysis (Checklist)	17	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 9 : Updating The Schedule Using Logic and Progress (Checklist)	20	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Best Practice 10 : Maintaining a Baseline Schedule (Checklist)	28	Acceptable	Not Acceptable	Not Acceptable	Acceptable	Not Acceptable	Not Acceptable
Result		Pass	Eliminated	Eliminated	Eliminated	Eliminated	Eliminated

Table 4 - Compensatory Model – Additive Weighting Technique of Scheduling Process[39]

Best Practice	Relative Rank	Normalized Weight	GAO		AACE		NASA		PMO		PMBOK		COMPANY	
			Performance	Weight Value	Performance	Weight Value	Performance	Weight Value	Performance	Weight Value	Performance	Weight Value	Performance	Weight Value
BP #1	9	0,20	10	2,00	3	0,60	6	1,20	10	2,00	1	0,20	3	0,60
BP #2	8	0,18	14	2,49	1	0,18	8	1,42	14	2,49	1	0,18	1	0,18
BP #3	3	0,07	17	1,13	4	0,27	1	0,07	16	1,07	1	0,07	0	0,00
BP #4	7	0,16	12	1,87	4	0,62	3	0,47	12	1,87	1	0,16	3	0,47
BP #5	6	0,13	9	1,20	1	0,13	7	0,93	9	1,20	0	0,00	0	0,00
BP #6	5	0,11	12	1,33	0	0,00	12	1,33	12	1,33	1	0,11	0	0,00
BP #7	2	0,04	9	0,40	0	0,00	7	0,31	9	0,40	0	0,00	0	0,00
BP #8	4	0,09	17	1,51	7	0,62	15	1,33	17	1,51	3	0,27	0	0,00
BP #9	0	0,00	20	0,00	8	0,00	10	0,00	20	0,00	0	0,00	0	0,00
BP #10	1	0,02	28	0,62	12	0,27	13	0,29	28	0,62	6	0,13	0	0,00
Total Score	45	1	148	12,56	40	2,69	82	7,36	147	12,49	14	1,11	7	1,24

TCM from AACE and PMBOK from PMI are not suitable as a reference for improving Company guidelines. As shown in Table 3, there are too many gaps between GAO and

[36] Wisnugroho, J. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study.
[37] Pratama, F.N. (2020). Indonesia Aviation Fuel Facilities Project Cost Estimating Process vs the NASA Cost Estimating Process – a Process Benchmarking Study; *PM World Journal*, Vol. X, Issue I, January. https://pmworldlibrary.net/wp-content/uploads/2021/01/pmwj101-Jan2021-Pratama-Indonesia-aviation-fuel-facilities-project-cost-estimate.pdf
[38] Sullivan, W., Wicks, E., & Koelling, C. (2023). Engineering Economy (17th ed.). Pearson.
[39] Ibid

these alternatives. It is caused by the content of the alternatives being too general in the scheduling process. It is understandable because TCM and PMBOK are discussed from a high point of view, so there is no in-depth discussion of each matter.

The Company guideline is in the lowest second rank, even though in terms of performance value, the Company guideline is the lowest where this is due to the ordinal ranking. It can be concluded that the Company guideline still has many gaps in every aspect of GAO's Best Practice. These gaps need to be filled to improve the Company's scheduling process.

Step 6 – Selection of Preferred Alternative

Scheduling Process

From the two methods conducted, GAO is the best alternative for improving Company guidelines in the scheduling process, leaving PMO, NASA, AACE, and PMBOK behind. When developing new Company guidelines, PMO can be used as a second reference to complement GAO.

Cost Estimating Process

From two previous studies about benchmarking the cost estimating process in Indonesia, the following result is shown in Table 6. Wisnugroho had compared GAO as the basis with three other alternatives, while Pratama had compared NASA with four alternatives where GAO is in that study. So, those studies produce different results due to different approaches. To process those data, the author must complete Wisnugroho's data by comparing GAO to NASA using GAO as the basis.

The author evaluates NASA using the GAO's Cost Estimation and Assessment Checklist with a score range from 1 to 5 (1: very unsatisfactory; 2: unsatisfactory; 3: neutral; 4: satisfactory; 5: very satisfactory). This was conducted differently from the scheduling process because it adapts to the assessment format used by Wisnugroho[40], so it can eliminate bias regarding the rating scale.

Using the MADM compensatory model and the previous analysis results to obtain ordinal rankings, the two data above can be further processed to determine which alternative is the best in the cost estimation process.

From Table 7, GAO is still the best alternative and can be used by companies in developing the process of cost estimates, leaving NASA, GPCCar, AACE, and PMI behind.

[40] Wisnugroho, J. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study.

Table 5 - NASA Scoring Based on GAO's Cost Estimating Checklist[41]

Associated Task	NASA
The Estimate	35
Purpose, Scope, and Schedule	20
Cost Assessment Team	9
Technical Baseline Description	6
Work Breakdown Structure (WBS)	29
Ground Rules and Assumptions	16
Data	10
Developing a Point Estimate	20
Estimating Software Costs	20
Sensitivity Analysis	15
Cost Risk and Uncertainty	15
Validating the Estimates Against Four Characteristics	12
Documenting the Estimate	10
Presenting the Estimate to Management	15
Managing Program Cost: Planning	15
Managing Program Cost: Execution	9
Managing Program Costs: Updating	24
Total Score	280
Total Percentage	86,15%

Table 6 - Benchmarking Cost Estimating Process

SOURCES	NASA	GAO	GPCCaR	AACE	PMI
Pratama, F.	100,00%	90,57%	84,91%	72,33%	65,60%
Wisnugroho, J.		100,00%	90,15%	75,38%	56,31%
Author	86,15%				

Table 7 - Compensatory Model – Additive Weighting Technique of Cost Estimating Process[42]

Sources	Relative Rank	Normalized Weight	GAO		NASA		GPCCar		AACE		PMI	
			Performance	Weight Value	Performance	Weight Value	Performance	Weight Value	Performance	Weight Value	Performance	Weight Value
Wisnugroho, J.	2	0,67	1,00	0,67	0,86	0,57	0,90	0,60	0,75	0,50	0,56	0,38
Pratama, F.	1	0,33	0,91	0,30	1,00	0,33	0,85	0,28	0,72	0,24	0,66	0,22
Total Score	3	1	1,906	0,969	1,862	0,908	1,751	0,884	1,477	0,744	1,219	0,594

[41] By Author
[42] By Author

Step 7 – Performance Monitoring and Postevaluation of Results

GAO was chosen as the best alternative from the results of this study in the process of scheduling and cost estimation. Both of these standards have the same source, so they have the advantage of being able to eliminate bias if different sources are used.

To obtain well-directed Company improvement steps, the author uses the Pareto Principle - 80/20 rule[43] to select the most effective step that must be improved in the scheduling and cost-estimating process, as shown in Figures 9 and 10. These results can be reassessed using the checklist and scoring model that has been made until the target desired by the Company is obtained in the scheduling and cost-estimating process.

