Developing a Quantitative Decision Model of Project Completion Strategies in Distressed Infrastructure Projects[1, 2]

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ABSTRACT

Distressed infrastructure projects often suffer from a gap between performance measurement and strategic recovery decision-making. This paper develops a quantitative decision model for selecting project completion strategies by integrating Earned Value Management (EVM), engineering economic analysis, and Multi-Attribute Decision Making (MADM). Using a distressed LPG infrastructure project as the case study, EVM metrics are applied to diagnose current performance and to forecast future project outcomes. Five feasible completion alternatives are then evaluated using fourteen criteria covering cost, schedule, economic value, risk, contractual clarity, operational readiness, and reputational impact. Six MADM techniques are applied, followed by sensitivity and switching analyses to test ranking robustness. The proposed framework provides a systematic, empirical, and theory-based approach for translating project performance data into transparent and defensible recovery decisions under uncertainty.

Keywords: Distressed Infrastructure Projects, Project Completion Strategy, Earned Value Management, Engineering Economic Analysis, Decision Strategy

INTRODUCTION

A. Indonesia's LPG Demand and Infrastructure Development Challenges

Indonesia's consumption of liquefied petroleum gas (LPG) has exhibited a steady increase throughout the past decade. The Indonesian Ministry of Energy and Mineral reported that "domestic production has remained relatively unchanged at around 1.97

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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/

million tons annually and total consumption escalated to 8.7 million tons, reflecting a growth rate of 58.9% in 2023, compared to 2013."[3]

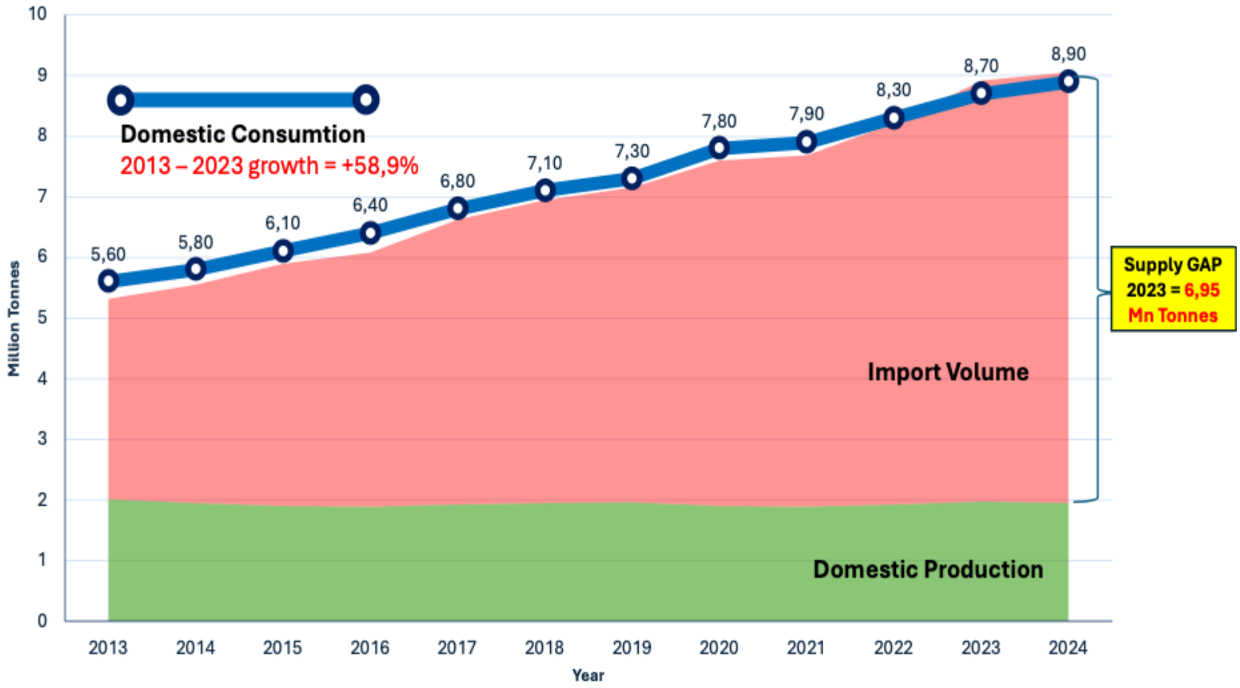

Figure 1. Indonesia LPG Total Consumption, Domestic Production, and Import Volume (2013–2023)[4]

The challenge is not only the demand volume, but also the uneven distribution of infrastructure. Development has predominantly occurred in Java, resulting in neglect of Eastern Indonesia. To mitigate this disparity, the Indonesian government commenced the construction of four LPG terminals in Eastern Indonesia in 2017.[5] The progress and status of these projects are detailed in Table 1.

[3] Ministry of Energy and Mineral Resources, Republic of Indonesia. (2024). Handbook of energy & economic statistics of Indonesia 2024. https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-economic-statistics-of-indonesia-2024.pdf
[4] Ministry of Energy and Mineral Resources, Republic of Indonesia. (2024). Loc. Cit.
[5] Ministry of Energy and Mineral Resources, Republic of Indonesia. (2017). Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 2157 K/10/MEM/2017 tentang penugasan kepada PT Pertamina (Persero) dalam pembangunan dan pengoperasian tangki penyimpanan bahan bakar minyak dan liquefied petroleum gas.

Table 1. List of LPG Construction Projects in Eastern Indonesia6

Project	Progress	Original Value (IDR)	Actual Cost (IDR)	Cost Overrun	Planned Duration	Actual Duration	Schedule Overrun
A*	100%	181.400.000.000	199.530.748.600	9,99%	18 months	34 months	88,80%
B*	100%	159.600.000.000	175.239.432.066	9,80%	18 months	23 months	27,70%
C*	100%	163.000.000.000	168.112.000.000	3,14%	18 months	59 months	227%
D**	94,35%	142.000.000.000	TBD	TBD	18 months	>88 months	>388%

*based on contract value / agreement
**the project still on going construction

The data indicate that all four projects experienced both cost and schedule overruns. Project D remains incomplete with no confirmed completion date. This paper, therefore, focuses on Project D as the case study, representing a distressed infrastructure project requiring strategic resolution.

B. Cost and Schedule Overrun

In general, project overruns remain widespread in capital project delivery. Kearney reports that "sixty percent of capital projects have more than a 10 percent overrun on costs and schedules, and nearly a third have more than 25 percent overrun on costs."[7] In Indonesia's downstream oil and gas industry, Zilikram states that "project overruns, affecting both time and budget, are widespread, with no exception in Indonesia's downstream oil & gas industry."[8] Similarly, Wisnugroho reports that "there are at least about 56% of projects experiencing 10% cost and schedule overrun and 36% experiencing up to 25% at 45 sample projects."[9] By standard definition, Mukuka, Aigbavboa, and Thwala state that "schedule overrun refers to the late completion or late delivery, from the time specified or agreed by all parties of the construction project, while

[6] Author
[7] Kearney. (2017, February 27). Excellence in capital projects: A goal yet to be achieved. https://www.kearney.com/industry/energy/article/-/insights/excellence-in-capital-projects-a-goal-yet-to-be-achievedm
[8] Zilikram, M. F. (2023, October). Benchmarking Indonesia's downstream oil & gas construction: Evaluating project scheduling and cost estimating processes against global "best-tested and proven" practices. PM World Journal, 12(10). https://pmworldjournal.com/article/benchmarking-indonesias-downstream-oil-gas-construction
[9] Wisnugroho, J. (2020, February). Indonesia oil & gas cost estimating vs international "best-tested and proven" practices: A benchmarking study. PM World Journal, 9(2). https://pmworldjournal.com/article/indonesia-oil-gas-cost-estimating-vs-international-best-tested-and-proven-practices

budget overrun occurs when a project is completed at a cost higher than what was budgeted."[10]

C. Earned Value as a Project Performance Diagnosis and Forecasting Tool

Giammalvo and the PTMC Team define Earned Value Management (EVM) as "a system consisting of a 'toolbox' of tested and proven project management tools, techniques, or methods for capturing physical progress, measuring, assessing, and evaluating that physical progress against an approved baseline, and looking at both historic and predicted or forecast performance, analyzing, and evaluating the impacts and making recommendations."[11]

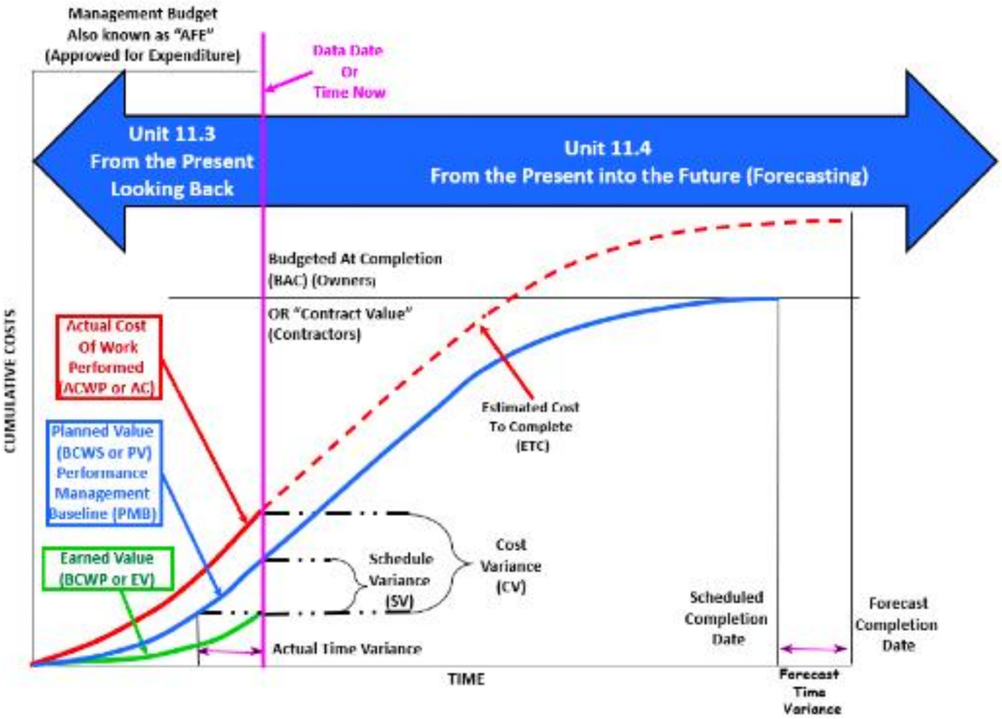

Figure 2 EVM S-curve illustrating performance measurement to date and completion forecast[12]

In the present project case, current EVM metrics confirm high cost and schedule overruns. However, EVM primarily functions as a performance measurement and early-warning system; it does not, by itself, select the optimal recovery strategy. GAO explains that EVM metrics help managers "understand performance status and to estimate cost

[10] 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. https://doi.org/10.1016/j.promfg.2015.07.989
[11] Giammalvo, P. D., & PTMC. (2021). Project controls/PMO handbook of "best tested and proven practices": Unit 11—Managing progress (CC BY-SA 4.0). PTMC.
[12] Giammalvo, P. D., & PTMC. (2021). Loc. cit

and time to complete, EVM can alert program managers to potential problems sooner than expenditures alone can."[13] Therefore, EVM outputs should be used as key inputs to a further decision model for evaluating remedial alternatives.

