Indonesia Aviation Fuel Facilities Project Cost Estimating Process vs the NASA Cost Estimating Process – a Process Benchmarking Study [1]

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ABSTRACT

The Cost Estimating Process is an important phase in project execution. Research shows that only a few projects were on budget in their delivery. Poor estimation during the project's planning phase is also one of the largest contributors to project failures. Hence, the importance of a reliable estimate of the project budget becomes very high for future projects. In this study, a process benchmarking analysis has been conducted to several Cost Estimating Best Practices and Guidelines against the NASA Cost Estimating Process using a combination of Dominance, Disjunctive Reasoning, and Additive Weighting Technique of Multi-Attributes Decision Making. The analysis result shows that the NASA Cost Estimating Process was the best alternative among other Cost Estimating Best Practices and Guidelines. The best alternative will be adapted for future projects' cost estimating process, with these three activities as priorities to be subject of improvement; (1) Develop and Incorporate the Cost Risk Assessment, (2) Update the Cost Estimate as Required, and (3) Document the Estimate.

Key Words: Cost Estimate, National Aeronautics and Space Administration (NASA), Cost Estimating Process, Benchmarking

INTRODUCTION

The research from KPMG, AIPM, and IPMA in 2019[2] mentioned that only 19% of organizations deliver a successful project. This number shows that the likelihood of achieving OTOBOSOR (On Time On Budget On Schedule On Return) criteria is a difficult task, primarily when project complexity always increased each year with technology development. Based on the same research, only 36% of the project was on the budget in their delivery. This data shows that most of the time, inadequate cost estimating on a project leads to project failure. Naybour's study (2015)[3] also stated that the PwC report on Insights and Trends: Current Portfolio, Programme and Project Management Practices found that inadequate estimation during the planning phase continues to be the largest contributor to project failures.

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[2] KMPG, AIPM, IPMA (2019). The Future of Project Management : Global Outlook 2019. Retrieved from https://www.ipma.world/assets/PM-Survey-FullReport-2019-FINAL.pdf
[3] Naybour, Paul (2015). Projects Fail Because of Poor Estimates in the Planning Phase. https://www.parallelprojecttraining.com/why-projects-fail-poor-estimates-planning-phase/

Figure-1 Key Findings from KPMG, AIPM and IPMA Project Management Survey 2019[1]

The Aviation Fuel Facilities Projects

Aviation Fuels was one of the leading products of Indonesia's state-owned Oil and Gas Company Downstream Business. The Company distributes Aviation Fuels to more than 50 airports in Indonesia and South East Asia. To maintain the quality and security of the supply of Aviation Fuel, Company already built several infrastructure facilities for Aviation Fuel Products throughout the country. The facilities had to support these three primary operations; Receiving, Storage, and Distribution.

Figure-2 Supply Chain of Aviation Fuel from Segregated off-airport terminal to airplane[4]

[4] Airlines for America (2018). Jet Fuel : From Well to Wing. https://www.airlines.org/wp-content/uploads/2018/01/jet-fuel-1.pdf

The Downstream Aviation Fuel Business Process started from a segregated off-airport terminal. This terminal receives various hydrocarbon products such as Gasoline, Gasoil, Heavy Oil, and Aviation Fuel (Jet Fuel and Aviation Gasoline) via Offshore or Onshore Oil Tanker berthing facilities from local or overseas refineries. Each product is stored in each specific Storage Tank. From these storage tanks, the Aviation Fuel will be transferred to On Airport Aviation Fuel Facilities. The transportation of the products often uses two methods. In the first method, Transfer Pump transported the product directly via Pipeline Facilities from Off-Airport Storage Tanks to On-Airport Storage Tanks. If a Pipeline were not available in the area, a bridger truck would transfer the products to the On-Airport Storage Tanks. The fuel is then transferred to the aircraft using hydrant system facilities (piping and pumping system from tanks directly to the airside below aircraft parking stand). And for the lower traffic airports, pump-equipped Refueler Truck is often used as alternatives to transfer the fuel to the aircraft.

The data from the Central Bureau of Statistics of Indonesia (2020)[5] showed that from 2009 to 2018, the amount of Domestic Passengers Departure from 5 Indonesia's main airport has been increasing by 86,89%.

Figure-3. Top 5 Indonesian Airports Domestic Passenger Departure[6]

State-owned Airport Operator Companies responded to this trend by developing aviation infrastructure by enlarging and modernizing existing airports and constructing new ones. From 2014 to 2019, one of the state-owned airport operator companies under the Ministry of

[5] Badan Pusat Statistik (n.d.). Jumlah Penumpang yang Berangkat pada Penerbangan Domestik di Bandara Utama Indonesia. https://www.bps.go.id/linkTableDinamis/view/id/812
[6] Author

Transportation's supervision had already expanding one main airport terminals and built four new airports[7]. The downstream division of state-owned Oil and Gas Company had to catch up with the industry's growth. The Company already constructed several Expansion Project and New Aviation Fuel Facilities following Aviation Fuel demand. Furthermore, from the year 2019, the state-owned airport operator companies planned to execute nine new Airport Development Projects. Several of them were already in the construction phase to this date[8][9]. Therefore, the state-owned Oil & Gas company expected to develop many Aviation Fuel Facilities Project shortly.

Project Cost Estimation

Cost estimation in project management is the method of estimating costs and other resources to complete a project within a defined scope. Cost estimation accounts for each factor needed for the project and calculates the project budget's total sum.

To achieve a successful Aviation Fuel Facilities Project, the Company had to develop accurate and credible cost estimation. Larson and Gray (2010)[10] stated that "project cost estimation is crucial to the success of the project and should be considered from earliest stages of the project; otherwise, poor estimation could lead to the project failure in terms of time, cost, or even in the stakeholder opinion." Wisnugroho stated that "60% of capital projects experience a 10% cost and schedule overrun, and around 30% experience cost and schedule overrun up to 25%"[11]. These facts showed that developing a credible and accurate Project Cost Estimation was a big challenge for most companies and organizations.