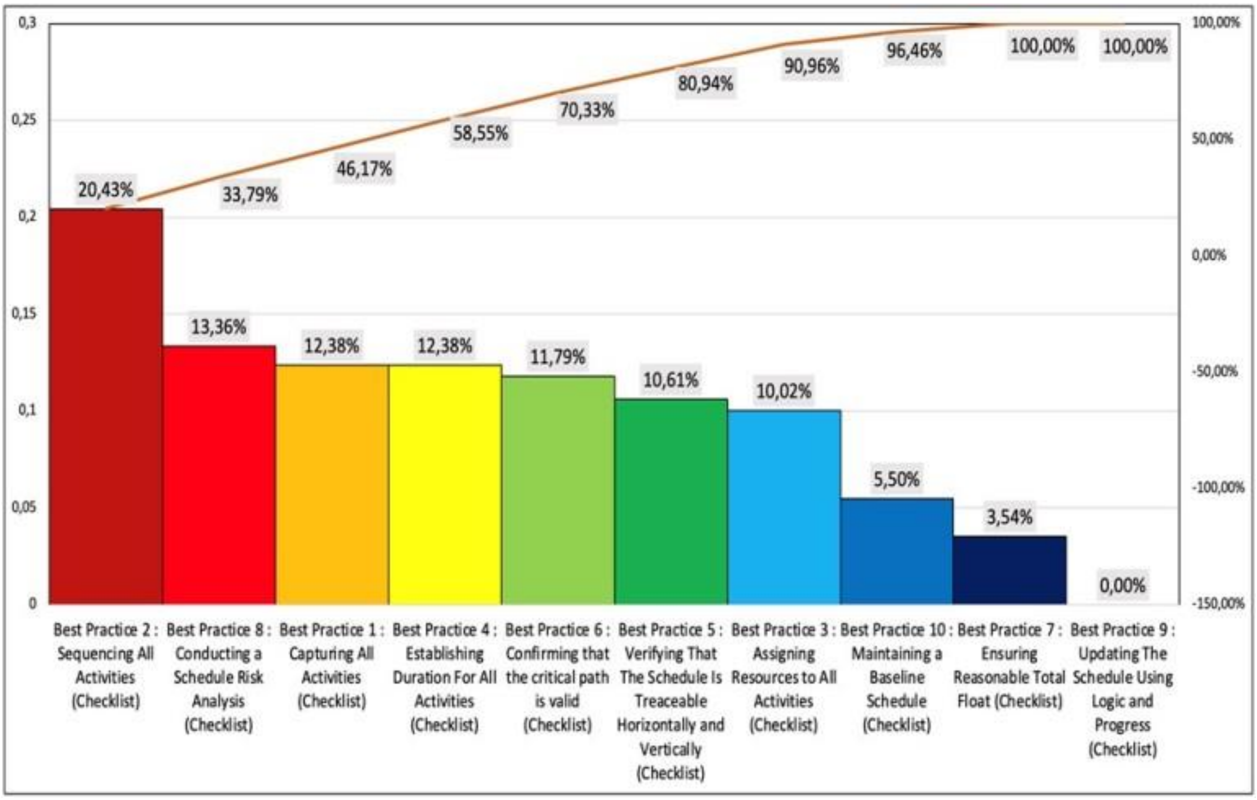

Figure 9. Company Scheduling Process Deviation Compared to GAO[44]

[43] Asana. (2022, December 8). Memahami Prinsip Pareto (Aturan 80/20) [2022] • Asana. Retrieved from https://asana.com/id/resources/pareto-principle-80-20-rule
[44] By Author

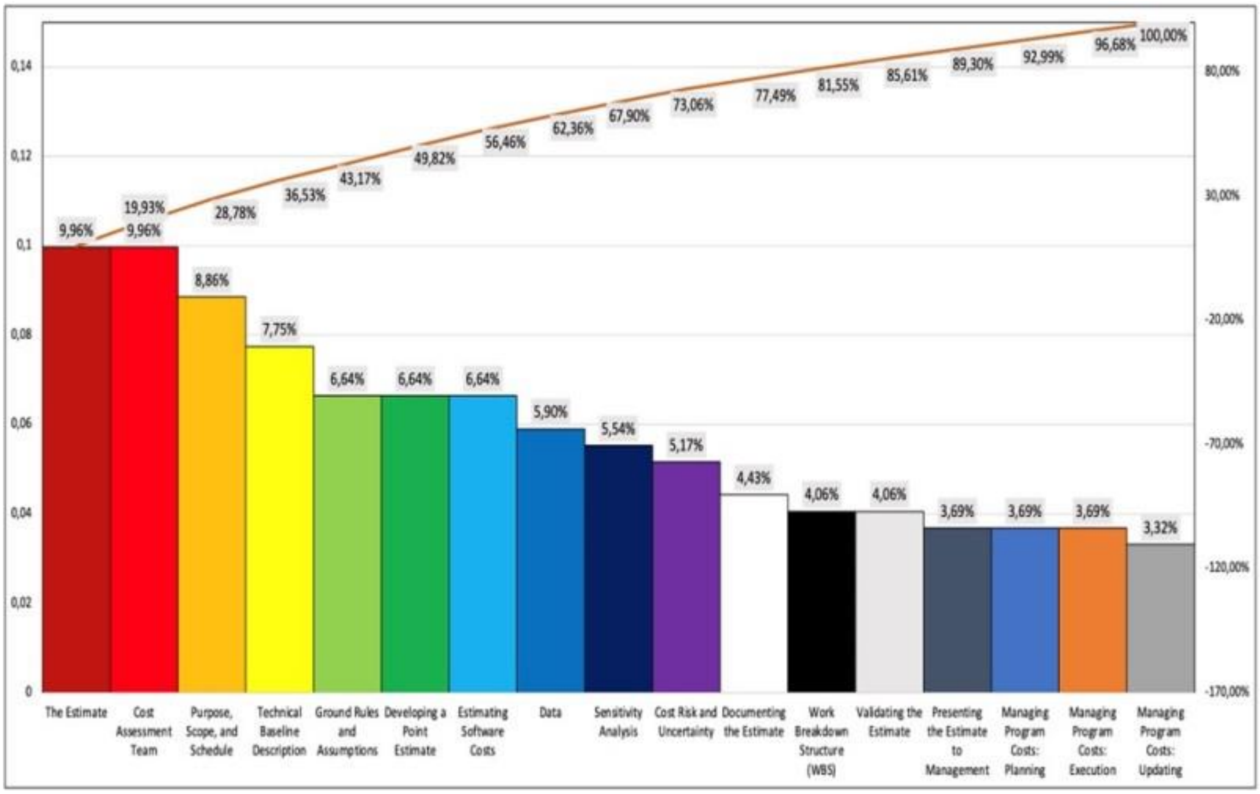

Figure 10. Company Cost Estimating Process Deviation Compared to GAO[45]

CONCLUSION

The objective of this research is to answer all the questions below,

- How can we rate the best scheduling process practice among other standards?

  For the scheduling process using GAO, there are three ways to assess the schedule: Best Practice Checklist, Appendix II, and Appendix VI. The author chooses the Best Practices Checklist as an assessment tool because it has the essentials to make a good schedule. While Appendix II is used as an auditor's tool, and Appendix VI is used to assess quantitatively the schedule health. The assessment can be carried out based on compliance with the GAO's Checklist and further analysis using MADM.

[45] Wisnugroho, J. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study.

- What is the best scheduling process practice to be followed by the Company?

  The analysis results show that GAO is the "Best-Tested and Proven" practice compared to other best practices for scheduling and cost-estimating processes, as shown in Tables 4 and 7.

- What gaps need to be filled in the Company's scheduling process?

  Figures 9 and 10 show the gaps that need to be filled. It has been sorted from those with the largest gaps so that the Company can set priorities for developing internal rules. According to the Pareto principle, to minimize work, the Company can focus on the top 20% of problems.

- What are the priorities for the Company to improve it?

  The Company can prioritize "Best Practice 2: Sequencing All Activities" in the scheduling process and "The Estimate - Cost Assessment Team - Purpose, Scope, and Schedule" in the cost estimating process to improve the Company's internal guidelines because it has fulfilled the most significant 20% of the problems.

- What are the recommended checklist and scoring models the Company must follow?

  The Company can follow the checklist and scoring model the author developed and the previous study described in this paper for the scheduling and cost-estimating process.

- Is there any effect between the gap in scheduling and cost-estimating processes from previous research?

  Yes, there is a difference of about 95% in the scheduling process between the GAO and the Company, which leads to a decrease in the quality of cost estimates. It can be seen that "Purpose, Scope, and Schedule" are among the most significant things in the gap between best practice and internal rules. "Sequencing All Activities" also plays a vital role in the unclear scope of cost estimation, so it tends to produce underestimated results.