D. Early Decision and Cost of Delay

The costs of delays should be considered. Besides contractual penalties, delays can diminish project value by causing lost revenue from operations, higher owner overhead, and the present-value effect of delayed cash inflows. Sullivan, Wicks, and Koelling explain that "most of the cash-flow consequences of the alternatives lie in the future."[14] For the purposes of this study, Cost of Delay (CoD) is defined as the cumulative effect of lost daily net revenue, additional overhead costs during the delay period, and any loss in the present value of future cash flows caused by the delay in project completion. This formulation is consistent with engineering-economy principles of discounted cash-flow analysis and with Reinertsen's view that "without a cost of delay, queues appear to be free and therefore, unworthy of attention." [15,16]

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[13] U.S. Government Accountability Office. (2020). Cost estimating and assessment guide: Best practices for developing and managing program costs (GAO-20-195G, pp. 227).
[14] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering economy (17th ed., Global ed.). Pearson Education Limited.
[15] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit
[16] Reinertsen, D. G. (2009). The principles of product development flow: Second-generation lean product development. Celeritas Publishing

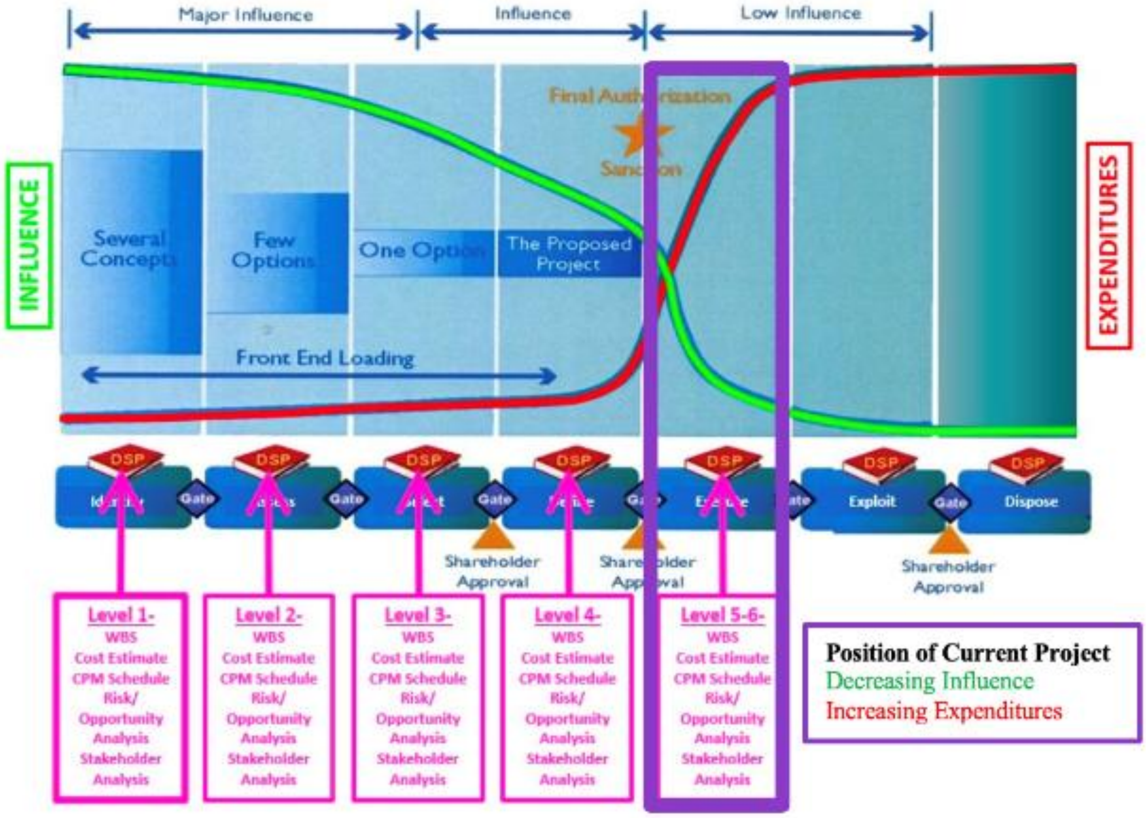

***Figure 3. Decision Support Package (DSP) Content Across Phase Gates Illustrated*[17]**

Moreover, decision timing is critical. As illustrated by the MacLeamy curve and Paulson curve in Figure 3, "the cost impact of project changes increases sharply as a project progresses from early design into execution, while the owner's ability to influence project outcomes declines significantly."[18,19] Consequently, corrective decisions made later in the project life cycle tend to be more expensive. Stecklein et al. state that "the costs to fix errors increase as the project matures."[20] Early decision-making supported by economic and risk-informed evaluation can improve cost visibility. GAO states that "using

[17] Paulson, Boyd C. 1976. "Designing to Reduce Construction Costs." Journal of the Construction Division 102 (4): 587-592. The actual graphic was taken from the Zadco Oil website about 10 years ago and is no longer accessible.
[18] MacLeamy, P. (2004). The MacLeamy Curve [presentation/diagram]. MSA-IPD. https://msa-ipd.com/MacleamyCurve.pdf
[19] Paulson Jr., B.C., 1976. Designing to Reduce Construction Costs. Journal of the Construction Division, 102(4), pp.587–592.
[20] Stecklein, J. M., Dabney, J., Dick, B., Haskins, B., Lovell, R., & Moroney, G. (2004). Error cost escalation through the project life cycle. National Aeronautics and Space Administration, Lyndon B. Johnson Space Center.
https://ntrs.nasa.gov/citations/20100036670

a risk and uncertainty analysis, a cost estimator can inform decision-makers about a program's potential range of costs and cost drivers."[21]

E. Research Questions

Based on this condition, the study is guided by the following three research questions:

1. What is the current performance profile of the project using Earned Value metrics (CPI, SPI, CV, SV), and what are the forecasted Estimate-to-Complete (ETC) and Estimate-at-Completion (EAC) under standard EVM forecasting methods?

2. What feasible project completion alternatives are available, and what are the quantitative outcomes for each alternative?

3. Which alternative maximizes project owner value when evaluated by a quantitative decision model, and how robust is the recommended ranking to key assumption changes?

[21] U.S. Government Accountability Office. (2020). Loc.Cit

METHODOLOGY

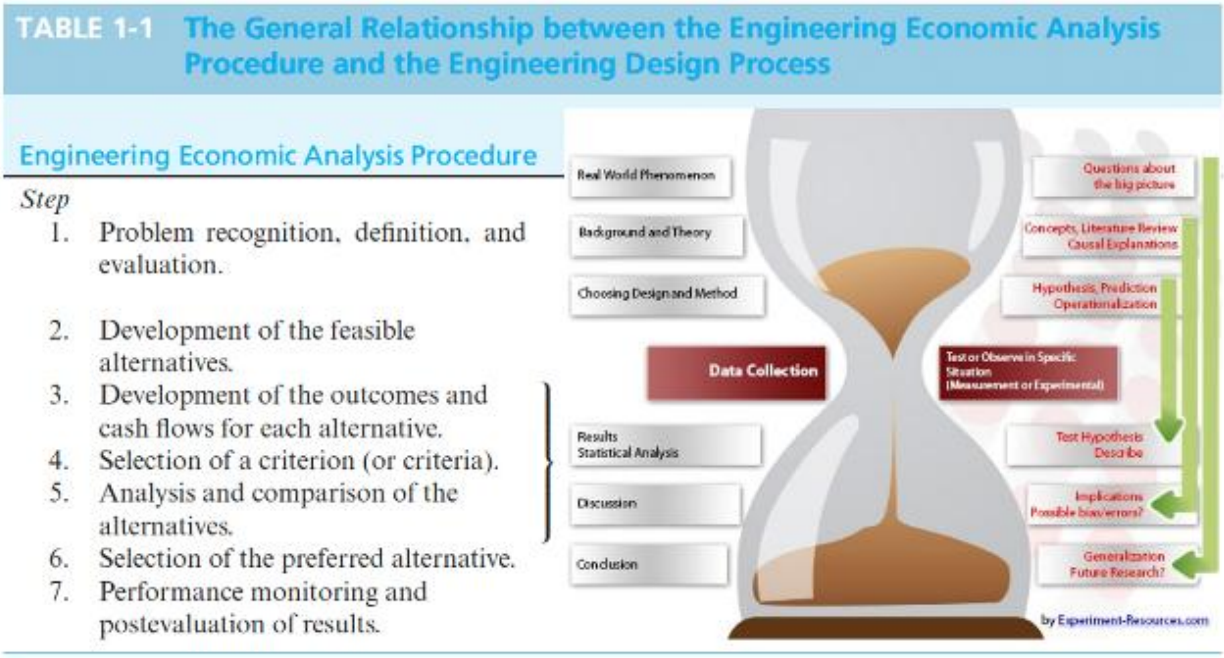

Figure 4 Engineering Economic Analysis Procedure[22]