[7] Pradana, R.S. (2019). Ini Klaim AP II Kembangkan Bandar Udara 5 Tahun Terakhir. https://ekonomi.bisnis.com/read/20191020/98/1161245/ini-klaim-ap-ii-kembangkan-bandar-udara-5-tahun-terakhir
[8] Ananta, Yanurisa (2019). Ini 5 Proyek Bandara Raksasa RI, Ada yang Bisa Salip Changi. https://www.cnbcindonesia.com/news/20190120134328-4-51489/ini-5-proyek-bandara-raksasa-ri-ada-yang-bisa-salip-changi
[9] Ramli, R.R. (2020). AP I Beberkan Progres Pembangunan Sejumlah Bandara yang Tengah Dibangun", Klik untuk baca: https://money.kompas.com/read/2020/08/10/195601026/ap-i-beberkan-progres-pembangunan-sejumlah-bandara-yang-tengah-dibangun?page=all
[10] Muhammad T. Hatamleh, Mohammed Hiyassat, Ghaleb Jalil Sweis, Rateb Jalil Sweis, (2018). "Factors affecting the accuracy of cost estimate: case of Jordan", Engineering, Construction and Architectural Management, Vol. 25 Issue: 1, pp.113-131, https://doi.org/10.1108/ECAM-10-2016-0232
[11] Wisnugroho, Joko. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study. https://pmworldlibrary.net/wp-content/uploads/2020/02/pmwj90-Feb2020-Wisnugroho-benchmarking-indonesia-og-cost-estimating-vs-international3.pdf

	Primary Characteristic	*Secondary Characteristic*		
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

Table 1 – AACE Cost Estimate Classification System

Figure-4 AACE Cost Estimate Classification System[12]

Figure 4 above showed that AACEI[13] defines 5 Estimate Class of Cost Estimate. The table indicates that another process, such as project definition deliverables, significantly influenced cost estimation accuracy. Therefore, Cost Estimating was not a stand-alone activity. The quality of estimation depends on the result of another process that preceded it in a project life cycle.

The Best Practices and Guidelines of Cost Estimating

The Company already developed guidelines and procedures for developing Project Cost Estimation. The guidelines and procedures have been used in the Aviation Fuel Facilities projects' cost estimating process in the past. Several international companies, institutions, and organizations such as US-GAO[14], AACEI, GPCCaR[15], and PMI[16] also had their guidelines and best practices in Cost Estimating. In 2020, Wisnugroho already found that GAO Cost Estimating & Assessment Guide was superior to the other International "Best-Tested and Proven" Practices

[12] What is cost estimation? We explain it to you in 4 steps. https://costmanagement.eu/blog-article/what-is-cost-estimation-we-explain-it-to-you-in-4-steps
[13] Carlik, C.W.et.al.(2015). AACE International Recommended Practice No. 87R-14 Cost Estimate Classification System – As Applied for The Petroleum Exploration and Production Industry. United States of America: AACE International.
[14] The United States. Government Accountability Office. (2009). Schedule Assessment Guide: Best Practices for Project Schedule. Washington, DC: Government Printing Office. https://www.gao.gov/new.items/d093sp.pdf
[15] PP Admin (2015). GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR). http://www.planningplanet.com/guild/gpccar/introduction-to-managing-project-controls
[16] Project Management Institute (n.d.). https://www.pmi.org/

mentioned above based on ten projects used as a reference[17]. In this paper, another International Guidelines for cost estimating, The NASA Cost Estimating Handbook, will be used as a benchmarking reference to the current company Cost Estimation Process and another international "best-tested and proven" practices, including the GAO Cost Estimating & Assessment Guide. The author selected the cost estimation process of projects specifically in Aviation Fuel Facilities field to be assessed with the "best-tested and proven" practices.

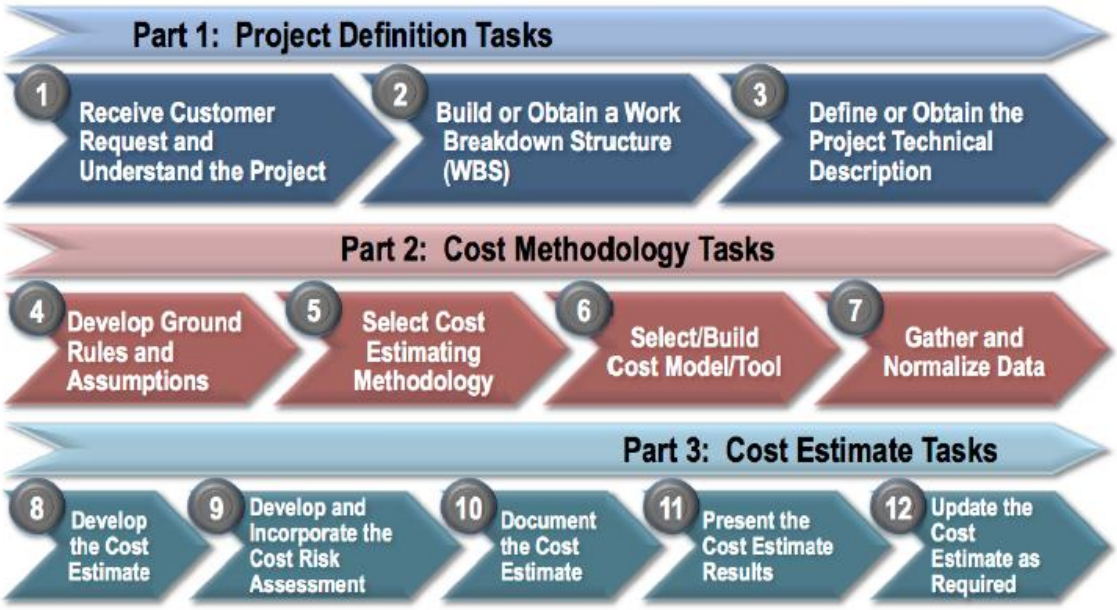

Figure-5 The NASA Cost Estimating Process[18]

The NASA Cost Estimating Process divided into three main parts :

1. Project Definition Tasks
2. Cost Methodology Tasks
3. Cost Estimate Tasks

The process above was also substantively consistent with the GAO's process but tailored to fit NASA's needs.

As mentioned above, several Aviation Fuel Facilities Project already used the current author's Company Cost Estimating Guideline and Procedure. These existing guidelines and procedures

[17] Wisnugroho, Joko. (2020). Indonesia Oil & Gas Cost Estimating vs International "Best-Tested and Proven" Practices – A Benchmarking Study. https://pmworldlibrary.net/wp-content/uploads/2020/02/pmwj90-Feb2020-Wisnugroho-benchmarking-indonesia-og-cost-estimating-vs-international3.pdf
[18] National Aeronautics and Space Administration. (2008). NASA Cost Estimating Handbook.Chapter 2. https://www.nasa.gov/pdf/263676main_2008-NASA-Cost-Handbook-FINAL_v6.pdf

should be evaluated and improved for future projects to increase the cost-effectiveness and the project's success rate.

METHODOLOGY

Step 1- PROBLEM STATEMENT

In this paper, the author demonstrates the evaluation of current Company Cost Estimation Guidelines and Procedures and determining the best International "best practices" to be adopted to improve or change the current guidelines. The author will send the study's result in this paper to the Company management to increase the awareness of the importance of including International best practices as a reference to Company Cost Estimating Guidelines. This study should find the answers to the questions below:

- How much is the score of the Company's current cost estimating practices compared to NASA Cost Estimating Handbook best practices?
- What is the best international cost estimating guidelines to be adopted by the Company for Aviation Facilities Project?

Step 2-FEASIBLE ALTERNATIVES

This research will evaluate the current Company Cost Estimating Process and several international organizations' best practices or guidelines such as GAO Cost Estimating and Assessment Guide, TCM from AACE, GPC Compendium, and Reference and PMBOK from PMI against NASA Cost Estimating Handbook.