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APPENDICES

APPENDIX 1 - RATING AND SCORING MODEL OF STANDARD COMPLY WITH GAO'S SCHEDULING CHECKLIST

Best Practice 1 : Capturing All Activities (Checklist)		GAO	AACE	NASA	PMO	PMBOK	COMPANY
Key Question							
1	A WBS is the cornerstone of the program schedule. Its elements are linked to one another with logical relationships and lead to the end product or final delivery. The schedule clearly reflects the WBS and defines the activities necessary to produce and deliver each product.	1	1	1	1	0	1
2	The schedule reflects all effort (steps, events, work required, and outcomes) to accomplish the deliverables described in the program's work breakdown structure.	1	1	1	1	0	1
3	The IMS includes planning for all activities that have to be accomplished for the en-tire duration of the program, including all blocks, increments, phases, and the like.	1	1	1	1	1	1
4	The IMS includes the summary and intermediate and all detailed schedules. The same schedule serves as the summary, intermediate, and detailed schedule by simply rolling up lower levels of effort into summary activities or higher-level WBS elements.	1	0	1	1	0	0
5	The government-owned detailed schedule includes all activities the government, its contractors, and others must perform to complete the work, including receipt of government-furnished equipment or information, deliverables, or services from other programs.	1	0	1	1	0	0
6	The schedule contains primarily detail activities, and milestones are not used to represent work.	1	0	1	1	0	0
7	If the government program management office and its contractor use different scheduling software packages, a process is defined to preserve integrity between the different schedule formats, and the converted data are verified and validated when the schedules are updated.	1	0	0	1	0	0
8	Level-of-effort (LOE) activities represent effort that has no measurable output and cannot be	1	0	0	1	0	0

	associated with a physical product or defined deliverable.						
9	Activity names contain noun-verb combinations, are descriptive, and are clear enough to identify their associated product without the need to review high-level summary or predecessor activity names.	1	0	0	1	0	0
10	Activities within the schedule are easily traced to key documents and other information through activity or task codes.	1	0	0	1	0	0
	Best Practice 2 : Sequencing All Activities (Checklist)	**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
	Key Question						
1	The schedule contains complete network logic between all activities so that it can correctly forecast the start and end dates of activities within the plan.	1	1	1	1	1	1
2	The majority of relationships within the detailed schedule are finish-to-start.	1	0	0	1	0	0
3	Except for the start and finish milestones, every activity within the schedule has at least one predecessor and at least one successor.	1	0	1	1	0	0
4	Any activity that is missing predecessor or successor logic—besides the start and finish milestones—is clearly justified in the schedule documentation.	1	0	1	1	0	0
5	The schedule contains no dangling logic. That is,						
5. a	Each activity (except the start milestone) has an F–S or S–S predecessor that drives its start date.	1	0	1	1	0	0
5. b	Each activity (except the finish milestone and deliverables that leave the program without subsequent effect on the program) has an F–S or F–F successor that it drives.	1	0	1	1	0	0
6	The schedule does not contain start-to-finish logic relationships.	1	0	0	1	0	0
7	Summary activities do not have logic relationships because the logic is specified for activities that are at the lowest level of detail in the schedule.	1	0	0	1	0	0

8	Instead of SNET constraints, conditions of supply by an outside vendor or contractor are represented as actual activities in the schedule.	1	0	0	1	0	0
9	Date constraints are thoroughly justified in the schedule documentation. Unavoidable hard constraints are used judiciously and are fully justified in reference to some controlling event outside the schedule.	1	0	1	1	0	0
10	Lags are used in the schedule only to denote the passage of time between two activities.	1	0	1	1	0	0
11	Every effort is made not to use lags and leads but to break activities into smaller tasks to identify realistic predecessors and successors so that logic interfaces are clearly available for needed dependency assignments.	1	0	0	1	0	0
12	Lags and leads in a schedule are used judiciously and are justified by compelling reasons outside the schedule in its documentation.	1	0	1	1	0	0
13	The schedule is assessed for path convergence. That is, activities with many predecessors have been examined to see whether they are needed and whether alternative logic can be used to link some predecessors to other activities.	1	0	0	1	0	0

Best Practice 3 : Assigning Resources to All Activities (Checklist)		GAO	AACE	NASA	PMO	PMBOK	COMPANY
Key Question							
1	The amount of available resources, whether labor or nonlabor, affects estimates of work and duration, as well as the availability of resources for subsequent activities.	1	1	0	1	1	0
2	The schedule should realistically reflect the resources that are needed to do the work and—compared to total available resources—should determine whether all required resources will be available when they are needed.	1	0	0	1	0	0
3	Resources are either labor or nonlabor, where labor is tracked in hours or FTEs and nonlabor can refer to subcontracts, consumable material, machines, and other purchased equipment. Resources are identified as fixed or variable.	1	0	0	1	0	0

4	Significant material and equipment resources are captured within the schedule along with other equipment resources that facilitate the project.	1	0	0	1	0	0
5	Budgets for direct labor, travel, facilities, equipment, material, and the like are assigned to both work and planning packages so that total costs to complete the program are identified at the outset.	1	0	0	1	0	0
6	Summary activities and milestones are not assigned resources.	1	0	0	0	0	0
7	If EVM is used to monitor the program, the fully loaded schedule, including materials, equipment, direct labor, travel, and LOE activities, is the basis for the PMB.	1	0	0	1	0	0
8	Activity owners are able to explain the logic behind their resource estimates.	1	0	0	1	0	0
9	The same assumptions that formed resource estimates for the cost estimate are applied to the estimated resources loaded into the schedule and are documented in the BOE. Underlying resource assumptions for the entire estimated scope of work are documented in the schedule basis document in appropriate detail.	1	0	0	1	0	0
10	Resource information is stored in the schedule in the form of assignments. If resource management is performed outside the schedule, a documented process feeds resource assignments back into the schedule so that it reflects the resolution of resource issues conducted separately.	1	0	1	1	0	0
11	Once the schedule is resource loaded, all resources in the schedule are crosschecked with the program budget and contractual cost constraints.	1	1	0	1	0	0
12	Resource peaks are examined for the feasibility of the available budget, the availability of resources, and the timeliness of the peaks. If the cumulative overlay of resources against major milestones shows resource peaks just beyond major milestone points, resources may have to be reallocated.	1	0	0	1	0	0
13	Resources have been leveled—that is, the scheduled time of activities or the assignment of resources has been adjusted to account for the availability of resources.	1	1	0	1	0	0

14	In general, activities that are delayed through resource leveling have the greatest free float available and the fewest resources assigned.	1	0	0	1	0	0
15	If critical resources delay the entire project, changes to resolve the resource conflicts are thoroughly documented in the schedule narrative and understood by all.	1	0	0	1	0	0
16	Planners and managers carefully examine and temper or adjust where necessary.	1	0	0	1	0	0
17	Resources are leveled only on detail schedules that include detailed resource estimates supported by historical data and sound estimating methodologies.	1	1	0	1	0	0
Best Practice 4 : Establishing Duration For All Activities (Checklist)		**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
Key Question							
1	Activity durations are directly related to the assigned resources and estimated work required.	1	1	1	1	1	0
2	In general, estimated detailed activity durations are shorter than the reporting period management requires.	1	0	0	1	0	0
3	Durations are as short as possible, to a point, to facilitate the objective measurement of accomplished effort.	1	1	0	1	0	0
4	Long durations should be broken into shorter activities if logical breaks can be identified in the work being performed. If it is not practical to divide the work into smaller activities or insert intermediate milestones, justification for long durations is provided in the schedule basis document.	1	0	0	1	0	1
5	Very short durations, such as 1 day or less, may imply a schedule that is too detailed and require more-frequent updates to schedule duration and logic than is otherwise necessary.	1	0	0	1	0	0
6	LOE activities are clearly marked in the schedule and derive their durations from other discrete activities.	1	0	1	1	0	0
7	All activity durations within the schedule are defined by the same time unit (hours, days, weeks). Days are preferred.	1	0	0	1	0	1