In writing this paper, the author will refer to the Engineering Economic Analysis Procedure with its seven steps of analysis.[23]

Step 1 - Problem Definition

Using EVM Matrix analysis, the primary project diagnosis can be established. The EVM analysis was developed using an Owner's Independent Performance Measurement Baseline (PMB). As Giammalvo and the PTMC Team note, "it is not a 'best tested and proven' approach for the owner to track project performance against the contractor's PMB alone."[24] This is because the contractor's PMB does not capture owner-side management activities, owner-supplied equipment or materials, and owner's risk contingency; as Giammalvo states that "excluding these items can produce an overly optimistic CPI and an unrealistically optimistic SPI for the owner."[25]

[22] Steps of the Scientific Method – The Stages of Scientific Research. (n.d.). Explorable.com. https://explorable.com/steps-of-the-scientific-method
[23] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit
[24] Giammalvo, P. D., & PTMC. (2021). Loc. Cit
[25] Giammalvo, P. D., & PTMC. (2021). Loc. Cit

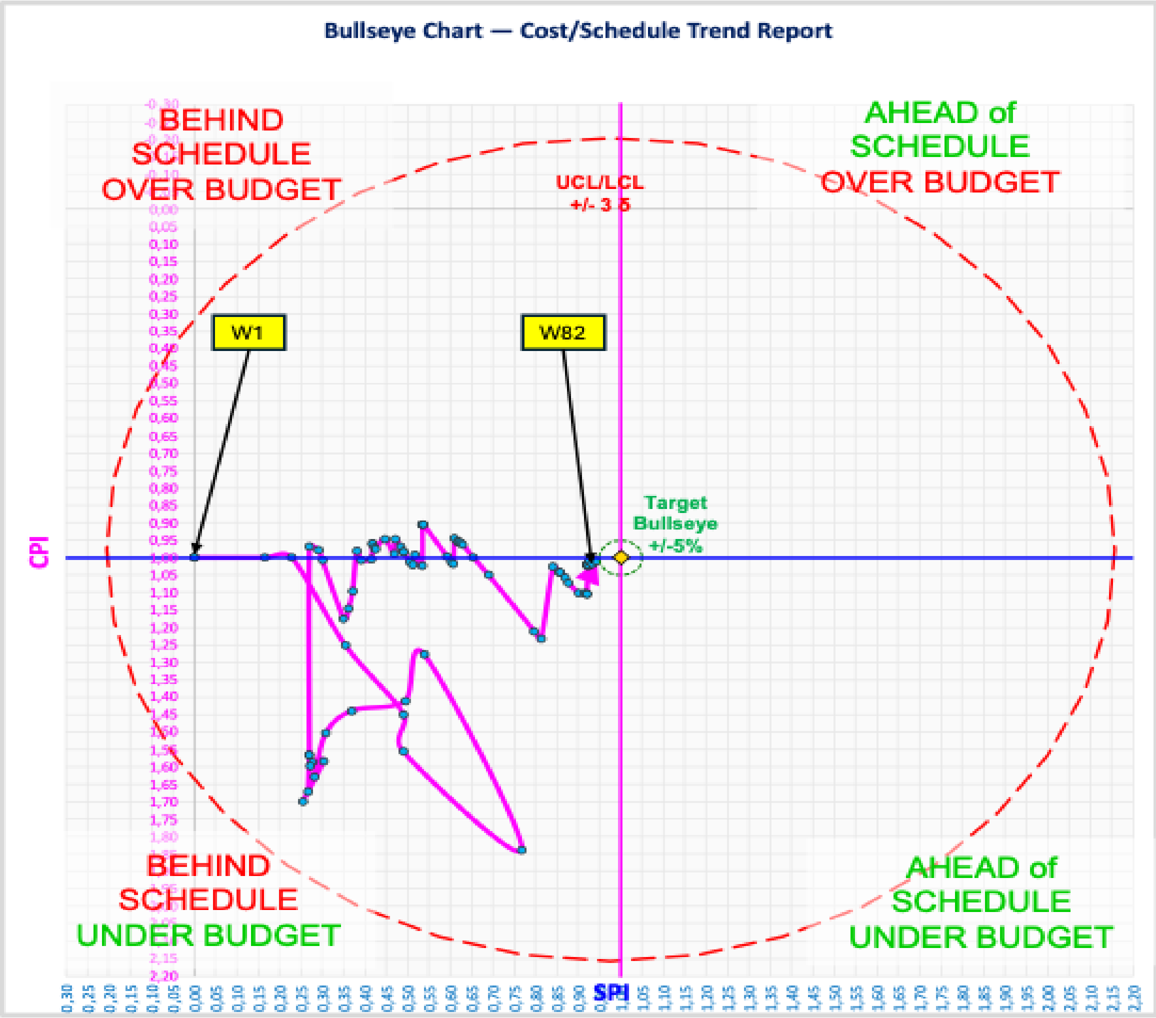

Figure 5 Bullseye Chart – Cost/Schedule Trend Report for Project D[26]

This study tracks the CPI and SPI using a bullseye chart. All observed data points are within ±3 sigma control limit, indicating statistically stable variation in cost and schedule performance. But the points are outside the target ±5% bullseye, so the project is performing stably but not achieving the performance target. The project continued to experience schedule delays and cost overruns. As the project neared completion, things began to settle down near the reference point. This is consistent with Lipke's explanation that "as the EV approaches project completion, it converges to the planned cost. Schedule Variance must converge to 0.0 at project completion, while the Schedule Performance Index concludes at 1.0."[27]

[26] Putra, H. C. (2026, April 8). Project performance analysis using earned value management: An owner's perspective. 14 Clover.
[27] Lipke, W. (2012, September). Earned schedule contribution to project management. PM World Journal, 1(2). https://pmworldlibrary.net/wp-content/uploads/2013/02/PMWJ-Sep2012-LIPKE-FeaturedPaper-EarnedScheduleContributiontoPM.pdf

The diagnostic results show that the project has hit a critical juncture. Moving forward with the current approach won't likely get us to an acceptable outcome. Instead, we need to carefully examine what completion strategies are possible so we can deliver better results for the owner while keeping a lid on the risks and costs that come with more delays.[28,29]

Step 2 - Identify The Feasible Alternative

In engineering economic analysis, a defensible recommendation begins with the explicit identification of feasible alternatives before any scoring, weighting, screening, or ranking is performed. In this study, later Multi-Criteria Decision Analysis (MCDA) is used only after the alternatives have been defined, because MCDA is intended to help decision-makers "make rational choices between alternative options when these are required to achieve multiple specific objectives."[30] Hence, the quality of the decision is not only a function of the rigor of the scoring method but also of the match between the set of options and the owner's goals, constraints, and feasible actions. This is consistent with HM Treasury's view that MCDA supports the "identification and ranking of choices during the longlist appraisal stage,"[31] and with Keeney's argument that "alternatives are relevant only because they are means to achieve values."[32]

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[28] National Aeronautics and Space Administration. (2015). NASA Cost Estimating Handbook (Version 4.0). National Aeronautics and Space Administration.

[29] U.S. Government Accountability Office. (2015). *Schedule assessment guide: Best practices for project schedules* (GAO-16-89G). U.S. Government Accountability Office.

[30] Government Analysis Function. (2024, May 1). *An introductory guide to multi-criteria decision analysis (MCDA).* UK Government. https://analysisfunction.civilservice.gov.uk/policy-store/an-introductory-guide-to-mcda/

[31] HM Treasury. (2024). *Use of multi-criteria decision analysis in options appraisal of economic cases.* UK Government. https://assets.publishing.service.gov.uk/media/6645e4b2b7249a4c6e9d3631/Use_of_MCDA_in_options_appraisal_of_economic_cases.pdf

[32] Keeney, R. L. (1996). Value-focused thinking: Identifying decision opportunities and creating alternatives. *European Journal of Operational Research, 92*(3), 537–549. https://doi.org/10.1016/0377-2217(96)000197-5

Table 2 Description of Project Completion Strategy Alternatives[33]

ALT	Alternative	Description & Scope
A1	**Status Quo — Continue**	Continue current contract under existing terms. Grant further EOTs as needed. Contractor completes full original scope. Owner retains existing risk allocation.
A2	**Contract Restructuring**	Negotiate amended contract with revised milestones, acceleration incentives, LD recalibration, and risk re-sharing. Original scope retained but commercially restructured.
A3	**Partial Owner Takeover / De-Scoping**	Owner takes over non-critical remaining scope (landscaping, non-essential utilities). Contractor delivers essentials (mechanical completion, commissioning).
A4	**Terminate & Re-tender**	Issue termination for convenience or default. Re-tender remaining scope to new contractor. Settle claims and performance bond.
A5	**Descope to Essential Scope Only**	Delete non-essential scope via variation order. Keep only regulatory/functional minimum to achieve operational commissioning.

Step 3 - Development of The Feasible Alternative

3.1 Project EVM Baseline

Table 3 presents the project performance baseline at data date M82, developed using the Owner's Independent PMB. This baseline serves as the analytical foundation for the subsequent steps, since the forecasting of project completion and the development of alternative-specific outcomes are both built upon the relationship between planned value, earned physical progress, and actual cost incurred to date.