NASA Cost Estimating Handbook

The latest edition of the NASA Cost Estimating Handbook (CEH) was the 4th edition published in 2015. The purpose of NASA CEH was to serve as a guide for cost estimating at NASA. It intends to cover an audience of non-estimating professionals, new cost estimators, and experienced cost analysts. In the book, NASA stated the need for cost estimating and cost analyses; "NASA and many external organizations are consumers of cost estimates and analyses. The Agency needs estimates for Project Office formulation and implementation phases, non-advocate cost estimates, source selections, what-if exercises, affordability studies, economic analyses, and Analysis of Alternatives (AoA), as well as to support numerous types of decisions related to projects." [19]

System cost must be a design variable to help focus on significant cost drivers during design and challenge estimates strongly deviating from historical data. The cost assessment method set out in this handbook will provide the decision-maker with a clear view of the cost risk inherent in the project, the cost of alternatives within the project, and the details required to decide the

[19] National Aeronautics and Space Administration. (2015). NASA Cost Estimating Handbook Version 4.0. Washington, DC.

allocation of resources. When a decision is taken to continue with the project, cost forecasts offer important cost-risk information to management to enhance resource control in both the current and the future and provide insight into the effect of project adjustments on the program budget.

As a result, the cost estimation process must be adaptable and versatile while remaining firm on the values, goals, and cost estimation practices. Cost Estimators should submit cost estimates to the following groups :

- Projects, programs, Centers, Mission Directorates, and the Agency as a whole
- External stakeholders (e.g., Congress and the Office of Management and Budget [OMB])
- Auditors (e.g., the Government Accountability Office [GAO] and the NASA Office of Inspector General [OIG])
- Taxpayers.

GAO Cost Estimating and Assessment Guide

To allow efficient use of public funds, the government must employ effective management strategies and procedures, including evaluating government program efficiency. Besides, lawmakers, elected leaders, and the public want to know if government agencies fulfill their objectives and also want to see the detail of their program costs.

"The U. S. Government Accountability Office (GAO) has shown that in order to conduct oversight of the federal government, including agencies' stewardship of public funds, reliable cost information is required. We developed this Guide to establish a consistent methodology based on best practices that can be used across the federal government for developing, managing, and evaluating program cost estimates." [20]

The GAO Cost Estimating and Assessment Guide provides best practices for creating an accurate, high-quality cost estimate and best practices related to efficient control of program costs by earned value management (EVM). The use of these best practices can make it easier for government programs to correctly predict and control their expenditures to enhance program management and implementation. For this document, the cost estimate is a description of the individual cost components using proven methods and relevant data to estimate the program's potential costs based on what is known today. Cost estimation management includes updating the estimates with the real details as they become available, revising the estimates to represent program adjustments, and assessing the discrepancies between the expected and actual costs.

GAO published the first edition of the GAO Cost Estimating and Assessment Guide in 2009 and post the first update in 2020. The Guide provides agencies across the US Government with a way

[20] The United States. Government Accountability Office. (2009). Schedule Assessment Guide: Best Practices for Project Schedule. Washington, DC: Government Printing Office.

to produce reliable and high-quality cost estimates. The Guide outline the critical step in the estimating process.

Guild of Project Controls Compendium and Reference (GPCCaR)

The GPCCaR explained the purposes and method used in Managing Cost Estimating & budgeting in their 8th module.

"The purpose of the Managing Cost Estimating and Budgeting Module is to introduce the tools, techniques, and methodologies associated with cost estimating and budgeting that has been identified as being "best tested and proven" practices and which have been found to work on "most projects, most of the time"; provide a logical or rational sequence showing when those tools or techniques would normally and customarily be used and in selected instances, show how to use those tools/techniques and/or where to find additional information on how to use or apply them." [21]

The module stated that "Cost Estimate" is defined in our standard Business Dictionary as "Approximation of the possible cost of a product, program or project, calculated based on available information." Whereas "Cost Budget" is defined as a "Financial Schedule prepared for each major category of expenditure, such as operating costs, funding costs, or production costs."

Cost estimation is the method of creating an "educated guess" of what a program, project, work package, or operation would cost in the future. In contrast, cost budgeting is based on that accepted estimate and distributed over time by phased loading, work packages, or activities. Cost estimating is producing a monetary value or set of values to be checked and approved by management.

Upon approval, this value or set of values becomes the time-phased budget of the initiative, project, job package, or operation for which progress against the plan is measured, analyzed, evaluated, the performance of which is used by management to make decisions.

Total Cost Management Framework from AACE International

"Total cost management (TCM) is the effective application of professional and technical expertise to plan and control resources, costs, profitability, and risk. Simply stated, TCM is a systematic approach to managing cost throughout the life cycle of any enterprise, program, facility, project, product, or service. The TCM Framework is a representation of that systematic approach." [22]

It describes the relationship of each cost engineering practice field to other areas of practice, including allied careers.

[21] PP Admin (2015). GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR). Module 01 : Managing Project Controls. http://www.planningplanet.com/guild/gpccar/introduction-to-managing-project-controls
[22] Stephenshon, H. L. (2015). Total Cost Management Framework: An Integrated Approach to Portfolio, Program, and Project Management Second Edition. AACE International.

It offers a process for the application of cost engineering skills and expertise. A vital aspect of the TCM System is that it illustrates and distinguishes the main fields of application for cost management: project control and strategic asset management. Those working in the field of project management will find parallels with the Project Management Institute (PMI) Guide to

the Project Management Body of Information (PMBOK Guide) as project control is a branch of project management.

The TCM Framework, with a greater emphasis on project management, strengthens many of the processes. More specifically, the TCM Framework recognizes strategic cost control strategies for business and resource planning, operations and maintenance, and product cost management, both upstream and downstream of project processes.

In particular, asset owners would appreciate the expanded coverage of historical data management, cost modeling, economic and decision-making analysis, and value analysis.

The TCM Framework represents a significant contribution to the cost management profession relevant to all industries. It is an AACE fundamental technical document that joins the existing body of expertise in associated fields (project management, operations management, and management accounting). It aligns with organizational and portfolio thinking, which connects all activities and procedures to overall company goals and objectives.

Project Management Body of Knowledge (PMBOK) Guide

"PMI defines the project management body of knowledge (PMBOK) as a term that describes the knowledge within the profession of project management. The project management body of knowledge includes proven traditional practices that are widely applied as well as innovative practices that are emerging in the profession." [23]

PMBOK contains both published and unpublished materials. The body of knowledge is continually evolving. This PMBOK® Guide describes a subset of the Project Management Information Body widely accepted as good practice.

PMBOK Guide explained further concerning Project Cost Management in chapter 7 :

Project Cost Management covers the procedures involved in preparing, forecasting, budgeting, financing, managing, and monitoring costs to complete the project within the range of the approved budget. The Project Cost Management processes were as follows:

- Plan Cost Management— The process of determining how project costs are
- to be calculated, budgeted, handled, tracked, and monitored.
- Estimate Costs— The process of establishing an estimate of the monetary
- resources required to complete the development of the project.