8	Planning packages representing summarized or less-defined future work should be integrated into network logic.	1	0	0	1	0	0
9	Activity durations are estimated under most likely conditions, not optimal or "success-oriented" conditions. "Most likely" for estimated durations implies that duration estimates do not contain padding or margin for risk. They should also not be unrealistically short or arbitrarily reduced by management to meet a program challenge.	1	0	0	1	0	0
10	All assumptions related to activity duration estimates are documented in appropriate detail, such as describing the methodology used to create the estimate (for example, parametric analysis of historical data or opinion of a subject matter expert) and all specifying supporting historical or analogous data.	1	1	0	1	0	0
11	Activity duration estimates for a WBS element in a schedule should clearly map to and correspond with the basis of the cost estimate for the same WBS element.	1	1	1	1	0	0
12	Calendars are used to specify valid working times for activities and, when feasible, resources.	1	0	0	1	0	1
Best Practice 5 : Verifying That The Schedule Is Treaceable Horizontally and Vertically (Checklist)		**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
Key Question							
1	The schedule is horizontally traceable. That is, the schedule						
1. a	depicts logical relationships between different program elements and product hand-offs and clearly shows when major deliverables and hand-offs are expected;	1	0	1	1	0	0
1. b	includes complete logic from program start to program finish and fully integrates the entire scope of work from all involved in the program;	1	0	0	1	0	0
1. c	includes milestones representing key decisions or deliverables with traced and validated predecessor activities to ensure that they are directly related to completing the milestone;	1	0	1	1	0	0
1. d	clearly identifies and logically links giver/receiver milestones between schedules that are defined in the schedule basis document;	1	0	1	1	0	0

1. e	dynamically reforecasts the date of a key milestone through network logic if activities related to accomplishing the milestone are delayed;	1	0	1	1	0	0
1. f	is affected by activities whose durations are extended by many days.	1	0	1	1	0	0
2	The schedule is vertically traceable. That is, it						
2. a	demonstrates that data are consistent between summary, intermediate, and detailed levels including dates that are frequently validated through a process;	1	1	1	1	0	0
2. b	allows activity owners to trace activities to higher-level milestones with intermediate and summary schedules;	1	0	0	1	0	0
2. c	allows lower-level schedules to be rolled up into the overall program schedule, which includes government activities, other contractor schedules, and interfaces with external parties.	1	0	1	1	0	0

Best Practice 6 : Confirming that the critical path is valid (Checklist)		GAO	AACE	NASA	PMO	PMBOK	COMPANY
Key Question							
1	The schedule's critical path is valid. That is, the critical path or longest path (in the presence of constraints)						
1. a	does not include LOE activities, summary activities, or other unusually long activities, except for future planning packages;	1	0	1	1	0	0
1. b	is a continuous path from the status date to the finish milestone;	1	0	1	1	0	0
1. c	does not include constraints that cause unimportant activities to drive a milestone date;	1	0	1	1	0	0
1. d	has no lags or leads;	1	0	1	1	0	0
1. e	is derived in summary schedules by vertical integration of lower-level detailed schedules, not by preselected activities that management has presupposed are important.	1	0	1	1	0	0

2	If backward-pass date constraints are present on activities other than the finish milestone, both the critical path and the longest path have been identified. With a number of constraints, activities with zero or negative total float may outnumber activities that are actually driving the key program completion milestone.	1	0	1	1	0	0
3	The critical path, or longest path (in the presence of constraints), is used as a tool for managing the program. That is, management						
3. a	has vetted and justified the current critical path as calculated by the software;	1	0	1	1	0	0
3. b	uses the critical path to focus on activities that will be detrimental to the key program milestones and deliveries if they slip;	1	0	1	1	0	0
3. c	examines and mitigates risk in activities on the critical path that can potentially delay key program deliveries and milestones;	1	0	1	1	0	0
3. d	has reviewed and analyzed near-critical paths because these activities are likely to overtake the existing critical path and drive the schedule;	1	0	1	1	0	0
3. e	recognizes not only activities with the lowest float but also activities that are truly driving the finish date of key milestones;	1	0	1	1	0	0
3. f	evaluates the critical path before the schedule is baselined and after every status update to ensure that it is valid.	1	0	1	1	1	0
Best Practice 7 : Ensuring Reasonable Total Float (Checklist)		**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
Key Question							
1	The total float values calculated by the scheduling software are reasonable and accurately reflect a schedule's flexibility.	1	0	1	1	0	0
2	The program really has the amount of schedule flexibility indicated by the levels of float.	1	0	1	1	0	0
3	Remaining activities in the schedule are sorted by total float and assessed for reasonableness. Any activities that appear to have a great deal of float are examined for missing or incomplete logic.	1	0	1	1	0	0

4	Total float values that appear to be excessive are documented to show that the program management team has performed an assessment and agreed that the logic and float are consistent with the plan.	1	0	1	1	0	0
5	Total float is calculated to the main deliveries and milestones as well as to the program's completion.	1	0	1	1	0	0
6	Total and free float inform management as to which activities can be reassigned resources in order to mitigate slips in other activities.	1	0	1	1	0	0
7	Management balances the use of float with the fact that total float is shared along a path of activities.	1	0	1	1	0	0
8	Periodic reports routinely show the amount of float consumed in a period and remaining on the critical and near-critical paths.	1	0	0	1	0	0
9	Date constraints causing negative float have been justified. If delay is significant, plans to recover the implied schedule slip have been evaluated and implemented.	1	0	0	1	0	0
Best Practice 8 : Conducting a Schedule Risk Analysis (Checklist)		**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
Key Question							
1	A schedule risk analysis was conducted to determine						
1. a	the likelihood that the program completion date will occur,	1	0	1	1	1	0
1. b	how much schedule risk contingency is needed to provide the acceptable certainty of completion by a specific date	1	0	1	1	0	0
1. c	risks most likely to delay the project, and	1	0	1	1	1	0
1. d	the paths or activities that are most likely to delay the program.	1	0	1	1	1	0
2	The schedule was assessed against best practices before the simulation was conducted. The schedule network clearly identifies work to be done and the relationships between detailed activities and includes a minimum number of justified date constraints.	1	0	1	1	0	0

3	The SRA has optimistic, most likely, and pessimistic duration data fields.	1	0	1	1	0	0
4	The SRA accounts for correlation in the uncertainty of activity durations.	1	1	1	1	0	0
5	Risks are prioritized by probability and magnitude of effect.	1	1	1	1	0	0
6	The risk register was used in identifying the discrete risks potentially driving the schedule before the SRA was conducted.	1	1	1	1	0	0
7	The SRA data and methodology are available and documented.	1	0	1	1	0	0
8	The SRA identifies the activities in the simulation that most often ended up on the critical path, so that near-critical path activities can be closely monitored.	1	1	1	1	0	0
9	The risk inputs have been validated. The probabilities and impact ranges are reasonable and based on information gathered from knowledgeable sources, and there is no evidence of bias in the risk data.	1	0	1	1	0	0
10	The baseline schedule includes schedule contingency to account for the occurrence of risks. Schedule contingency is calculated by performing an SRA and comparing the schedule date with that of the simulation result at a preferred level of certainty.	1	1	1	1	0	0
11	Schedule contingency is held by the program manager and allocated to contractors, subcontractors, partners, and others as necessary for their scope of work.	1	0	0	1	0	0
12	The program documents the derivation and amount of contingency management has set aside for risk mitigation and unforeseen problems. An assessment of schedule risk is performed to determine whether the contingency is sufficient.	1	1	1	1	0	0
13	A contractor performs an SRA during the formulation of the performance measurement baseline to provide the basis for contractor schedule reserve at the preferred confidence level.	1	0	0	1	0	0
14	An SRA is performed on the schedule periodically as the schedule is updated to reflect actual progress	1	1	1	1	0	0