Each alternative was then defined under a common viewpoint and consistent boundary conditions to ensure a comparable evaluation basis, with sufficient definition to assess the cost impact of each proposed alternative, consistent with NASA cost-estimating guidance and Sullivan, Wicks, and Koelling's principle that "the prospective outcomes of

[33] By Author

the alternatives, economic and other, should be consistently developed from a defined viewpoint."[34,35]

Table 3 EVM Metric Calculation[36]

EVM Metric	Value	Formula
Budget at Completion (BAC)	181.030.000.000	*Contract value*
Budgeted Cost for Work Scheduled (BCWS) at M82	181.030.000.000	*BAC × planned %*
Budgeted Cost for Work Performed (BCWP) at M82	169.172.535.000	*BAC × Physical %*
Actual Cost of Work Performed (ACWP) at M82	167.663.562.934	*BCWP / CPI*
Cost Variance (CV)	1.508.972.066	*BCWP - ACWP*
Schedule Variance (SV)	(11.857.465.000)	*BCWP - BCWS*
Cost Performance Index (CPI)	1,009	*BCWP / ACWP*
Schedule Performance Index (SPI)	0,943	*BCWP / BCWS*
Cost Variance %	0,89%	*Cost Variance / BCWP*
Schedule Variance %	-6,55%	*Schedule variance / BCWS*
To Complete Performance Index (BAC-based)	0,887	*(BAC−BCWP)/(BAC−ACWP)*

3.2 Independent Estimate for Completion Forecast

This study adopts an Independent Estimate at Completion (IEAC) approach grounded in earned value management and extended through Monte Carlo simulation. IEAC4 was selected as the preferred deterministic reference because it places greater weight on CPI and is more reliable late in a project since less weight is given to SPI. This is particularly

[34] National Aeronautics and Space Administration. (2015). NASA cost estimating handbook (Version 4.0), Appendix G: Cost risk and uncertainty methodologies. National Aeronautics and Space Administration. https://www.nasa.gov/wp-content/uploads/2020/11/ceh_appg.pdf
[35] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit
[36] By Author

relevant with the NDIA case, where "the project has progressed into a late execution phase, and the utility of SPI has degraded."[37]

Table 4 Four Common Ways of Calculating IEAC[38]

IEAC	Formula	Assumption	Comments
IEAC1	$= ACWP + \frac{BAC - BCWPcum}{CPI}$	Future cost performance will be the same as all past cost performance.	"Best Case" when CPI is less than 1.0 and "Worst Case" when CPI is greater than 1.0.
IEAC2	$= ACWP + \frac{BAC - BCWPcum}{SPI}$	Future cost performance will be influence by past schedule performance.	Use with caution as SPI is diluted by LOE and loses accuracy over the last third of the project.
IEAC3	$= ACWP + \frac{BAC - BCWPcum}{SPI \times CPI}$	Future cost performance will be influence by past schedule and cost performance.	In contrast to IEAC1, this calculation typically yields the "Worst Case" when SPI and CPI are less than 1.0.
IEAC4	$= ACWP + \frac{BAC - BCWPcum}{(0.2 \times SPI) + (0.8 \times CPI)}$	Similar to IEAC3, except increased weight is placed on CPI.	More reliable than IEAC3 late in a project since less weight is given to SPI.

The forecast model is defined as:

$$EAC_i = AC_t + \frac{BAC - EV_t}{PF_i}, where\ PF = 0,2\ SPI + 0,8CPI$$

Then, PF is treated as a stochastic variable. Rather than assuming a parametric distribution, PF values are sampled empirically by bootstrap from the calibration window M28–M82 (n = 55 periods). Over 10,000 iterations, this produces a distribution of EAC outcomes from which percentiles are extracted directly.

[37] National Defense Industrial Association. (2021). Integrated program management division (IPMD) guide to managing programs using predictive measures (3rd ed.)
[38] National Defense Industrial Association. (2021). Loc.cit

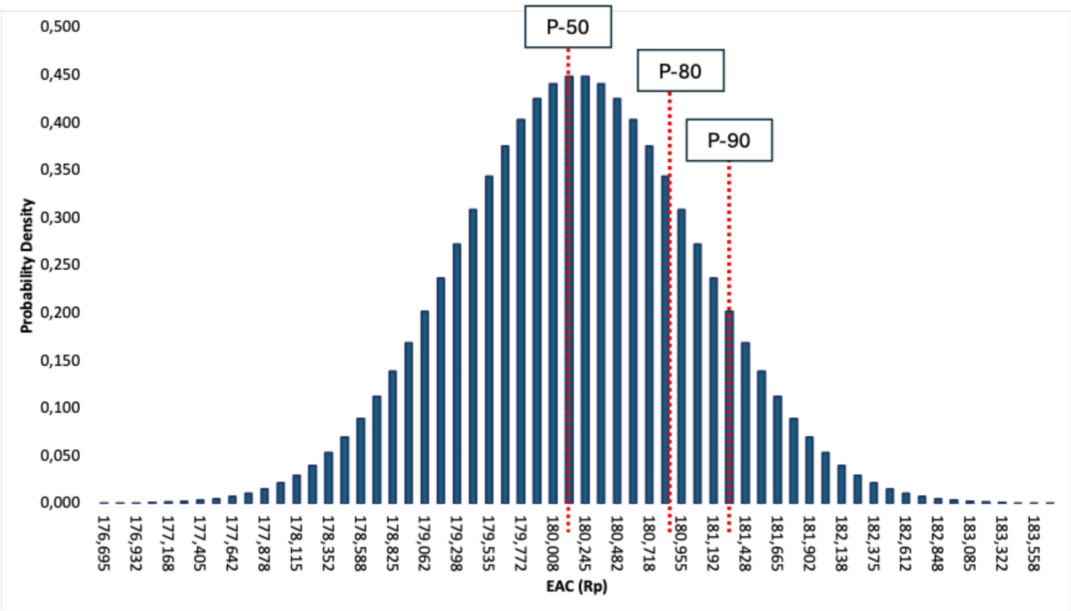

Figure 6 Probabilistic distribution of simulated IEAC (Cost) outcomes[39]

From the resulting distribution, the following probabilistic project cost completion parameters are derived:

Table 5 Summary of IEAC (Cost) Forecast Result[40]

MONTE CARLO EAC DISTRIBUTION		PROBABILITY OF MEETING TARGETS	
Minimum EAC	178.216.174.882	Probability EAC ≤ BAC	79,44%
P10	178.952.385.924	Probability EAC ≤ P80	81,32%
P50	180.299.815.271	Probability EAC ≤ P90	90,12%
Mean EAC	180.185.906.360	Budget Overrun	289.479.181
P80	181.068.723.506	Overrun % of BAC	0,16%
P90	181.319.241.961	Maximum EAC	181.635.153.696
P95	181.617.092.483	Std Dev EAC	887.464.293

At the data date (M82), the project records CPI = 1.009 and SPI = 0.943, with physical completion at 94.35%. The simulation yields a P50 EAC of Rp 180.30 billion against a BAC of Rp 181.03 billion, with a 79,44% probability that the final cost will not exceed the original budget.

3.3 Independent Estimate Completion Date

Schedule forecasting was undertaken using the Earned Schedule framework, which converts earned value into time-based measures and allows schedule status to be expressed in months rather than in monetary units. This reformulation is important

[39] By Author
[40] By Author

because it overcomes the well-known weakness of traditional SPI, which tends to converge to 1.00 near project completion regardless of lateness. Accordingly, schedule efficiency was first represented by the time-based schedule performance index[41]:

$$ES = C + I$$

$$SV_{(t)} = ES - AT$$

$$SPI_{(t)} = \frac{ES}{AT}$$

Where,
ES = Earned schedule;
C = Completed time periods;
I = Incremental time fraction
$SV_{(t)}$ = Schedule variance in time
AT = Actual Time.

Forecast duration is expressed as an Independent Estimate at Completion in time.

$$IEAC_{(t)} = \frac{PD}{SPI_{(t)}}$$

$$IEAC_{(t)} = AT + \frac{(PD - ES)}{PF_{(t)}}$$

Where PF(t) is a performance factor, a time-based performance factor representing expected future schedule efficiency. The forecast completion date is then obtained as

$$IECD = Start\ Date + IEAC_{(t)}$$

In this study, the future time performance factor, PF(t), is treated as a stochastic variable that is sampled from historically observed schedule-efficiency behavior, such as SPI(t) or another recent time-performance factor. For each simulation run, a randomly selected value of PF is inserted into the forecast equation to generate SPI(t). This process is repeated 10,000 times, and the results are presented below.

[41] Henderson, K., & Lipke, W. (2007). Earned schedule in action [Conference paper]. 19th International Integrated Program Management Conference, Alexandria, VA, United States. https://www.earnedschedule.com/Docs/Earned%20Schedule%20in%20Action%202.pdf

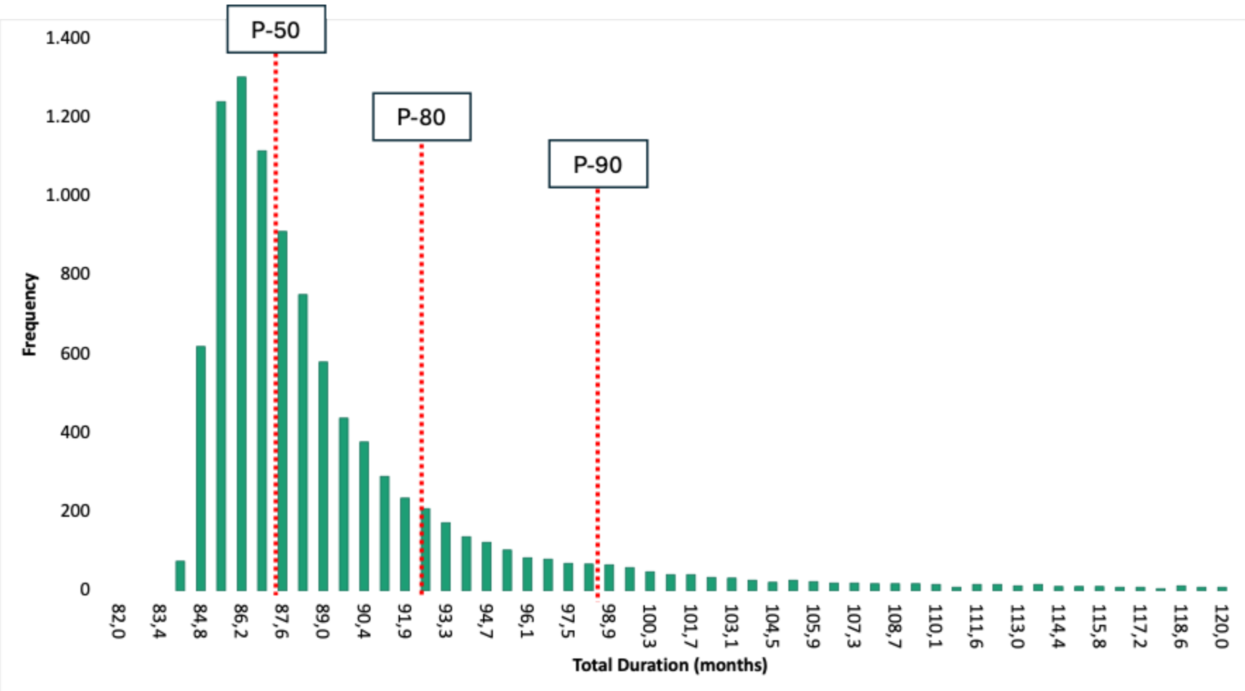

Figure 7 Probabilistic distribution of simulated IEAC (Time) outcomes[42]