[23] Project Management Institute Project Management Institute. (2017). A Guide to the Project Management Body of Knowledge (PMBOK® Guide) — Sixth Edition and Agile Practice Guide (ENGLISH) (pp. 1-2). Newton Square, PA: Project Management Institute.

- Determine Budget— The process of aggregating the approximate costs of individual tasks or work packages to create an authorized cost baseline.
- Control Costs— The process of tracking the project's status to update the project's cost and manage adjustments to the cost baseline.

Company Cost Estimating Guidelines

The Company Guidelines in Cost Estimating contains several predecessor activities such as User's Terms of Reference Submittal, Scope Definition, FEED, and Bill of Quantity creation. Based on the detailed Bill of Quantity, the estimator should define every item's detailed price on the list with the basis of RFQ to suppliers or approved brand list, data bank, Company's internal unit price analysis, and other sources allowed as per the guidelines. The total detailed price will be multiplied by various factors, which differ based on the project's total precise price/estimation.

Step 3-DEVELOPMENT OF OUTCOMES

All the Guidelines mentioned in step 2 will be benchmarked with the three parts of the NASA Cost Estimating Process as defined in the NASA CEH. The steps of NASA's Cost Estimating Process showed in the table below :

NO	STEP OF NASA COST ESTIMATING PROCESS
	PART 1 : PROJECT DEFINITION TASKS
1	Receive Customer Request and Understand the Project
2	Build or Obtain a Work Breakdown Structure (WBS)
3	Define or Obtain the Project Technical Description
	PART 2 : COST METHODOLOGY TASKS
4	Develop Ground Rules and Assumptions
5	Select Cost Estimating Methodology
6	Select/Build Cost Model/Tool
7	Gather and Normalize Data
	PART 3 : COST ESTIMATE TASKS
8	Develop the Cost Estimate
9	Develop and Incorporate the Cost Risk Assessment
10	Document the Cost Estimate
11	Present the Cost Estimate Results
12	Update the Cost Estimate as Required

Table 1 NASA Cost Estimating Process[24]

The 12 steps of the NASA Cost Estimating Process, as mentioned in Table 1, will be used as attributes to be compared and select the best Cost Estimating Guideline using several methods

[24] Adapted from National Aeronautics and Space Administration. (2015). NASA Cost Estimating Handbook Version 4.0. Washington, DC.

and approaches available. The 12 attributes will be tested using Multi-Attributes Decision Making (MADM) non-compensatory approach for the first method.

Dominance

The dominance method indicates one or more alternatives that perform better or equal on all criteria than the other options. The approach is accompanied by the step-by-step removal of other choices from the collection of alternatives without compromising their shortcomings. The method of dominance is based entirely on the score criterion for this elimination.

The alternative is dominated and thus excluded from consideration if there is another alternative that is better based on one or more criteria and is equal to the remaining criteria. However, the likelihood of an option dominating or being dominated by all scores is minimal, so that in most cases, the method will not supply a result. The dominance method is mainly used to pre-screen a large set of alternatives, resulting in a smaller set of alternatives.

Below was the result of the Dominance technique used to compare the Cost Estimating Guidelines, with 12 steps of the NASA Cost Estimating Process as the attributes.

MAJOR ACTIVITIES/BEST PRACTICES ->	Receive Customer Request and Understand the Project	Build or Obtain a Work Breakdown Structure (WBS)	Define or Obtain the Project Technical Description	Develop Ground Rules and Assumptions	Select Cost Estimating Methodology	Select/Build Cost Model/Tool	Gather and Normalize Data	Develop the Cost Estimate	Develop and Incorporate the Cost Risk Assessment	Document the Cost Estimate	Present the Cost Estimate Results	Update the Cost Estimate as Required	Dominance?
NASA vs Company	Better	Better	Better	Better	Better	Better	Better	Better	Better	Better	Better	Better	YES
NASA vs GAO	Equal	Better	Equal	Better	Equal	Equal	Equal	Better	Equal	Better	Equal	Equal	MAYBE
NASA vs GPCCaR	Equal	Better	Equal	Better	Better	Better	Equal	Better	Equal	Better	Equal	Equal	YES
NASA vs TCM	Better	Better	Equal	Better	Equal	Better	Equal	Better	Better	Better	Better	Better	YES
NASA vs PMBOK	Better	Better	Equal	Better	Better	Better	Equal	Better	Better	Better	Better	Better	YES
Company vs GAO	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	NO
Company vs GPCCaR	Worse	Worse	Worse	Worse	Equal	Worse	Worse	Worse	Worse	Worse	Worse	Worse	NO
Company vs TCM	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	Worse	NO
Company vs PMBOK	Worse	Worse	Worse	Equal	Equal	Worse	Worse	Worse	Worse	Worse	Worse	Worse	NO
GAO vs GPCCaR	Equal	Equal	Equal	Equal	Better	Better	Equal	Equal	Equal	Better	Equal	Equal	MAYBE
GAO vs TCM	Better	Equal	Equal	Better	Equal	Better	Equal	Equal	Better	Better	Better	Better	YES
GAO vs PMBOK	Better	Better	Equal	Better	Better	Better	Equal	Equal	Better	Better	Better	Better	YES
GPCCaR vs TCM	Better	Equal	Equal	Better	Worse	Better	Equal	Equal	Better	Better	Better	Better	YES
GPCCaR vs PMBOK	Better	Better	Equal	Better	Equal	Better	Equal	Equal	Better	Better	Better	Better	YES
TCM vs PMBOK	Equal	Better	Equal	Better	Better	Equal	Equal	Equal	Better	Equal	Better	Equal	MAYBE

Table 2 Dominance Technique Applied[25]

The comparison between Cost Estimating Guidelines' alternatives were based on the fulfilled major activities or best practices list in each step of the NASA Cost Estimating Process (CEP). Table 3 showed the detailed percentage of fulfilled major activities or best practices list in each stage of NASA CEP for every Cost Estimating Guidelines alternatives. The detailed table showed the score/percent fulfilled of each step Major Activities/Best Practices Checklist for every alternative presented in the appendix.