	on activity durations and sequences, as well as new risks.						
Best Practice 9 : Updating The Schedule Using Logic and Progress (Checklist)		**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
Key Question							
1	Schedule progress is recorded regularly and the schedule has been updated recently. Schedule status is updated with actual and remaining progress.	1	1	1	1	0	0
2	Schedule status is based on progress records for the current time period; they include pertinent activity information such as name, unique ID, original and remaining durations, forecasted and actual start and finish dates, and float.	1	0	0	1	0	0
3	The status date (or data date) denoting the date of the latest update to the schedule is recorded.	1	0	0	1	0	0
4	At least one in-progress activity is critical.	1	0	0	1	0	0
5	No activities precede the status date without actual start or finish dates and actual effort up to the status date. No activities beyond the status date have actual start or finish dates or actual effort.	1	0	0	1	0	0
6	Activities that are behind schedule by the status date have a remaining duration estimate, and the delay's effect has been assessed.						
6. a	If the delay is significant, plans to recover the implied schedule slip have been evaluated and implemented, if so decided.	1	1	1	1	0	0
6. b	Resources are reviewed and may be reassigned, depending on schedule progress.	1	1	1	1	0	0
7	Responsibility for changing or statusing the schedule is assigned to someone who has the proper training and experience in CPM scheduling.	1	1	1	1	0	0
8	Changes that were made to the schedule during the update have been documented.	1	0	1	1	0	0
9	New activities are reviewed for completeness of predecessor and successor logic, resource assignments, and effects on the critical path and float calculations.	1	0	1	1	0	0

10	Activities that have started out of sequence or have been completed out of sequence have been addressed using either retained logic or progress override to reflect the order in which they were carried out.	1	1	1	1	0	0
11	Management reviews schedule updates to verify and assess effects on the plan. Significant variances between planned and actual performance, as well as between planned and actual logic, are documented and understood.	1	1	1	1	0	0
12	The schedule structure is examined after each update to ensure that logic is not missing or broken, all date constraints are necessary, and no artifacts impede the ability of the schedule to dynamically forecast dates.	1	1	1	1	0	0
13	The current schedule, once management approves it, is assigned a version number and archived.	1	1	1	1	0	0
14	A schedule narrative accompanies each status update and includes						
14. a	the status of key milestone dates, including the program finish date;	1	0	0	1	0	0
14. b	the status of key hand-offs or giver and receiver dates;	1	0	0	1	0	0
14. c	explanations for any changes in key dates;	1	0	0	1	0	0
14. d	changes in network logic, including lags, date constraints, and relationship logic and their effect on the schedule;	1	0	0	1	0	0
14. e	a description of the critical paths, near-critical paths, and longest paths along with a comparison to the previous period's paths; and	1	0	0	1	0	0
14. f	any significant scheduling software options that have changed between update periods, such as the criticality threshold for total float; progress override versus retained logic; or whether resource assignments progress with duration.	1	0	0	1	0	0
Best Practice 10 : Maintaining a Baseline Schedule (Checklist)		**GAO**	**AACE**	**NASA**	**PMO**	**PMBOK**	**COMPANY**
Key Question							
1	A baseline schedule						

1. a	is set promptly after the program begins;	1	1	1	1	1	0
1. b	is the basis for measuring performance;	1	1	1	1	1	0
1. c	represents the original configuration of the program plan and signifies the consensus of all stakeholders regarding the required sequence of events, resource assignments, and acceptable dates for key deliverables;	1	1	1	1	1	0
1. d	is compared to the current schedule to track variances from the plan.	1	1	1	1	1	0
2	The as-built version of the schedule is planned to be archived and will						
2. a	represent the plan as executed to completion;	1	1	1	1	1	0
2. b	be compared to the original plan for an assessment of lessons learned;	1	1	1	1	1	0
2. c	become a valuable basis of estimate input for schedule estimates of future analogous projects;	1	1	1	1	0	0
2. d	become the basis for creating and validating fragnets where possible.	1	0	0	1	0	0
3	A schedule basis document is a single document that						
3. a	defines the organization of the IMS;	1	0	0	1	0	0
3. b	describes the logic of the network;	1	0	0	1	0	0
3. c	describes the basic approach to managing resources;	1	0	0	1	0	0
3. d	provides a basis for all parameters used to calculate dates;	1	0	0	1	0	0
3. e	describes the general approach to the project;	1	0	0	1	0	0
3. f	defines how to use the schedule file;	1	0	0	1	0	0
3. g	describes the schedule's unique features;	1	0	0	1	0	0

3. h	describes the schedule change management process;	1	0	0	1	0	0
3. i	contains a dictionary of acronyms and custom fields;	1	0	0	1	0	0
3. j	gives an overview of the assumptions and ground rules, including justification for -- calendars, -- lags, -- date constraints, -- long activity durations, and -- calendars and working times;	1	0	0	1	0	0
3. k	describes the use and assignments of resources within the schedule in appropriate detail;	1	0	0	1	0	0
3. l	describes the critical risks prioritized in a schedule risk analysis as well as schedule contingency;	1	0	0	1	0	0
3. m	discusses the derivation of the critical paths, longest path, and total float for the program;	1	0	0	1	0	0
3. n	is considered a living document that reflects updates to the baseline schedule.	1	0	0	1	0	0
4	Changes to the baseline schedule are reviewed and approved according to the change control process.	1	1	1	1	0	0
5	Schedule variances that exceed predetermined thresholds are reported to management, along with the cause and any corrective actions.	1	1	1	1	0	0
6	Negative schedule variances are investigated to see if the associated effort is on the critical path.	1	1	1	1	0	0
7	Schedule measures, such as the number of activities that have started or finished early, on time, or later than planned, are analyzed for the effect of any variances.	1	1	1	1	0	0
8	Trend analysis is conducted regularly to examine measures such as decreasing float and schedule contingency erosion.	1	1	1	1	0	0
9	The focus of any schedule recovery or acceleration techniques is on critical activities.	1	0	1	1	0	0

APPENDIX 2 - RATING AND SCORING MODEL OF STANDARD COMPLY WITH GAO'S COST-ESTIMATING

No	Best Practices Checklist	Associated Task	Alternatives
			NASA
1	The Estimate	The cost estimate type is clearly defined and is appropriate for its purpose.	5
		The cost estimate contains all elements suitable to its type—ICA, ICE, IGCE, LCCE, rough order of magnitude, total ownership cost: development, procurement, operating and support, disposal costs, and all sunk costs.	5
		All program costs have been estimated, including all life-cycle costs.	5
		The cost estimate is independent of funding source and appropriations.	5
		An affordability analysis has been performed at the agency level to see how the program fits within the overall portfolio. - The agency has a process for developing cost estimates that includes the 12-step best practice process outlined in chapter 1. - An overall agency portfolio sand chart displays all costs for every program.	5
		The estimate is updated as actual costs become available from the EVM system or requirements change.	5
		Post mortems and lessons learned are continually documented.	5
2	Purpose, Scope, and Schedule	The estimate's purpose is clearly defined.	5
		Its scope is clearly defined.	5
		The level of detail the estimate is to be conducted at is consistent with the level of detail available for the program. For example, an engineering buildup estimate should be conducted only on a well-defined program.	5
		The team has been allotted adequate time and resources to develop the estimate.	5
3	Cost Assessment Team	The estimating team's composition is commensurate with the assignment: - The team has the proper number and mix of resources. - Team members are from a centralized cost estimating organization. - The team includes experienced and trained cost analysts. - The team includes, or has direct access to, analysts experienced in the program's major areas. - Team members' responsibilities are clearly defined. - Team members' experience, qualifications, certifications, and training	1