The resulting distribution is used to obtain the following probabilistic project schedule completion parameters:

Table 6 Table 5 Summary of IEAC (time) Forecast Result[43]

SCHEDULE STATUS AT DATA DATE (M82)		PROBABILISTIC DURATION RESULTS		
Planned Duration (PD)	18 months	Percentile	Duration (months)	Additional from M82
Actual Time Elapsed (AT)	82 months			
Earned Schedule (ES)	0,9435 months	P10	85,04	3,04
SPI(t) = ES / AT	0,0565	P20	85,55	3,55
% Physical Complete	94,35%	P50	87,37	5,37
Remaining Work	5,65%	P80	92,10	10,10
Sch Overrun vs Baseline (AT-PD)	64 months	P90	98,38	16,38

The probabilistic schedule forecast overall confirms the project is well beyond its originally planned duration and remains at risk for continued slippage based on its demonstrated historical execution pattern.

3.4 Assumption of Each Alternative

This step defines the computational assumptions used to derive the quantitative and qualitative outcomes of each completion strategy before they are consolidated.

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[43] By Author

a. Cost to Completion[44]

For each alternative *i*, the model first defines the additional owner-side expenditure required to implement that strategy and combines it with the actual cumulative cost at the data date. Total cost at completion is calculated as follows:

$$TCC_i = AC_{M82} + Addcost_i$$

Where,
TCC_i = total cost at completion for alternative i;
$AC_i M82_j$ = actual cumulative cost at data date M82;
$AddCost_i$ = additional owner cost required under alternative i.

Budget variance relating to the approved budget at completion is then expressed as:

$$VarBAC_i = \frac{TCC_i}{BAC} - 1$$

Where,
$VarBAC_i$ = variance versus budget at completion for alternative i;
BAC = Budget at Completion.

The associated schedule effect is measured as delay beyond the original baseline:

$$Delay_i = At + D_i - PD$$

Where,
$Delay_i$ = total delay beyond the original baseline;
AT = actual time elapsed at the status date;
D_i = months to completion from M82 under alternative i;
PD = original planned duration.

b. Revenue Lost / Cost of Delay[45]

In this study, lost revenue during the remaining delay period is simplified as a monthly delay charge multiplied by the alternative-specific remaining duration. This is a study-specific linear approximation of the broader cost-of-delay concept, which recognizes that delayed completion defers benefit realization and creates an economic penalty.

[44] National Defense Industrial Association. (2021). Loc.cit
[45] Reinertsen, D. G. (2009). Loc.cit

$$LR_i = Delay\ Cost \times D_i$$

Where,
LR_i = total lost revenue for alternative i;
Delay Cost = assumed monthly economic cost of delay;
D_i = months to completion from M82.

The remaining operating life retained after completion is estimated as:

$$YearsRet_i = max\left(0, Life - \frac{D_i}{12}\right)$$

Where,
$YearsRet_i$ = retained operating years after completion;
Life = assumed total economic life of the asset in years.

c. NPV Calculation[46]

The Net Present Value (NPV) calculation employs the Present Worth method. This method involves discounting all future cash inflows and outflows to a common present point using the minimum attractive rate of return (MARR). The general formulation is:

$$PW_{(i)} = \sum_{k=0}^{N} F_k(1+i)^{-k})$$

Where,
PW(i) = present worth at discount rate i;
F_k = net cash flow at the end of period k;
i = effective interest rate per period or MARR;
N = study period.

Under the PW decision rule, a project is economically justified when *PW(i = MARR) ≥ 0*. Applied to the present study, the incremental NPV from M82 is modeled as:

[46] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit

$$NPV_i = -AddCost_i - LR_i + \sum_{t=1}^{N_i} \frac{NCF_{i,t}}{(1+r)^t}$$

Where,
NPV_i = incremental net present value of alternative i from M82;
$AddCost_i$ = additional owner cost;
LR_i = revenue lost during delay;
$NCF_{i,t}$ = annual net cash flow after commissioning under alternative i in year t;
r = discount rate or MARR;
N_i = retained operating years.

e. Qualitative Attributes and EMV[47]

To reflect execution uncertainty, each alternative is assigned a probability of success and then converted into Expected Monetary Value (EMV) through a probability-weighted outcome structure:[7]

$$EMV_i = p_i(NPV_i) + (1 - p_i)(NPV_i - AddCost_i)$$
$$EMV_i = p_i \times V_{success,i} + (1 - p_i) \times v_{failure,i}$$

Where,
EMV_i = expected monetary value of alternative i;
p_i = probability of successful implementation;
$Vsuccess_{,i}$ = value if the alternative succeeds;
$Vfailure_{,i}$ = value if the alternative fails. In the workbook,

These values are represented by the success-case NPV and a reduced downside case. The model then supplements the quantitative outputs with three qualitative scores on a 1–5 scale: contractual cleanliness, operational readiness, and reputational impact.

3.5 Consolidated Outcomes Summary Matrix

The consolidated matrix presented in Table 7 covers nine attributes spanning financial exposure, schedule performance, economic value, execution risk, and strategic fit, enabling direct side-by-side comparison across alternatives under a common analytical framework.

[47] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit

Table 7 Summary of Alternatives Outcome[48]

Criteria	Attribute	A1 Status Quo	A2 Restructure	A3 Partial Takeover	A4 Terminate	A5 Descope	Direction
C1	Months to completion (from M82)	11,00	12,00	8,00	24,00	6,00	MIN
C2	Additional cost to owner (IDR)	38.960.726	1.810.300.000	9.051.500.000	18.103.000.000	(1.810.300.000)	MIN
C3	Total cost at completion (IDR)	181.068.723.506	182.840.300.000	190.081.500.000	199.133.000.000	179.219.700.000	MIN
C4	Variance vs BAC (%)	0,02%	1,00%	5,00%	10,00%	-1,00%	MIN
C5	Delay beyond original baseline (months)	76,00	76,00	72,00	88,00	70,00	MIN
C6	Total lost revenue during delay (IDR)	8.100.000.000	8.100.000.000	5.400.000.000	16.200.000.000	4.050.000.000	MIN
C7	Years operational retained (20-yr life)	19,00	19,00	19,33	18,00	19,50	MAX
C8	NPV incremental from M82 (IDR)	58.715.890.563	57.090.808.661	55.123.067.797	29.593.101.074	67.915.860.216	MAX
C9	Total Cost of Delay remaining (IDR)	8.100.000.000	8.100.000.000	5.400.000.000	16.200.000.000	4.050.000.000	MIN
C10	Probability of success	0,80	0,90	0,75	0,55	0,65	MAX
C11	EMV (IDR)	58.708.098.418	56.909.778.661	52.860.192.797	21.446.751.074	68.549.465.216	MAX
C12	Contractual Cleanliness (1-5)	4	5	3	1	2	MAX
C13	Operational Readiness (1-5)	3	5	3	1	2	MAX
C14	Reputational Impact (1-5)	2	4	3	1	2	MAX

: Best Value   : Worst Value

Step 4 - Selection of The Criteria

4.1 Multi-Attribute Decision-Making (MADM)

The criteria selection in this study is developed within the MCDA framework and operationalized through Multi-Attribute Decision-Making (MADM) techniques. HM Treasury explains that "MCDA is a technique that helps decision-makers make rational choices between alternatives. It is particularly effective when there is a mix of qualitative and quantitative criteria not directly comparable against each other and when the perspectives of multiple stakeholders may need to be considered."[49] Therefore, this study applies six MADM approaches to compare the five project completion alternatives:

- **Dominance**: used to identify whether one alternative is clearly inferior across the relevant criteria.
- **Satisficing**: used as a threshold-screening test.

[48] By Author
[49] HM Treasury. (2024). Loc. Cit

- **Disjunctive reasoning**: used to identify alternatives or criteria that meet at least one high-priority acceptance condition, especially where a strong attribute may justify further consideration.
- **Lexicography**: used to rank alternatives according to the most important criterion first, then the next criterion only if a tie remains.
- **Non-dimensional scaling**: used to convert criteria with different units and directions into comparable normalized scores.
- **Additive weighting**: used to combine normalized performance scores with criteria weights, producing an overall weighted preference ranking.

4.2 Validation using Sensitivity Analysis

After the six MADM approaches are applied, the ranking is tested through sensitivity analysis to determine whether the preferred alternative remains stable when key assumptions change. HM Treasury states that "a sensitivity analysis to understand how the ordering of the options examined may change under different scoring or weighting assumptions."[50]

Sensitivity analysis is used as the validation step before the final recommendation. The preferred alternative should satisfy two conditions: first, it should perform strongly in the base-case MADM comparison; second, it should remain the preferred option even with reasonable changes in model assumptions.

FINDING

Step 5 - Analysis of Alternative

5.1 Non-Compensatory Model 1: Dominance

The dominance test was applied to screen clearly inferior alternatives before the weighted MADM stage. Hammond, Keeney, and Raiffa state that decision makers should "eliminate clearly inferior alternatives." [51] Table 9 shows that A4 is dominated by A1, A2, A3, and A5 across the selected criteria. Therefore, A4 should be treated as a weak candidate and tested further using other MADM methods.