[25] By Author

NO	STEP OF NASA COST ESTIMATING PROCESS	Total of Major Activities/Best Practice Checklist	ALTERNATIVES OF COST ESTIMATING GUIDELINE					
			NASA	Company	GAO	GPCCaR	TCM	PMBOK
	PART 1 : PROJECT DEFINITION TASKS							
1	Receive Customer Request and Understand the Project	5	9,43%	5,66%	9,43%	9,43%	6,60%	6,60%
2	Build or Obtain a Work Breakdown Structure (WBS)	6	11,32%	3,40%	7,55%	7,55%	7,55%	6,79%
3	Define or Obtain the Project Technical Description	3	5,66%	1,89%	5,66%	5,66%	5,66%	5,66%
	PART 2 : COST METHODOLOGY TASKS							
4	Develop Ground Rules and Assumptions	4	7,55%	1,89%	5,66%	5,66%	3,77%	1,89%
5	Select Cost Estimating Methodology	4	7,55%	5,66%	7,55%	5,66%	7,55%	5,66%
6	Select/Build Cost Model/Tool	4	7,55%	1,89%	7,55%	5,66%	3,77%	3,77%
7	Gather and Normalize Data	2	3,77%	3,46%	3,77%	3,77%	3,77%	3,77%
	PART 3 : COST ESTIMATE TASKS							
8	Develop the Cost Estimate	8	15,09%	7,55%	13,21%	13,21%	13,21%	13,21%
9	Develop and Incorporate the Cost Risk Assessment	3	5,66%	0,00%	5,66%	5,66%	3,46%	3,14%
10	Document the Cost Estimate	9	16,98%	3,77%	15,09%	13,21%	11,32%	11,32%
11	Present the Cost Estimate Results	3	5,66%	2,83%	5,66%	5,66%	3,77%	1,89%
12	Update the Cost Estimate as Required	2	3,77%	0,00%	3,77%	3,77%	1,89%	1,89%
	TOTAL	53	**100,00%**	**37,99%**	**90,57%**	**84,91%**	**72,33%**	**65,60%**

Table 3 Percentage of Each NASA CEP Steps for Cost Estimating Guideline Alternatives[26]

Step 4-SELECTION CRITERIA

Based on the result of the non-compensatory approach MADM with the Dominance Technique, it is clear that the NASA Cost Estimating Handbook and GAO were superior against another standard, and the Company standard was the worst alternative among others. However, with this technique, each step/attribute was considered equal to each other. The author will implement further analysis to find out the best alternative. The worst alternatives (company standard) will be excluded in further analysis using a compensatory approach.

FINDINGS

Step 5-ANALYSIS AND COMPARISON OF ALTERNATIVES

The compensatory approach of Multi-Attributes Decision Making will be tested for each cost estimating guidelines alternatives. In this case, the author will use the additive weighting technique of the compensatory approach. "Additive weighting is probably the most popular single-dimensional because it includes both the performance ratings and the importance weights of each attribute when evaluating alternatives."[27]

The procedures for using the additive weighting technique were as below :

1. Develop weights for attributes using ordinal rankings. In this paper, the attributes were each step of the NASA Cost Estimating Process.
2. Multiply the results of step 1 with appropriate non-dimensional attribute values.

[26] By Author
[27] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2014). Decision Making Considering Multiattributes. In Engineering Economy (16th ed., p. 587). Harlow, England: Pearson

3. The multiplied result for each attributes produces a partial contribution to the overall score for a particular alternative.
4. The partial contribution of all attributes summed, resulting in scores for each alternative.

For step 2, the author used the percent fulfilled of each Major Activities/Best Practices Checklist of NASA CEP's steps, as shown in Table 3, as the non-dimensional attribute values. In order to develop the ordinal rankings, as mentioned in step 1, the author used The Disjunctive Reasoning technique to grade the importance of every other NASA CEP step. As noted by GPCCaR, "Using the approach, we take a look at all the attributes and conduct a Pair-Wise comparison to determine which attributes are the most important by asking "which is more important?" and we give a score of 1 to the winning option and a score of 0 to the losing option. Then we add up the number of times each attribute scores a one, and that provides us with the relative importance of that attribute."[28]

1	Build or Obtain a WBS > Define/Obtain the Project Technical Description
2	Define/Obtain the Project Technical Description > Receive Customer Request and Understand the Project
3	Receive Customer Request and Understand the Project > Develop the Cost Estimates
4	Develop the Cost Estimates > Select Cost Estimating Methodology
5	Select Cost Estimating Methodology > Select/Build Cost Model/Tool
6	Select/Build Cost Model/Tool > Develop Ground Rules and Assumptions
7	Develop Ground Rules and Assumptions > Develop and Incorporate the Cost Risk Assessment
8	Develop and Incorporate the Cost Risk Assessment > Gather and Normalize Data
9	Gather and Normalize Data > Update the Cost Estimate as Required
10	Update the Cost Estimate as Required > Document the Cost Estimate
11	Document the Cost Estimate > Present the Cost Estimate Results

Table 4 Disjunctive Reasoning Technique Applied[29]

The table above showed the results of the disjunctive reasoning technique applied for each step of NASA CEP. The ">" means more important. Based on the important comparison of each attribute, the ordinal ranking was as follows:

[28] PP Admin (2015). GUILD OF PROJECT CONTROLS COMPENDIUM and REFERENCE (CaR). Module 10 : Managing Change http://www.planningplanet.com/guild/gpccar/managing-change-the-owners-perspective
[29] By Author

Step of NASA CEP	Number of Times on left of ">"
Build or Obtain a WBS	11
Define/Obtain the Project Technical Description	10
Receive Customer Request and Understand the Project	9
Develop the Cost Estimates	8
Select Cost Estimating Methodology	7
Select/Build Cost Model/Tool	6
Develop Ground Rules and Assumptions	5
Develop and Incorporate the Cost Risk Assessment	4
Gather and Normalize Data	3
Update the Cost Estimate as Required	2
Document the Cost Estimate	1
Present the Cost Estimate Results	0

Table 5 NASA CEP Steps Ordinal Ranking[30]

The higher number of ordinal ranking was signifying the greater importance of attributes. In order to develop the weight for each attribute, the ranking should be normalized by dividing each ranking number by the total of all the rankings.

Calculation of Weighting Factor			Calculation of Scores for Each Alternatives									
			NASA		GAO		GPCCaR		TCM		PMBOK	
Step of NASA CEP	Relative Rank	Normalized Weight (A)	Dimensionless Value (B)	Score (AxB)	Dimensionless Value (B)	Score (AxB)	Dimensionless Value (B)	Score (AxB)	Dimensionless Value (B)	Score (AxB)	Dimensionless Value (B)	Score (AxB)
Build or Obtain a WBS	11	0,22	11,32%	0,024	7,55%	0,016	7,55%	0,016	7,55%	0,016	6,79%	0,015
Define/Obtain the Project Technical Description	10	0,20	5,66%	0,011	5,66%	0,011	5,66%	0,011	5,66%	0,011	5,66%	0,011
Receive Customer Request and Understand the Project	9	0,18	9,43%	0,017	9,43%	0,017	9,43%	0,017	6,60%	0,012	6,60%	0,012
Develop the Cost Estimates	8	0,16	15,09%	0,024	13,21%	0,021	13,21%	0,021	13,21%	0,021	13,21%	0,021
Select Cost Estimating Methodology	7	0,14	7,55%	0,010	7,55%	0,010	5,66%	0,008	7,55%	0,010	5,66%	0,008
Select/Build Cost Model/Tool	6	0,12	7,55%	0,009	7,55%	0,009	5,66%	0,007	3,77%	0,004	3,77%	0,004
Develop Ground Rules and Assumptions	5	0,10	7,55%	0,007	5,66%	0,006	5,66%	0,006	3,77%	0,004	1,89%	0,002
Develop and Incorporate the Cost Risk Assessment	4	0,08	5,66%	0,004	5,66%	0,004	5,66%	0,004	3,46%	0,003	3,14%	0,002
Gather and Normalize Data	3	0,06	3,77%	0,002	3,77%	0,002	3,77%	0,002	3,77%	0,002	3,77%	0,002
Update the Cost Estimate as Required	2	0,04	3,77%	0,001	3,77%	0,001	3,77%	0,001	1,89%	0,001	1,89%	0,001
Document the Cost Estimate	1	0,02	16,98%	0,003	15,09%	0,003	13,21%	0,003	11,32%	0,002	11,32%	0,002
Present the Cost Estimate Results	0	0,00	5,66%	0,000	5,66%	0,000	5,66%	0,000	3,77%	0,000	1,89%	0,000
TOTAL	51	1,00		0,114		0,101		0,095		0,086		0,080