		are identified. - The team participated in on-the-job training, including plant and site visits.	
		A master schedule with a written study plan has been developed.	5
		The team has access to the necessary subject matter experts.	3
4	Technical Baseline Description	There is a technical baseline: - The technical baseline has been developed by qualified personnel such as system engineers. - It has been updated with technical, program, and schedule changes, and it contains sufficient detail of the best available information at any given time. - The information in the technical baseline generally drives the cost estimate and the cost estimating methodology. - The cost estimate is based on information in the technical baseline and has been approved by management.	3
		The technical baseline answers the following: - What the program is supposed to do—requirements; - How the program will fulfill its mission—purpose; - What it will look like—technical characteristics; - Where and how the program will be built—development plan; - How the program will be acquired—acquisition strategy; - How the program will operate—operational plan; - Which characteristics affect cost the most—risk.	3
5	Work Breakdown Structure (WBS)	A product-oriented WBS represents best practice.	5
		It reflects the program work that needs to be done. It - clearly outlines the end product and major work for the program; - contains at least 3 levels of indenture; - is flexible and tailored to the program.	5
		The 100 percent rule applies: the sum of the children equals the parent. - The WBS defines all work packages, which in turn include all cost elements and deliverables. - In addition to hardware and software elements, the WBS contains program management and other common elements to make sure all the work is covered.	4

		Each system has one program WBS but may have several contract WBS's that are extended from the program WBS, depending on the number of subcontractors.	5
		The WBS is standardized so that cost data can be collected and used for estimating future programs. It - facilitates portfolio management, including lessons learned; - matches schedule, cost estimate, and EVM at a high level; - is updated as changes occur and the program becomes better defined; - includes functional activities within each element that are needed to support each product deliverable; - is the starting point for developing the program's detailed schedule; - provides a framework for identifying and monitoring risks and the effectiveness of contingency plans; - provides for a common language between the government program management office, technical specialists, prime contractors, and subcontractors.	5
		The WBS has a dictionary that: - defines each element and how it relates to others in the hierarchy; - clearly describes what is included in each element; - describes resources and functional activities needed to produce the element product; - links each element to other relevant technical documents.	5
6	Ground Rules and Assumptions	All ground rules and assumptions have been: - Developed by estimators with input from the technical community. - Based on information in the technical baseline and WBS dictionary. - Vetted and approved by upper management. - Documented to include the rationale behind the assumptions and historical data to back up any claims. - Accompanied by a level of risk of each assumption's failing and its effect on the estimate.	5
		To mitigate risk, - All GR&As have been placed in a single spreadsheet tab so that risk and sensitivity analysis can be performed quickly and efficiently. - All potential risks including cost, schedule, technical, and programmatic (e.g., risks associated with budget and funding, start up activities, staffing, and organizational issues) have been identified and traced to specific WBS elements. i. A schedule risk analysis has been performed to determine the program schedule's realism. ii. A cost risk analysis, incorporating the results of the schedule risk analysis, has been performed to determine the program's cost estimate realism.	3

		Budget constraints, as well as the effect of delaying program content, have been defined. - Peaks and valleys in time-phased budgets have been explained. - Inflation index, source, and approval authority have been identified. - Dependence on participating agencies, the availability of government furnished equipment, and the effects if these assumptions do not hold have been identified. - Items excluded from the estimate have been documented and explained. - Technology was mature before it was included; if its maturity was assumed, the estimate addresses the effect of the assumption's failure on cost and schedule.	3
		Cost estimators and auditors met with technical staff to determine risk distributions for all assumptions; the distributions were used in sensitivity and uncertainty analyses of the effects of invalid assumptions. Management has been briefed, and the results have been documented.	5
7	Data	As the foundation of an estimate, data: - Have been gathered from historical actual cost, schedule and program, and technical sources; - Apply to the program being estimated; - Have been analyzed for cost drivers; - Have been collected from primary sources, if possible, and secondary sources as the next best option, especially for cross-checking results; - Have been adequately documented as to source, content, time, units, assessment of accuracy and reliability, and circumstances affecting the data; - Have been continually collected, protected, and stored for future use; - Were assembled as early as possible, so analysts can participate in site visits to understand the program and question data providers.	5
		Before being used in a cost estimate, the data were: - Fully reviewed to understand their limitations and risks; - Segregated into nonrecurring and recurring costs; - Validated, using historical data as a benchmark for reasonableness; - Current and found applicable to the program being estimated; - Analyzed with a scatter plot to determine trends and outliers; - Analyzed with descriptive statistics; - Normalized to account for cost and sizing units, mission or application, technology maturity, and content so they are consistent for comparisons; - Normalized to constant base-year dollars to remove the effects of inflation, and the inflation index was documented and explained.	5

8	Developing a Point Estimate	The cost estimator considered various cost estimating methods: - Analogy, early in the life cycle, when little was known about the system being developed: i. Adjustments were based on program information, physical and performance characteristics, contract type. - Expert opinion, very early in the life cycle, if an estimate could be derived no other way. - The build-up method later, in acquisition, when the scope of work was well defined and a complete WBS could be determined. - Parametrics, if a database of sufficient size, quality, and homogeneity was available for developing valid CERs and the data were normalized correctly. i. Parametric models were calibrated and validated using historical data. - Extrapolating from actual cost data, at the start of production.	5
		Cost estimating relationships were considered: - Statistical techniques were used to develop CERs: i. Higher R-squared; - Statistical significance, for determining the validity of statistical relationships; i. Significance levels of F and t statistics. - Before using a CER, the cost estimator: i. Examined the underlying data set to understand anomalies; ii. Checked equations to ensure logical relationships; iii. Normalized the data; iv. Ensured that CER inputs were within the valid dataset range; v. Checked modeling assumptions to ensure they applied to the program. - Learning curve theory was applied if: i. Much manual labor was required for production; ii. Production was continuous or adjustments had to be made; iii. Items to be produced required complex processes; iv. Technological change was minimal between production lots; v. The contractor's business process was being continually improved.	5
		Production rate and breaks in production were considered.	5
		The point estimate was developed by aggregating the WBS element cost estimates by one of the cost estimating methods. i. Results were checked for accuracy, double-counting, and omissions and were validated with cross-checks and independent cost estimates.	5
9	Estimating Software Costs	The software cost estimate followed the 12-step estimating process: - Software was sized with detailed knowledge of program scope, complexity, and interactions, and the cost estimators worked with software engineers to determine the appropriate sizing metric.	5

		- It was sized with source lines of code, function, object, feature point, or other counts.	
		The software sizing method was appropriate: - Source lines of code were used if requirements were well defined and if there was a historical database of code counts for similar programs and a standard definition for a line of code. - Function points were used if detailed requirements and specifications were available, software did not contain many algorithmic functions, and an experienced and certified function point counter was available. - COSMIC points were used if functional user requirements are known and the application is for business, real-time, embedded, or infrastructure software. - Object points were used if computer-aided software engineering tools were used to develop the software. - Reports, interfaces, conversions, extensions and forms / workflow were used for ERP programs. - Use cases and use case points were used if system and user interactions were defined. - Autogenerated and reused source lines of code were identified separately from new and modified code to account for pre- and postimplementation efforts. - Several methods were used to size the software to increase the accuracy of the sizing estimate. - The final software size was adjusted for growth based on historical data, and growth is continually monitored over time.	5
		Software cost estimates included: - Development labor costs for coding and testing, other labor supporting software development, and nonlabor costs like purchasing hardware and licenses. - Productivity factors for converting software size into labor effort, based on historical data and calibrated to match program size and development environment. - Industry average productivity factors and risk ranges, if no historical data were available. - Assumptions about productive labor hours in a day and work days in a year. - Development schedules accounting for staff availability, prior task dependencies, concurrent and critical path activities, number and length of shifts, overtime allowance, down time, and worker locations. - Costs for help desk support, database development, and corrective, adaptive, and preventive maintenance as part of the software's life cycle cost. - Time and effort associated with rework to fix defects. - Training cost estimators to calibrate parametric tools to match the	5