[50] HM Treasury. (2024). Loc. Cit
[51] Business Book Summaries. (2016). Smart choices: John S. Hammond, Ralph L. Keeney, and Howard Raiffa. EBSCO Publishing. https://biblioteca.ufm.edu/library/images/3/3c/Smart_Choices.pdf

Table 8 Non-Compensatory Model Technique 1: Dominance[52]

Pair	Comparison	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	Result
1	A1 vs A2	A1	A1	A1	A1	A1	A1	A1	A1	A1	A2	A1	A2	A2	A2	No dominance
2	A1 vs A3	A3	A1	A1	A1	A3	A3	A3	A1	A3	A1	A1	A1	A1	A3	No dominance
3	A1 vs A4	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1	A1 dominates A4
4	A1 vs A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A1	A1	A1	No dominance
5	A2 vs A3	A3	A2	A2	A2	A3	A3	A3	A2	A3	A2	A2	A2	A2	A2	No dominance
6	A2 vs A4	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2	A2 dominates A4
7	A2 vs A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A2	A5	A2	A2	A2	No dominance
8	A3 vs A4	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3	A3 dominates A4
9	A3 vs A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A3	A3	No dominance
10	A4 vs A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5	A5 dominates A4

5.2 Non-Compensatory Model 2: Satisficing

The satisficing test was applied to confirm whether each alternative meets minimum acceptable thresholds before compensatory ranking. Simon describes satisficing models as providing "good enough decisions with reasonable costs of computation," and Table 10 shows that A4 fails most thresholds, while A1, A2, A3, and A5 pass all requirements. Therefore, A4 should remain subject to further validation through other MADM models.[53]

52 By Author
53 Simon, H. A. (1978). Rational decision-making in business organizations: Nobel Memorial Lecture. Nobel Prize. https://www.nobelprize.org/uploads/2018/06/simon-lecture.pdf

Table 9 Non-Compensatory Model Technique 1: Satisficing (Screening)[54]

Criteria	Direction	Threshold	A1 Status Quo	A2 Restructure	A3 Partial Takeover	A4 Terminate	A5 Descope
C1	MIN	18,00	PASS	PASS	PASS	FAIL	PASS
C2	MIN	15.000.000.000	PASS	PASS	PASS	FAIL	PASS
C3	MIN	199.133.000.000	PASS	PASS	PASS	PASS	PASS
C4	MIN	8,0%	PASS	PASS	PASS	FAIL	PASS
C5	MIN	84,00	PASS	PASS	PASS	FAIL	PASS
C6	MIN	12.000.000.000	PASS	PASS	PASS	FAIL	PASS
C7	MAX	18,50	PASS	PASS	PASS	FAIL	PASS
C8	MAX	-	PASS	PASS	PASS	PASS	PASS
C9	MIN	12.000.000.000	PASS	PASS	PASS	FAIL	PASS
C10	MAX	0,60	PASS	PASS	PASS	FAIL	PASS
C11	MAX	25.000.000.000	PASS	PASS	PASS	FAIL	PASS
C12	MAX	2	PASS	PASS	PASS	FAIL	PASS
C13	MAX	2	PASS	PASS	PASS	FAIL	PASS
C14	MAX	2	PASS	PASS	PASS	FAIL	PASS

Table 10 Non-Compensatory Model Technique 1: Satisficing (Result Summary)[55]

Alt	PASS count	FAIL count	Total	Status	Mandatory retention	Final
A1	14	0	14	ALL PASS	YES (do-nothing)	RETAINED
A2	14	0	14	ALL PASS	No	RETAINED
A3	14	0	14	ALL PASS	No	RETAINED
A4	2	12	14	FAIL ≥1	No	ELIMINATED
A5	14	0	14	ALL PASS	No	RETAINED

5.3 Non-Compensatory Model 3: Disjunctive Reasoning

The disjunctive reasoning test identifies the strongest criteria before applying the Lexicographic Ordering (LO) method. Based on the pairwise comparison results, C8, C11, C3, C10, and C1 are the five highest-ranked criteria. Mezurnishvili et al. state that “the LO method implies ranking alternatives based on the most important criterion first”;

54 By Author
55 By Author

therefore, this priority order should guide the subsequent non-compensatory comparison.[56]

Table 11 Non-Compensatory Model Technique 3: Disjunctive Reasoning (Result)[57]

No	Attributes	Number of times on left of > (= Ordinal Ranking)
1	C8 — NPV incremental from M82	13
2	C11 — EMV (risk-adjusted)	12
3	C3 — Total cost at completion	11
4	C10 — Probability of success	10
5	C1 — Months to completion (from M82)	9
6	C9 — Total Cost of Delay remaining	8
7	C2 — Additional cost to owner	7
8	C4 — Variance vs BAC (%)	6
9	C6 — Total lost revenue during delay	5
10	C5 — Delay beyond original baseline (months)	4
11	C7 — Years operational retained (20-yr life)	3
12	C12 — Contractual Cleanliness	2
13	C13 — Operational Readiness	1
14	C14 — Reputational Impact	0

5.4 Non-Compensatory Model 4: Lexicography

The lexicographic model applies the priority sequence from the disjunctive reasoning test to compare alternatives criterion by criterion. Sullivan, Wicks, and Koelling state that the alternative with the "highest value for the most important attribute is then chosen."[58] Table 13 shows that A5 ranks highest on C8, C11, and C3; therefore, A5 should be treated as the leading alternative for further validation[59]

[56] Mezurnishvili, I., Pavlenishvili, L., Shalibashvili, A., Chachava, M., & Chitanava, M. (2024). Multi-criteria analysis in regulatory impact assessment in Georgia: Executive summary. Operational Research Institute. https://www.undp.org/sites/g/files/zskgke326/files/2024-07/research_summary._english.pdf
[57] By Author
[58] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit
[59] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit

Table 12 Non-Compensatory Model Technique 3: Lexicography[60]

No	Attributes	Rank	Alternate Rank
1	**C8 — NPV incremental from M82**	**13**	**A5 > A1 > A2 > A3 > A4**
2	C11 — EMV (risk-adjusted)	12	A5 > A1 > A2 > A3 > A4
3	C3 — Total cost at completion	11	A5 > A1 > A2 > A3 > A4
4	C10 — Probability of success	10	A2 > A1 > A3 > A5 > A4
5	C1 — Months to completion (from M82)	9	A5 > A3 > A1 > A2 > A4
6	C9 — Total Cost of Delay remaining	8	A5 > A3 > A1=A2 > A4
7	C2 — Additional cost to owner	7	A5 > A1 > A2 > A3 > A4
8	C4 — Variance vs BAC (%)	6	A5 > A1 > A2 > A3 > A4
9	C6 — Total lost revenue during delay	5	A5 > A3 > A1=A2 > A4
10	C5 — Delay beyond original baseline (months)	4	A5 > A3 > A1=A2 > A4
11	C7 — Years operational retained (20-yr life)	3	A5 > A3 > A1=A2 > A4
12	C12 — Contractual Cleanliness	2	A2 > A1 > A3 > A5 > A4
13	C13 — Operational Readiness	1	A2 > A1=A3 > A5 > A4
14	C14 — Reputational Impact	0	A2 > A3 > A1=A5 > A4

5.5 Compensatory Model 1: Nondimensional Scaling

Nondimensional scaling was used to make criteria with different units, scales, and directions comparable before aggregation. Its main advantage is that it converts heterogeneous measures into unitless scores, allowing transparent cross-criteria comparison. Vafaei et al. state that normalization is used "to allow aggregation of criteria with numerical and comparable data."[61] Table 13 indicates that A2 should be treated as the leading compensatory result.

[60] By Author
[61] Vafaei, N., Ribeiro, R. A., & Camarinha-Matos, L. M. (2016). Normalization techniques for multi-criteria decision making: Analytical hierarchy process case study. In L. M. Camarinha-Matos, A. J. Falcão, N. Vafaei, & S. Najdi (Eds.), Doctoral Conference on Computing, Electrical and Industrial Systems (pp. 261–269). Springer. https://doi.org/10.1007/978-3-319-31165-4_26

Table 13 Compensatory Model Technique 1: Non-Dimensional Scaling[62]

#	Attribute	Dir	A1	A2	A3	A4	A5
C8	NPV incremental from M82	MAX	0,760	0,718	0,666	0,000	1,000
C11	EMV (risk-adjusted)	MAX	0,791	0,753	0,667	0,000	1,000
C3	Total cost at completion	MIN	0,907	0,818	0,455	0,000	1,000
C10	Probability of success	MAX	0,714	1,000	0,571	0,000	0,286
C1	Months to completion	MIN	0,722	0,667	0,889	0,000	1,000
C9	Total Cost of Delay remaining	MIN	0,667	0,667	0,889	0,000	1,000
C2	Additional cost to owner	MIN	0,907	0,818	0,455	0,000	1,000
C4	Variance vs BAC (%)	MIN	0,907	0,818	0,455	0,000	1,000
C6	Total lost revenue during delay	MIN	0,667	0,667	0,889	0,000	1,000
C5	Delay beyond original baseline (months)	MIN	0,667	0,667	0,889	0,000	1,000
C7	Years operational retained (20-yr)	MAX	0,667	0,667	0,889	0,000	1,000
C12	Contractual Cleanliness (1-5)	MAX	0,750	1,000	0,500	0,000	0,250
C13	Operational Readiness (1-5)	MAX	0,500	1,000	0,500	0,000	0,250
C14	Reputational Impact (1-5)	MAX	0,333	1,000	0,667	0,000	0,333
TOTAL SCORE			**9,959**	**11,258**	**9,379**	**0,000**	**11,119**
RANK	**Position (1 = best)**		**3**	**1**	**4**	**5**	**2**

5.6 Compensatory Model 2: Additive Weighting (WSM)

Additive weighting was used to combine normalized criterion performance with relative importance weights, enabling a single overall score for each alternative. Sullivan, Wicks, and Koelling state that the method "includes both the performance ratings and the importance weights of each attribute when evaluating alternatives."[63] Table 15 shows that A5 obtains the highest weighted score, followed by A2; therefore, A5 should be treated as the leading weighted-sum result.