Table 6 Additive Weighting Technique Compensatory Approach for alternatives[31]

The additive weighting technique results show that the NASA Cost Estimating Handbook got the best scores with 0.114, followed by GAO Cost Estimating and Assessment Guide with 0.101 scores as the second best. The score between the NASA Cost Estimating Handbook (CEH) and GAO Cost Estimating and Assessment Guide was quite close. This result is by the statement in the NASA CEH, "NASA's cost estimating process is consistent with the estimating process recommended within GAO's Cost Estimating and Assessment Guide. NASA has retained the

[30] By Author
[31] By Author

structure of its general cost estimating process flow for consistency and tailoring purposes, rather than exactly duplicate the GAO Process."[32] It could be concluded that NASA CEH was adopting all GAO's Cost Estimating and Assessment Guide and complements it with added appropriate detailed steps for NASA's project-specific purposes and objectives.

Step 6-SELECTION OF PREFERRED ALTERNATIVES

Based on the Dominance Technique and Additive Weighting technique applied to each Cost Estimating Guide alternatives, the NASA Cost Estimating Handbook maintains its position as the best alternative cost estimating guidelines. With dominance technique, NASA Cost Estimating Handbook proved to be superior compared to other alternatives. And it also gets the highest score in additive weighting technique results, with a score of 0,114. The Company should adapt the NASA Cost Estimating Handbook steps to develop the cost estimate and evaluate the current guideline of the cost estimating process used by the Company.

Step 7-PERFORMANCE MONITORING

Based on NASA Cost Estimating Handbook, the Company had to adapt the current Company cost estimating guideline for Aviation Facilities Project by following the NASA CEH's 12 steps of the Cost Estimating Process. Based on benchmarking, the author found two steps of the NASA Cost Estimating Process that have 0% implementation in the current Company cost estimating process, i.a. Step 9 and 12. The author used the Pareto chart to prioritize the steps to be adopted immediately to Company guideline based on the most significant deviation to each major activities/best practices of NASA CEP's steps.

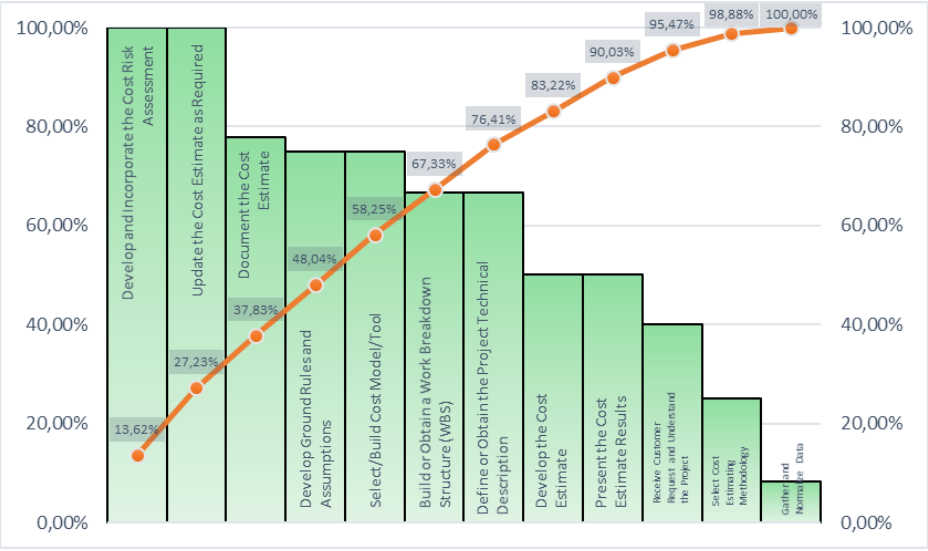

Figure-6 Company Cost Estimating Process Deviation Compared to NASA Cost Estimating Process[33]

[32] National Aeronautics and Space Administration. (2015). NASA Cost Estimating Handbook Version 4.0 (p. 4). Washington, DC.
[33] By Author

The improvement of current Company cost estimating guidelines based on NASA CEP should start based on prioritization showed above. The Company should implement the process that had the biggest deviation from NASA CEP first, followed by adaptation to detailed major activities/best practices of NASA CEP steps to complements the current process that already got a good score against NASA CEP (below 40% deviation).

CONCLUSIONS

As mentioned in step 1 of this paper, the study should find the answers to the question below :

- How much is the score of the Company's current cost estimating practices compared to NASA Cost Estimating Handbook best practices?
  Based on benchmarking results, the Company's current cost estimating practices only got 37,99% compliance with NASA CEH's Cost Estimating Process.

- What is the best international cost estimating guidelines to be adopted by the Company for Aviation Facilities Project?
  Based on the results of the study and comparison of selected cost estimation guidelines by Multi-Attributes Decision making using both non-compensatory and compensatory approach (Dominance, Disjunctive Reasoning, and Additive Weighting Technique). The NASA Cost Estimating Handbook was superior to other international guidelines and should be adapted to the current Company cost estimating procedure for Aviation Facilities Project.

The adaptation should start from these top 3 steps that had the most significant deviation or lowest percent compliance to NASA CEP's major activities / best practices :

1. Develop and Incorporate the Cost Risk Assessment

Major Activities should be implemented in the Company's cost estimating guideline :

a. The Company should perform Cost-Risk Assessment
b. The Company should perform Sensitivity Analysis
c. The Company should choose the level of unallocated future expense

2. Update the Cost Estimate as Required

Major Activities should be implemented in the Company's cost estimating guideline :

a. The Company should assess and utilize customer feedback along with Lessons learned and incorporate this feedback into the next version of the estimate
b. The Company should update the estimate when project content changes and as the project moves through its life-cycle phases and conducts milestone reviews.