		program and model results cross-checking for accuracy. - Estimators' accounting for integrating commercial off-the-shelf software into the system, including developing custom software and glue-code. - Impact of risks facing ERP system implementations as outlined in table 18. - Costs associated with interfacing bolt-on applications for ERP systems.	
		IT infrastructure and services components of the software cost estimate included: - Costs associated with the physical attributes of the IT infrastructure, the performance and complexity requirements, and economic considerations. - Impact of risks affecting IT infrastructure, as outlined in table 19. - Costs associated with labor and material nonrecurring and recurring efforts.	5
10	Sensitivity Analysis	The cost estimate was accompanied by a sensitivity analysis that identified the effects of changing key cost driver assumption and factors. - Well-documented sources supported the assumption or factor ranges. - The sensitivity analysis was part of a quantitative risk assessment and not based on arbitrary plus or minus percentages. - Cost-sensitive assumptions and factors were further examined to see whether design changes should be implemented to mitigate risk. - Sensitivity analysis was used to create a range of best and worst case costs. - Assumptions and performance characteristics listed in the technical baseline description and GR&As were tested for sensitivity, especially those least understood or at risk of changing. - Results were well documented and presented to management for decisions.	5

		The following steps were taken during the sensitivity analysis: - Key cost drivers were identified. - Cost elements representing the highest percentage of cost were determined and their parameters and assumptions were examined. - The total cost was reestimated by varying each parameter between its minimum and maximum range. - Results were documented and the reestimate was repeated for each parameter that was a key cost driver. - Outcomes were evaluated for parameters most sensitive to change.	5
		The sensitivity analysis provided a range of possible costs, a point estimate, and a method for performing what-if analysis.	5
11	Cost Risk and Uncertainty	A risk and uncertainty analysis quantified the imperfectly understood risks that are in the program and identified the effects of changing key cost driver assumptions and factors. - Management was given a range of possible costs and the level of certainty in achieving the point estimate. - A risk adjusted estimate that reflects the program's risks was determined. - A cumulative probability density function, an S curve, mapped various cost estimates to a certain probability level and defensible contingency reserves were developed. - Periodic risk and uncertainty analysis was conducted to improve estimate uncertainty.	5
		The following steps were taken in performing an uncertainty analysis: - Program cost drivers and associated risks were determined, including those related to changing requirements, cost estimating errors, business or economic uncertainty, and technology, schedule, program, and software uncertainty. i. All risks were documented for source, data quality and availability, and probability and consequence. ii. Risks were collected from staff within and outside the program to counter optimism. iii. Uncertainty was determined by cost growth factor, expert opinion (adjusted to consider a wider range of risks), statistics and Monte Carlo simulation, technology readiness levels, software engineering maturity models and risk evaluation methods, schedule risk analysis, risk cube (P-I matrix) method, or risk scoring. - A probability distribution modeled each cost element's uncertainty based on data availability, reliability, and variability. i. A range of values and their respective probabilities were determined either based on statistics or expressed as 3-point estimates (best case, most likely, and worst case), and rationale for choosing which method was discussed. ii. Documentation of the rationale for choosing the probability	5

		distributions should be provided.	
		iii. Probability distribution reflects the risk shape and the tails of the distribution reflect the best and worst case spread as well as any skewness. Distribution bounds were adjusted to account for stakeholder bias using organization default values when data specific to the program are not available. iv. If the risk driver approach is used, the data collected, including probability of occurrence and impact, were applied to the risks themselves. v. Prediction interval statistical analysis was used for CER distribution bounds. - The correlation between cost elements was accounted for to capture risk. i. The correlation ensures that related cost elements move together during the simulation, resulting in reinforcement of the risks. ii. Cost estimators examined the amount of correlation already existing in the model. If no correlation is present, an insertion of 0.25 correlation was added. - A Monte Carlo simulation model was used to develop a distribution of total possible costs and an S curve showing alternative cost estimate probabilities. i. High-priority risks were examined and identified for risk mitigation. ii. Strength of correlated cost elements were examined and additional correlation added if necessary to account for risk. - The probability associated with the point estimate was identified. - Contingency reserves were recommended for achieving the desired confidence level. i. The mean of the distribution tends to fall around the 55%–65% confidence level because the total cost distribution follows a lognormal trend (i.e., tendency to overrun rather than underrun costs). ii. Budgeting to at least the mean of the distribution or higher is necessary to guard against potential risk. iii. The cost risk and uncertainty results were vetted through a core group of experts to ensure that the proper steps were followed.	

		iv. The estimate is continually updated with actual costs and any variances recorded to identify areas where estimating was difficult or sources of risks were not considered. - The risk-adjusted cost estimate was allocated, phased, and converted to thenyear dollars for budgeting, and high-risk elements were identified to mitigate risks. i. Results from the uncertainty analysis were used to prioritize risks based on probability and impacts as they affected the cost estimate.	
		- Contingency reserves were recommended for achieving the desired confidence level. i. The mean of the distribution tends to fall around the 55%–65% confidence level because the total cost distribution follows a lognormal trend (i.e., tendency to overrun rather than underrun costs). ii. Budgeting to at least the mean of the distribution or higher is necessary to guard against potential risk. iii. The cost risk and uncertainty results were vetted through a core group of experts to ensure that the proper steps were followed. iv. The estimate is continually updated with actual costs and any variances recorded to identify areas where estimating was difficult or sources of risks were not considered. - The risk-adjusted cost estimate was allocated, phased, and converted to thenyear dollars for budgeting, and high-risk elements were identified to mitigate risks. i. Results from the uncertainty analysis were used to prioritize risks based on probability and impacts as they affected the cost estimate.	

		A risk management plan was implemented jointly with the contractor to identify and analyze risk, plan for risk mitigation, and continually track risk. - A risk database watch list was developed, and a contractor's EVM system was used for root cause analysis of cost and schedule variances, monitoring worsening trends, and providing early risk warning. - Event-driven reviews, technology demonstrations, modeling and simulation, and risk-mitigation prototyping were implemented.	5
12	Validating the Estimates Against Four Characteristics	It is comprehensive, includes all possible costs, ensures that no costs were omitted or double-counted, and explains and documents key assumptions. - It completely defines the program, reflects the current schedule, and contains technically reasonable assumptions. - It captures the complete technical scope of the work to be performed, using a logical WBS that accounts for all performance criteria and requirements.	3
		It was documented so well that it can easily be repeated or updated and traced to original sources by auditing. - Supporting documentation identifies data sources, justifies all assumptions, and describes all estimating methods (including relationships) for all WBS elements. - Schedule milestones and deliverables can be traced and are consistent with the documentation.	3
		It is accurate, not too conservative or too optimistic; is based on an assessment of most likely costs, adjusted properly for inflation; and contains few minor mistakes. - WBS estimates were checked to verify that calculations were accurate and accounted for all costs and that proper escalation factors were used to inflate costs so they were expressed consistently and accurately. - Questions associated with estimating techniques were answered to determine the estimate's accuracy. - CERs and parametric cost models were validated to ensure that they were good predictors of costs, their data were current and applied to the program, the relationships between technical parameters were logical and statistically significant, and results were tested with independent data.	3
		Data limitations from uncertainty or bias were identified; results were crosschecked; an ICE was developed to see if results were similar. - Major assumptions were varied and other outcomes recomputed to determine their sensitivity to changes in the assumptions. - Risk and uncertainty analysis was conducted.	3