[62] By Author
[63] Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Loc.Cit

Table 14 Compensatory Model Technique 2: Additive Weighting[64]

#	Dir	Calculation of Weighting Factors: Step 1 Relative Rank	Step 2 Normalized Weight (A)	A1 B	A1 B × A	A2 B	A2 B × A	A3 B	A3 B × A	A4 B	A4 B × A	A5 B	A5 B × A
C8	MAX	14	0,13	0,76	0,10	0,72	0,10	0,67	0,09	0,00	0,00	1,00	0,13
C11	MAX	13	0,12	0,79	0,10	0,75	0,09	0,67	0,08	0,00	0,00	1,00	0,12
C3	MIN	12	0,11	0,91	0,10	0,82	0,09	0,45	0,05	0,00	0,00	1,00	0,11
C10	MAX	11	0,10	0,71	0,07	1,00	0,10	0,57	0,06	0,00	0,00	0,29	0,03
C1	MIN	10	0,10	0,72	0,07	0,67	0,06	0,89	0,08	0,00	0,00	1,00	0,10
C9	MIN	9	0,09	0,67	0,06	0,67	0,06	0,89	0,08	0,00	0,00	1,00	0,09
C2	MIN	8	0,08	0,91	0,07	0,82	0,06	0,45	0,03	0,00	0,00	1,00	0,08
C4	MIN	7	0,07	0,91	0,06	0,82	0,05	0,45	0,03	0,00	0,00	1,00	0,07
C6	MIN	6	0,06	0,67	0,04	0,67	0,04	0,89	0,05	0,00	0,00	1,00	0,06
C5	MIN	5	0,05	0,67	0,03	0,67	0,03	0,89	0,04	0,00	0,00	1,00	0,05
C7	MAX	4	0,04	0,67	0,03	0,67	0,03	0,89	0,03	0,00	0,00	1,00	0,04
C12	MAX	3	0,03	0,75	0,02	1,00	0,03	0,50	0,01	0,00	0,00	0,25	0,01
C13	MAX	2	0,02	0,50	0,01	1,00	0,02	0,50	0,01	0,00	0,00	0,25	0,00
C14	MAX	1	0,01	0,33	0,00	1,00	0,01	0,67	0,01	0,00	0,00	0,33	0,00
SUM		105	1,00	Sum =	0,76	Sum =	0,78	Sum =	0,67	Sum =	0,00	Sum =	0,88
RANK					3		2		4		5		1

5.7 Model Comparison and Convergence

The six MADM results show partial convergence rather than full consensus (Table 15). A5 is the strongest candidate because it wins both Lexicography and Weighted Sum Model (WSM), while A2 wins Nondimensional Scaling (NDS) and ranks second in WSM. A4 remains consistently weak, being eliminated or ranked last across the models. However, A5 should not yet be treated as the final decision. The Government Analysis Function states that the MCDA output-review stage should "conduct sensitivity analysis – which may require iteration of steps from the 'weighting criteria' phase onwards."[65] Therefore, the ranking should be stress-tested against criteria weights, thresholds, and normalization assumptions.

Table 15 Comparison of 6 MADM Technique Results[66]

Alternative	D	S	DR	L	NDS	WSM	WIN
A1 Status Quo	—	Pass	—	#2	#3	#3	0
A2 Restructure	—	Pass	—	#3	#1 ★	#2	1
A3 Partial Takeover	—	Pass	—	#4	#4	#4	0
A4 Terminate	—	Eliminated	—	#5	#5	#5	0
A5 Descope	—	Pass	—	#1 ★	#2	#1 ★	2

64 By Author
65 Government Analysis Function. (2024, May 1). Loc. cit
66 By Author

5.8 Sensitivity Analysis

The sensitivity analysis was used as a robustness check before confirming A5 as the preferred strategy. Its purpose was to examine whether the ranking remains defensible when the main judgment-sensitive inputs are changed, particularly criteria weights, execution risk, delay exposure, normalization method, and the switching condition between A5 and A2. The scenario structure is summarized in Table 17, while the detailed calculations are presented in Appendix[67].

Table 16 Sensitivity Analysis Scenario Design for Testing A5 Robustness[68]

#	Sensitivity test	Variable Tested	Sensitivity Range	Decision Question
S1	Weight sensitivity	Weights of C8, C11, C3, C10, and C1	Base, +10%, -10%, +20%, -20%; weights re-normalized to 1.00	Does A5 remain first when the highest-weight criteria change?
S2	Risk sensitivity	Probability of success for A5 and A2	Base: A5 65%, A2 90%; optimistic: A5 80%, A2 95%; pessimistic: A5 50%, A2 80%; severe downside: A5 35%, A2 65%	Does A5 remain preferred when execution-success assumptions deteriorate?
S3	Delay sensitivity	A5 months-to-completion and A5 cost-of-delay multiplier	Base 1.00; delay +10%; delay +20%; CoD +10%; CoD +20%; combined downside: 1.20 × 1.20	Does A5 remain preferred when delay exposure or cost of delay increases?
S4	Normalization sensitivity	Normalization method used for WSM input scores	Min-max normalization versus ratio normalization	Is the winner affected by the normalization formula?
S5	Switching analysis	Combined degradation of A5 NPV, probability of success, and months-to-completion	A5 performance degraded from 100% to 70% of base case in 5% increments	At what point does A2 overtake A5?

[67] This paper includes APPENDICES that will demonstrate how to IMPLEMENT what this paper recommends. For anyone who needs or wants the APPENDICES, email me hendracharisma@gmail.com and the author will email you with the full paper with the APPENDICES
[68] By Author

Step 6 - Selection of the Preferred Alternative

6.1 Decision Rule and Selection Logic

The purpose of Step 6 is to translate the MADM comparison into a defensible selection rule, not to select an alternative merely because it wins one model. A preferred alternative should satisfy four tests: pass initial screening, show support across more than one method, perform well under weighted compensatory scoring, and remain stable under sensitivity analysis. Based on Step 5, A5 is the provisional preferred alternative because it wins Lexicography and WSM, while A2 remains the main challenger, and A4 remains structurally weak.

***Table 17 Decision Rule and Selection Logic for Preferred Alternative Selection*[69]**

Decision test	Purpose	Observed result	Implication
Non-compensatory screening	Identify weak or infeasible candidates	A4 is dominated or fails thresholds	A4 should not be preferred
Model convergence	Check repeated support across methods	A5 wins Lexicography and WSM	A5 becomes leading candidate
Challenger check	Avoid single-method bias	A2 wins NDS and ranks second in WSM	A2 remains fallback option
Decision robustness	Test sensitivity before commitment	Weight, threshold, normalization, and risk assumptions to be tested	Final decision should be conditional

6.3 Final Recommendation

Based on the comparison of the MADM model results and the sensitivity analysis, the results are presented in Table 18. A5 De-scope should be selected as the preferred alternative. It remains the winner in 43 out of 45 tested scenarios, including the base WSM case, all weight sensitivity cases, all risk sensitivity cases, and all delay sensitivity cases. The only material challenge occurs in the switching analysis, where A2 overtakes A5 only when A5's NPV, probability of success, and completion duration are simultaneously degraded to the severe downside range. Therefore, A5 is a robust but not unconditional recommendation. A2 should be retained as the fallback option if A5's execution-risk profile deteriorates beyond the switching threshold, while A4 should not be preferred because it remains consistently weak across the MADM models.

[69] By Author

Table 18 Summary of Sensitivity Analysis Results and Winner Distribution[70]

Test	Variable Changed	Scenarios	Winner Distribution	A5 Stable?	Main Challenger
01. Base WSM	None (baseline)	1	A5	Yes	—
02. Weight Sensitivity	C8/C11/C3/C10/C1 weights ±10/20%	25	25 A5 / 0 A2	Yes	none
03. Risk Sensitivity	A5/A2 probability of success	4	4 A5 / 0 A2	Yes	none
04. Delay Sensitivity	A5 Months & Cost of Delay +10/20%	6	6 A5 / 0 A2	Yes	none
05. Normalization Method	Min-Max vs Ratio	2	1 A5 / 0 A2	Partial	—
06. Switching Analysis	A5 NPV+Prob+Months degraded 100→70%	7	6 A5 / 1 A2	Switch	A2
TOTAL SCENARIOS		**45**	**43 A5 / 1 A2**		

Step 7 - Performance Monitoring

A5 De-scope is the starting point for controlled implementation, not the end of the decision process. The selected alternative must be converted into a monitored recovery baseline: a revised WBS, updated completion schedule, revised cost-to-complete, risk register, and defined decision thresholds. This is consistent with AACE's project control process cycle, where "performance measurements are compared to the plan, and corrective, mitigating, or improvement actions are taken as may be determined."[71]

Monitoring needs to be conducted through a real-time owner control dashboard that gets updated frequently. At a minimum, the dashboard should track how much physical work has been done against what was planned for the essential scope, how much it's going to cost to finish, the CPI numbers, the Earned Schedule index, where things stand on the critical path, whether the project is ready to hand over, and how many punch-list items are still open.

Post-evaluation should be conducted after mechanical completion, gas-in, and commercial operation by comparing all actual criteria against the decision model assumptions. This review should include an updated risk analysis as new project data becomes available. NASA's cost-estimating guidance states that "risk analysis provides

[70] By Author
[71] AACE International. (2015). Total cost management framework: An integrated approach to portfolio, program, and project management (2nd ed.). AACE International

an analytical basis for establishing defensible cost estimates, and this analysis should be continuously reviewed and updated as more data become available."[72]

CONCLUSION

This paper addresses a fundamental governance question for distressed infrastructure projects: how can project owners move beyond diagnosing poor performance to a defensible strategy for completion, using a structured and evidence-based decision model. The integration of Earned Value Management (EVM) and Multi-Attribute Decision Making (MADM) offers a rational and data-driven method for assessing a project's current status, forecasting its future vulnerability, and evaluating possible recovery options.