3. Document the Cost Estimate

Major Activities should be implemented in the Company's cost estimating guideline :

a. When Company's estimator used a Cost Estimating Relationship (CER), It should be presented, and its source must be completely cited, or the model and collection of data from which it has been calibrated must be cited. The cost estimator reviewing the cost documentation should obtain sufficient details either from the document or from the sources referred to therein to reconstruct the CER and determine its related statistics. CER documentation should include descriptive statistics. This knowledge is vital for an adequate evaluation of the applicability of the CER.
b. When Company's estimators used subjective judgments to adjust estimates made by analogy with other systems or components of systems, they must identify the sources of those judgments (e.g., cost analysts, engineers). The estimators also had to cite each element's costs in engineering or grassroots estimate.
c. The Company should present detailed examples of methodologies used to estimate the first and second levels of the cost elements typically included in life-cycle cost estimates (LCCEs) for each phase.
d. The Company must document the Areas of ambiguity (e.g., ongoing agreements, concurrence, risk plan, performance criteria that have not yet been met, appropriateness of analogies, level of expertise on support principles, essential assumptions, etc.) must be documented.
e. The Company should perform sensitivity analysis to include the cost of changing significant input parameters. Risk analysis should consist of risk-adjusted point estimates. They also should perform crosschecks for all high-cost, high-risk portions of the estimate
f. When Company's estimator used an approach, GR&A, inputs, sources, etc., for the cost-risk analysis. It must be fully documented
g. The Company should track through a comparison or a cost trace when an estimate changes. Documentation must include the specific reasons for the change

FOLLOW ON RESEARCH

After the full adaptation of NASA's CEP, Company should keep monitoring the Aviation Facilities project that was estimated using the improved cost estimating guideline. The actual project's cost realization needs to be documented and compared with the planning cost. The result will be used as the evaluation of the improved cost estimating guideline. The Company should also compare the project results after implementing an improved cost estimating approach with historical data of past Aviation Facilities project to directly see the improvement of accuracy and reliability of the estimate.

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APPENDICES

Appendix I

NASA Cost Estimating Process Major Activities / Best Practices against alternatives

STEP 1								
Receive Customer Request and Understand the Project								
No	Major Activities		NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Identify the customer(s) and stakeholder(s) who will use the results of the estimate.		1	1	1	1	0	0
2	Document expectations for program/project by :							
	a.	Identifying the purpose of the estimate	1	1	1	1	1	1
	b.	Specifying mission needs, objectives, and goals	1	1	1	1	1	1
	c.	assessing the operating environment and life-cycle phase.	1	0	1	1	0,5	0,5
3	Gather and review all relevant project data for evaluation (e.g., an existing technical baseline or Cost Analysis Data Requirement [CADRe], previous estimates, lessons learned and customer feedback, budget data, and programmatic data such as schedules). Discuss schedule, data, expectations, and resource requirements with the requesting customer.		1	0	1	1	1	1
		TOTAL	5	3	5	5	3,5	3,5
		%Score to NASA Cost Estimating Process	100,00%	60,00%	100,00%	100,00%	70,00%	70,00%

STEP 2								
Build or Obtain a Work Breakdown Structure (WBS)								
No	Major Activities		NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	The WBS structure :		1	0,8	1	1	1	0,6
	a.	Project and Technical Planning & Scheduling	0,2	0,2	0,2	0,2	0,2	0,2
	b.	Cost estimation and budget formulation (in particular, costs collected in a product-oriented WBS can be compared to historical data collected for the same products)	0,2	0,2	0,2	0,2	0,2	0,2
	c.	Definition of the scope of statements of work and specifications for contract efforts	0,2	0,2	0,2	0,2	0,2	0,2
	d.	Project status reporting, including schedule, cost, workforce, technical performance, and integrated cost/schedule data (such as EVM and Estimate at Completion [EAC])	0,2	0	0,2	0,2	0,2	0
	e.	Creation of plans such as the Systems Engineering Management	0,2	0,2	0,2	0,2	0,2	0
2	Preparing or Obtaining a WBS :							
	a.	Begin with the NASA standard flight project WBS (only to Level 2)	1	0	0	0	0	0
	b.	Define the WBS elements to the lowest level appropriate to the level of project maturity for the estimate;	1	1	1	1	1	1
	c.	For a WBS structure below Level 2, refer to the CADRe standard as a reference for suggested lower level breakouts	1	0	0	0	0	0
	d.	Create a dictionary to define the WBS elements	1	0	1	1	1	1
	e.	Ensure that the cost estimating WBS is consistent with other project functions including scheduling (the cost estimator is responsible for preparing the cost WBS and mapping it back to the standard WBS).	1	0	1	1	1	1
		TOTAL	6	1,8	4	4	4	3,6
		%Score to NASA Cost Estimating Process	100,00%	30,00%	66,67%	66,67%	66,67%	60,00%

STEP 3							
Define or Obtain the Project Technical Description							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Gather and review all relevant project data (e.g., existing technical baseline or CADRe, previous estimates, lessons learned and customer feedback, and budget data as well as other programmatic data such as schedules);	1	0	1	1	1	1
2	Collect system characteristics, configuration, quality factors, security, operational concept, and the risks associated with the system	1	1	1	1	1	1
3	Obtain the system's (or the project's) milestones, schedule, management strategy, implementation/deployment plan, including launch, test strategy, security considerations, and acquisition strategy.	1	0	1	1	1	1
	TOTAL	3	1	3	3	3	3
	%Score to NASA Cost Estimating Process	100,00%	33,33%	100,00%	100,00%	100,00%	100,00%

STEP 4							
Develop Ground Rules and Assumptions (GR&A)							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Establish a set of programmatic, technical, and schedule GR&A to define the scope of the estimate (i.e., what costs are being included and what costs are excluded)	1	1	1	1	1	1
2	Coordinate and gain agreement/approval from the Program/project Manager (P/pM) (or other cost estimate point of contact)	1	0	1	0	0	0
3	Achieve consensus on the GR&A with stakeholders, vendors, end users, etc., to ensure their applicability and to avoid problems leading to inaccurate or misleading estimates	1	0	0	1	0	0
4	Document the GR&A as they evolve during the entire estimate process	1	0	1	1	1	0
	TOTAL	4	1	3	3	2	1
	%Score to NASA Cost Estimating Process	100,00%	25,00%	75,00%	75,00%	50,00%	25,00%

STEP 5							
Select Cost Estimating Methodology							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Analogy Method	1	1	1	1	1	1
2	Parametric Method	1	0	1	1	1	1
3	Grassroots/Eng Build Up	1	1	1	1	1	1
4	Extrapolation from Actuals	1	1	1	0	1	0
	TOTAL	4	3	4	3	4	3
	%Score to NASA Cost Estimating Process	100,00%	75,00%	100,00%	75,00%	100,00%	75,00%