13	Documenting the Estimate	The documentation describes the cost estimating process, data sources, and methods step by step so that a cost analyst unfamiliar with the program could understand what was done and replicate it. - Supporting data are adequate for easily updating the estimate to reflect actual costs or program changes and using them for future estimates. - The documentation describes the estimate with narrative and cost tables. - It contains an executive summary, introduction, and descriptions of methods, with data broken out by WBS cost elements, sensitivity analysis, risk and uncertainty analysis, management approval, and updates that reflect actual costs and changes. - Detail addresses best practices and the 12 steps of high-quality estimates. - The documentation is mathematically sensible and logical. - It discusses contingency reserves and how they were derived from risk and uncertainty analysis and the LCCE funding profile.	5
		It includes access to an electronic copy, and both are stored so that authorized personnel can easily find and use them for other cost estimates.	5
14	Presenting the Estimate to Management	The briefing to management: - was simple, clear, and concise enough to convey its level of competence. - illustrated the largest cost drivers, presenting them logically, with backup charts for responding to more probing questions. - was consistent, allowing management to focus on the estimate's content.	5
		The briefing contained: - A title page, outline, and brief statement of purpose of the estimate. - An overview of the program's technical foundation and objectives. - LCCE results in time-phased constant-year dollars, tracked to previous estimates. - A discussion of GR&As. - The method and process for each WBS cost element, with estimating techniques and data sources. - The results of sensitivity analysis and cost drivers that were identified. - The results of risk and uncertainty analysis with confidence interval, S curve analysis, and bounds and distributions. - The comparison of the point estimate to an ICE with discussion of differences and whether the point estimate was reasonable. - An affordability analysis based on funding and contingency reserves. - Discussion of any other concerns or challenges - Conclusions and recommendations.	5

		Feedback from the briefing, including management's acceptance of the estimate, was acted on and recorded in the cost estimate documentation.	5
15	Managing Program Cost: Planning	A cost estimate was used to measure performance against the original plan, using EVM.	3
		EVM and risk management were tightly integrated to ensure better program outcomes. - Strong leadership demands EVM be used to manage programs. - Stakeholders make it clear that EVM matters and hold staff accountable for results. - Management is willing to hear the truth about programs and relies on EVM data to make decisions on how to mitigate risk. - Policy outlines clear expectations for EVM as a disciplined management tool and requires pertinent staff to be continuously trained in cost estimating, scheduling, EVM, and risk and uncertainty analysis.	3
		EVM is implemented at the program level so that both government and contractor know what is expected and are held accountable. - EVM relied on the cost of completed work to determine true program status. - EVM planned all work to an appropriate level of detail from the beginning. - It measured the performance of completed work with objective techniques. - It used past performance to predict future outcomes. - It integrated cost, schedule, and performance with a single management control system. - It directed management to the most critical problems, reducing information overload. - It fostered accountability between workers and management.	3
		The EVM system complied with the agency's implementation of ANSI's 32 guidelines.	3

		The following steps in the EVM process were taken: - The work's scope was defined with a WBS, and effort was broken into work and planning packages. - The WBS and organizational breakdown structure were cross-walked to identify control accounts that show who will do the work. - An acceptable technique was used to schedule work to resource load activities. i. All activities were identified and sequenced, logically networked, clearly showing horizontal and vertical integration. ii. Activities were resource loaded with labor, material, and overhead and durations were estimated with historical data when available, and float was identified. iii. Program master schedule and critical path were identified. iv. A schedule risk analysis was performed based on an 11-point schedule assessment. v. Schedule reserve was chosen and prioritized for high-risk activities. vi. The schedule was updated using logic and durations to determine dates and reflects accomplishments and is continuously analyzed for variances and changes to the critical path and completion date. - Resources were adequate to complete each activity and were estimated to do the work, authorize budgets, and identify management reserve for high-risk efforts. - Objective methods for determining earned value were used.	3
		- The performance measurement baseline was developed for assessing program performance; EVM performance data were analyzed and variances from the baseline plan were recorded; the performance measurement baseline was updated. - EACs were forecast using EVM. - An integrated cost-schedule risk analysis was conducted. - EACs from EVM were compared with an EAC from risk analysis. - Management took action to mitigate risk. - A preaward IBR was performed where provided for to verify the performance measurement baseline's realism and compliance with ANSI guidelines. - Award fee criteria were developed to motivate the contractor to manage its contract with EVM to deliver the best possible product, were tied to specific contract events, and did not predetermine specific EVM measures. - A performance based payment contract was considered for fixed-price contracts where technical effort and risk are low. - The EVM system implemented was validated for compliance with the ANSI guidelines by independent and qualified staff and therefore can be considered to provide reliable and valid data from which to manage the program.	

16	Managing Program Cost: Execution	An IBR verified that the baseline budget and schedule captured the entire scope of work, risks were understood, and available and planned resources were adequate. - Separate IBRs were conducted at the prime contractor and all major subcontractors. - A performance measurement baseline assessment made a comprehensive and value-added review of control accounts. i. Before award, or not more than 6 months after, an IBR categorized risks by severity and provided team training. ii. Work definition (including provisions for rework and retesting), schedule integration, resource identification, earned value measures, and baseline validation were matured and reviewed. iii. Interviewers used a template in discussions with control account managers and identified where additional training was needed. iv. An action plan for assigning responsibility for handling risks was developed, and a final program risk rating was based on a summary of all identified risks. v. Management reserve was set aside that covered identified risks and care was taken to include risks identified during the IBR in the risk management plan. vi. An EVM analyst monitored corrective action requests for closure. vii. A memorandum for the record described the IBR findings.	3
		A contract performance report summarized EVM data. - The data were reviewed monthly to track program progress, risks, and plans. - Management used the data to i. integrate cost and schedule performance data with technical measures; ii. identify the magnitude and effect of problems causing significant variances; iv. inform higher management of valid and timely program status and project future performance. - Format 1 of the CPR reported data to at least level 3 of the WBS, and format 5 explained variances and the contractor's plans for fixing them.	3
		Program managers analyzed EVM data monthly and sequentially for variances and EACs. - The EVM data were checked for validity and anomalies. - Performance indexes were analyzed and plotted for trends and variances. - Schedule variances were analyzed against the most recently statused schedule to see if problems were occurring on or near the critical path. - Management reserve allocations in the WBS were examined and compared against risks identified in the cost estimate. - A range of EACs was developed, using a generic index-based formula or relying on probable cost growth factors on remaining work, combined with an integrated cost schedule risk analysis.	3

		- An independent date for program completion was determined, using schedule risk analysis that identifies which activities need to be closely monitored. - Senior management used EVM data to answer basic program questions.	
17	Managing Program Costs: Updating	The cost estimate was updated with actual costs, keeping it current and relevant. - Actual cost, technical, and schedule data were archived for future estimates.	5
		Authorized changes to the EVM performance measurement baseline were incorporated in a timely manner. - It reflected current requirements. - These changes were incorporated in a documented, disciplined, and timely manner so that budget, schedule, and work stayed together for true performance measurement. - Changes were approved and implemented in a well-defined baseline control process.	3
		Regular EVM system surveillance ensured the contractor's effective management of cost, schedule, and technical performance and compliance with ANSI guidelines. - The surveillance organization was independent and had authority to resolve issues. - Surveillance staff had good knowledge about EVM and agency programs. - An annual surveillance plan was developed and programs were chosen objectively. - Findings and recommendations were presented to the program team for clarification, and the final surveillance report had an action plan to resolve findings quickly.	3
		The contractor's overtarget baseline or overtarget schedule was detailed, reasonable, and realistic; planned for costs, schedule, and management review; and described measures in place to prevent another OTB.	5
		Updated EACs and other EVM data were continually reported to management.	3
		EVM and CFSR–like data were examined regularly to identify problems and act on them quickly.	5

About the Author

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Muhammad Fadhli Zilikram is an engineer with eight years of professional experience in the oil and gas sectors. Currently, he works at the National Oil Company of Indonesia. During his career, he has an experience as a Maintenance Engineer, Piping Inspector, Tank Inspector, Cost Estimator, Mechanical Engineer, and Project Engineer. He has involved in several projects, including Fuel Terminal, LPG Terminal, Pipeline, Marine Facilities, and other downstream oil & gas projects.

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