The analysis presented shows that the key EVM measures of CPI, SPI, CV, and SV provide a structured basis for measuring cost and schedule performance against the approved baseline. These indicators are further developed through Estimate-to-Complete (ETC) and Estimate-at-Completion (EAC) forecasting to provide insight into potential future cost and schedule outcomes, providing a defensible analytical basis upon which to make decisions regarding the viability of project continuation under the existing execution conditions.

An evaluation of completion strategies indicates that recovery of distressed projects does not have to be a simple continue or terminate decision. The owner needs a broader spectrum of realistic options that are reflective of contractual constraints, execution capacity, operational urgency, and the risk exposure of the owner. The alternatives considered in this study are status quo, contract restructure, partial takeover of the owner, termination, retender, and de-scope to the essential scope. Using the same criteria for cost, schedule, risk, contractual, operational, and value dimensions increases the comparability and transparency of the decision process.

In this case, A5 De-scope to Essential Scope Only is identified as the preferred alternative and remains the leading option in 43 of 45 sensitivity scenarios. It is not a result without conditions. Switching analysis indicates that A2 Contract Restructuring is only preferred if there is concurrent and material degradation in the value, probability of success, and schedule performance of A5. Hence, A5 is the preferred methodology, provided the implementation of A5 is supported by clear monitoring thresholds and a fallback in place.

This study contributes to the body of knowledge in the practice of project management and cost engineering by bridging the gap between performance measurement and strategic decision-making of recovery. EVM is a common tool for diagnosing variances

[72] National Aeronautics and Space Administration. (2015). Loc. Cit

and predicting completion exposure; however, EVM itself does not determine the best recovery strategy. This paper demonstrates that the integration of the EVM diagnostics and MADM-based evaluation can translate project performance data into a systematic decision-making procedure that is in accordance with the principles of the well-established cost engineering and engineering economy.

Future work should extend the model with probabilistic simulation, dynamic updating of decision inputs, and application to a portfolio of distressed infrastructure projects. For project recovery measures for deviations on cost and schedule to be successful, they need to be made into systematic, transparent, and value-oriented decisions under uncertainty.

BIBLIOGRAPHY

1. AACE International. (2015). Recommended practice 32R-04: Determining contingency using expected value analysis. AACE International.

2. AACE International. (2015). Total cost management framework: An integrated approach to portfolio, program, and project management (2nd ed.). AACE International.

3. AACE International. (2024). Recommended practice 71R-12: Required skills and knowledge of decision and risk management (Rev. ed., November 4, 2024). AACE International.

4. AACE International. (2026). Recommended practice 10S-90: Cost engineering terminology. AACE International. https://web.aacei.org/docs/default-source/rps/10s-90.pdf

5. Anbari, F. T. (2003). Earned value project management method and extensions. Project Management Journal, 34(4), 12–23. https://doi.org/10.1177/875697280303400403

6. Business Book Summaries. (2016). Smart choices: John S. Hammond, Ralph L. Keeney, and Howard Raiffa. EBSCO Publishing. https://biblioteca.ufm.edu/library/images/3/3c/Smart_Choices.pdf

7. Giammalvo, P. D., & PTMC. (2021). Project controls/PMO handbook of "best tested and proven practices": Unit 3—Developing business case (CC BY-SA 4.0). PTMC.

8. Giammalvo, P. D., & PTMC. (2021). Project controls/PMO handbook of "best tested and proven practices": Unit 11—Managing progress (CC BY-SA 4.0). PTMC.

9. Government Analysis Function. (2024, May 1). An introductory guide to multi-criteria decision analysis (MCDA). UK Government. https://analysisfunction.civilservice.gov.uk/policy-store/an-introductory-guide-to-mcda/

10. Henderson, K., & Lipke, W. (2007). Earned schedule in action [Conference paper]. 19th International Integrated Program Management Conference, Alexandria, VA, United States. https://www.earnedschedule.com/Docs/Earned%20Schedule%20in%20Action%202.pdf

11. HM Treasury. (2024). Use of multi-criteria decision analysis in options appraisal of economic cases. UK Government. https://assets.publishing.service.gov.uk/media/6645e4b2b7249a4c6e9d3631/Use_of_MCDA_in_options_appraisal_of_economic_cases.pdf

12. Humphreys, G. C. (2024). Project management using earned value (5th ed.). Humphreys & Associates, Inc.

13. International Organization for Standardization. (2026). ISO 21508:2026: Project, program, and portfolio management—Earned value management. International Organization for Standardization.

14. Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. Econometrica, 47(2), 263–291. https://doi.org/10.2307/1914185

15. Kearney. (2017, February 27). Excellence in capital projects: A goal yet to be achieved. https://www.kearney.com/industry/energy/article/-/insights/excellence-in-capital-projects-a-goal-yet-to-be-achieved

16. Keeney, R. L. (1996). Value-focused thinking: Identifying decision opportunities and creating alternatives. European Journal of Operational Research, 92(3), 537–549. https://doi.org/10.1016/0377-2217(96)00197-5

17. Klompjan, R., & Wouters, M. (2009). Restructuring of projects in distress. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.1402282

18. Lipke, W. (2012, September). Earned schedule contribution to project management. PM World Journal, 1(2). https://pmworldjournal.com/article/earned-schedule-contribution-to-project-management

19. MacLeamy, P. (2004). The MacLeamy curve [Presentation/diagram]. MSA-IPD. https://msa-ipd.com/MacleamyCurve.pdf

20. Merrow, E. W. (2011). Industrial megaprojects: Concepts, strategies, and practices for success. John Wiley & Sons.

21. Mezurnishvili, I., Pavlenishvili, L., Shalibashvili, A., Chachava, M., & Chitanava, M. (2024). Multi-criteria analysis in regulatory impact assessment in Georgia: Executive summary. Operational Research Institute. https://www.undp.org/sites/g/files/zskgke326/files/202407/research_summary._english.pdf

22. Ministry of Energy and Mineral Resources, Republic of Indonesia. (2017). Keputusan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 2157 K/10/MEM/2017 tentang penugasan kepada PT Pertamina (Persero) dalam pembangunan dan pengoperasian tangki penyimpanan bahan bakar minyak dan liquefied petroleum gas.

23. Ministry of Energy and Mineral Resources, Republic of Indonesia. (2024). Handbook of energy & economic statistics of Indonesia 2024. https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-economic-statistics-of-indonesia-2024.pdf

24. 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. https://doi.org/10.1016/j.promfg.2015.07.989

25. National Aeronautics and Space Administration. (2015). NASA Cost Estimating Handbook (Version 4.0). https://www.nasa.gov/sites/default/files/files/NASA_Cost_Estimating_Handbook_Version_4-0.pdf

26. National Defense Industrial Association. (2021). Integrated program management division (IPMD) guide to managing programs using predictive measures (3rd ed.).

27. Office of Management and Budget. (1992). Circular A-94: Guidelines and discount rates for benefit-cost analysis of federal programs. Executive Office of the President.

28. Paterson, S. J. C. (2018). A comparison between 8 common cost forecasting methods. PM World Journal, Vol. VII, Issue I, January. https://pmworldlibrary.net/wp-content/uploads/2018/01/pmwj66-Jan2018-Paterson-comparison-of-8-common-forecasting-methods-featured-paper.pdf

29. Putra, H. C. (2026, April 8). Project performance analysis using earned value management: An owner's perspective. 14 Clover.

30. Reinertsen, D. G. (2009). The principles of product development flow: Second-generation lean product development. Celeritas Publishing.

31. Saaty, T. L. (1980). The analytic hierarchy process. McGraw-Hill.

32. Simon, H. A. (1978). Rational decision-making in business organizations: Nobel Memorial Lecture. Nobel Prize. https://www.nobelprize.org/uploads/2018/06/simon-lecture.pdf

33. Stecklein, J. M. (2004). Error cost escalation through the project life cycle. National Aeronautics and Space Administration, Lyndon B. Johnson Space Center.

34. Steps of the scientific method: The stages of scientific research. (n.d.). Explorable.com. https://explorable.com/steps-of-the-scientific-method

35. Sullivan, W. G., Wicks, E. M., & Koelling, C. P. (2020). Engineering economy (17th ed., global). Pearson.

36. U.S. Department of Defense. (2018). Earned value management implementation guide. U.S. Department of Defense.

37. U.S. Government Accountability Office. (2015). Schedule assessment guide: Best practices for project schedules (GAO-16-89G). https://www.gao.gov/assets/gao-16-89g.pdf

38. U.S. Government Accountability Office. (2020). GAO cost estimating and assessment guide: Best practices for developing and managing program costs (GAO-20-195G). https://www.gao.gov/assets/gao-20-195g.pdf

39. Vafaei, N., Ribeiro, R. A., & Camarinha-Matos, L. M. (2016). Normalization techniques for multi-criteria decision making: Analytical hierarchy process case study. In L. M. Camarinha-Matos, A. J. Falcão, N. Vafaei, & S. Najdi (Eds.), Doctoral Conference on Computing, Electrical and Industrial Systems (pp. 261–269). Springer. https://doi.org/10.1007/978-3-319-31165-4_26

40. Vanhoucke, M. (2010). Measuring time: Improving project performance using earned value management. Springer.

41. Wisnugroho, J. (2020, February). Indonesia oil & gas cost estimating vs international "best-tested and proven" practices: A benchmarking study. PM World Journal, 9(2). https://pmworldjournal.com/article/indonesia-oil-gas-cost-estimating-vs-international-best-tested-and-proven-practices

42. Zilikram, M. F. (2023, October). Benchmarking Indonesia's downstream oil & gas construction: Evaluating project scheduling and cost estimating processes against global "best tested and proven" practices. PM World Journal, 12(10). https://pmworldjournal.com/article/benchmarking-indonesias-downstream-oil-gas-construction

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