STEP 6							
Select/Build Cost Model/Tool							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Review available choices and make a selection. If no suitable alternatives exist, explore the option of creating a model	1	0	1	1	1	1
2	Ensure that the model is validated.	1	0	1	0	1	0
3	Be prepared to defend the choice	1	0	1	1	0	0
4	Build your own model	1	1	1	1	0	1
	TOTAL	4	1	4	3	2	2
	%Score to NASA Cost Estimating Process	100,00%	25,00%	100,00%	75,00%	50,00%	50,00%

STEP 7							
Gather and Normalize Data							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Data Collection	1,00	0,84	1,00	1,00	1,00	1,00
	a. Cost Data	0,33	0,22	0,33	0,33	0,33	0,33
	b. Technical/Operational Data	0,33	0,33	0,33	0,33	0,33	0,33
	c. Project Data	0,33	0,28	0,33	0,33	0,33	0,33
2	Normalize Data	1	1	1	1	1	1
	TOTAL	2,00	1,84	2,00	2,00	2,00	2,00
	%Score to NASA Cost Estimating Process	100,00%	91,75%	100,00%	100,00%	100,00%	100,00%

STEP 8							
Develop the Cost Estimate							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Verify The GR&A	1	0	0	0	0	0
2	Populate the model with the normalized data	1	1	1	1	1	1
3	Ensure that the estimate is full cost compliant	1	0	1	1	1	1
4	Run the model to calculate cost	1	1	1	1	1	1
5	Time-phase the estimate	1	0	1	1	1	1
6	Adjust the estimate for inflation	1	1	1	1	1	1
7	Conduct any cross-check estimate or estimate reconciliation	1	0	1	1	1	1
8	Develop or update the cost track to previous or independent estimate	1	1	1	1	1	1
	TOTAL	8	4	7	7	7	7
	%Score to NASA Cost Estimating Process	100,00%	50,00%	87,50%	87,50%	87,50%	87,50%

STEP 9							
Develop and Incorporate the Cost Risk Assessment							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Cost-Risk Assessment	1	0	1	1	0,83	0,67
	Determine the project's cost drivers and risks with input from the P/pM and staff	0,17	0,00	0,17	0,17	0,17	0,17
	Develop probability distributions for the technical and schedule cost drivers	0,17	0,00	0,17	0,17	0,17	0,17
	Develop probability distributions for the cost model uncertainty	0,17	0,00	0,17	0,17	0,17	0,00
	Run the risk model	0,17	0,00	0,17	0,17	0,17	0,17
	Identify the probability that the actual cost is less than or equal to the point estimate	0,17	0,00	0,17	0,17	0,17	0,17
	Recommend sufficient UFE to achieve the desired percent confidence level.	0,17	0,00	0,17	0,17	0,00	0,00
2	Sensitivity Analysis	1	0	1	1	1	1
3	Choosing the Level of Unallocated Future Expense	1	0	1	1	0	0
	TOTAL	3	0	3	3	1,83	1,67
	%Score to NASA Cost Estimating Process	100,00%	0,00%	100,00%	100,00%	61,11%	55,56%

STEP 10							
Document the Cost Estimate							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Begin documentation efforts early and continue throughout the cost estimating process. Document sources in the actual models and include these details in the estimate write-up and in the estimate presentations. Provide the data or rationale to support qualitative or subjective inputs, like percent new design or manufacturing complexity.	1	1	1	1	1	1
2	When a CER is used, it should be presented, and its source must be cited fully, or the model and the set of data with which it was calibrated must be cited. A cost estimator reviewing the cost documentation should be able to obtain enough information either from the document or from the sources cited therein to reconstruct the CER and evaluate its associated statistics. CER documentation should include descriptive statistics (see Appendix C). This information is necessary to adequately assess the applicability of a CER.	1	0	1	1	1	1
3	Where subjective judgments are used to adjust estimates made by analogy with other systems or components of systems, the sources of those judgments must be identified (e.g., cost analysts, engineers) and full citations for the source(s) of the costs of each element in an engineering or grassroots estimate must also be cited.	1	0	1	1	1	1
4	Present detailed examples of methodologies used to estimate first and second levels of the cost elements normally included in life-cycle cost estimates (LCCEs) for each phase.	1	0	0	1	1	1
5	When used in the estimate, actual cost history from past or present contracts or analogous programs should be provided	1	1	1	0	0	0
6	Areas of uncertainty (such as pending negotiations, concurrency, schedule risk, performance requirements that are not yet firm, appropriateness of analogies, level of knowledge about support concepts, critical assumptions, etc.) must be documented	1	0	1	0	0	0
7	Sensitivity analysis should be performed to include the cost of changing significant input parameters. Risk analysis should include risk-adjusted point estimates. Crosschecks should be included for all high-cost, high-risk portions of the estimate	1	0	1	1	1	1
8	The approach, GR&A, inputs, sources, etc., for the cost-risk analysis must be fully documented	1	0	1	1	1	1
9	Tracking through a comparison or a cost trace is required when an estimate changes. Documentation must include the specific reasons for the change	1	0	1	1		
	TOTAL	9	2	8	7	6	6
	%Score to NASA Cost Estimating Process	100,00%	22,22%	88,89%	77,78%	66,67%	66,67%

STEP 11							
Present the Cost Estimate Results							
No	Major Activities	NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Create briefing materials and supporting documentation for internal and external presentations, as appropriate.	1	0,5	1	1	1	0
2	Present and defend the estimate.	1	1	1	1	1	0
3	Gather and provide feedback to capture improvements for the next estimate.	1	0	1	1	0	1
	TOTAL	3	1,5	3	3	2	1
	%Score to NASA Cost Estimating Process	100,00%	50,00%	100,00%	100,00%	66,67%	33,33%

STEP 12								
Update the Cost Estimate as Required								
No	Major Activities		NASA	Company	GAO	GPCCaR	TCM	PMBOK
1	Assess and utilize customer feedback along with Lessons learned and incorporate this feedback into the next version of the estimate.		1	0	1	1	0	0
2	Update the estimate when project content changes and as the project moves through its life-cycle phases and conducts milestone reviews.		1	0	1	1	1	1
		TOTAL	2	0	2	2	1	1
		%Score to NASA Cost Estimating Process	100,00%	0,00%	100,00%	100,00%	50,00%	50,00%

About the Author

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Femto Nur Pratama is a project engineer with seven years of professional experience in the oil and gas sectors. Currently, he works as an engineer at Infrastructure Management & Project Department of Indonesia's national oil company. During his career, he has an experience as an Instrument Engineer, Cost Estimator, Project Engineer, and he has been involved in several projects including LNG Onshore Receiving Facilities & Offtake Station, LNG Regasification Plant, Fuel Terminal, Pipeline, and Aviation Fuel Supply Facilities. He holds a bachelor's degree in Electronics and Instrumentation from Gadjah Mada University (UGM). He is attending a distance learning mentoring course under the tutorage of Dr. Paul D. Giammalvo, CDT, CCE, MScPM, MRICS, GPM-m Senior Technical Advisor, PT Mitrata Citragraha, to attain Certified Cost Professional certification from AACE International.

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