

Using Statistical Forecasting Methods to Accurately Track Contractor Performance Measurement Baselines in South Africa's Power Generation Industry ¹

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Abstract

Because of a shortage of accredited Project Controls Professionals in South Africa with proficiency in AACE and GPC methodologies, tools, techniques and recommended practices (RP), best practice is mostly ignored to track Contractor performance effectively. Proven and tested EVM and ES forecasting techniques are disputed; denying the true value of EVM.

The main sources of information that used for performing the analysis of this paper come from the NDIA², GPCCaR³ and the GAO⁴. This paper applies the EVM forecasting formulas, contained within these sources, to the case study project of Kusile Power Station to monitor and control the Contractor's schedules during the procurement and execution phases. GAO best practices were employed during the early phases to create a realistic and reliable baseline schedule.

This paper provides a set of guidelines for fellow practitioners to follow when developing similar mega, multi-disciplinary project forecasts, thereby mitigating the risk of potential claims during the project life cycle by assisting the PM team in making informed decisions.

Keywords: *Guild of Project Controls Compendium & Reference (GPCCaR), U.S. Government Accountability Office (GAO), National Defense Industrial Association (NDIA), IEAC, Z-Tables, Coefficient of Determination (R Squared), Regression Analysis, PERT.*

Introduction

This case study represents the Kusile Power Station project, which, when completed, will become one of the world's largest coal-fired power plant. It is the first South African power facility to incorporate wet flue gas desulphurization (FGD) technology generating with 6 Units x 800MW of power once fully operational.

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² National Defense Industrial Association / Integrated Program Management Division. (NDIA) (2014). A guide to Managing Programs Using Predictive Measures. Retrieved from <http://www.ndia.org/>

³ (GPCCaR) (2015, Nov 2). Module 9-5-Project Performance Forecasting | Project Controls – planning, scheduling, cost management and forensic analysis (Planning Planet). Retrieved May 3, 2018, Retrieved from <http://www.planningplanet.com/guild/gpccar/project-performance-forecasting>

⁴ GAO-16-89G, Schedule Assessment Guide: Best Practices for Project Schedules (2015, December). Retrieved from <https://www.gao.gov/assets/680/674404.pdf>

The synchronisation of Unit 1 was achieved on 26 December 2016, full load during March 2017 and finally commercial operation in the first quarter of 2018. The Kusile Project furthermore achieved a major milestone of Back Energization on 14 May 2017 for Unit 2. The achievement of this milestone was six weeks ahead of the P80 re-baselined target schedule. Back Energization is an important milestone for the project as it gives a true indication of the readiness of the Unit 2 export system. Back Energization is a true litmus test of the Unit's interface with Transmission and National Control. It also indicates progress regarding Grid Code requirements, Generator Protection and Unit 2 MV switchgear, all of this via the distributed control system (DCS). The purpose for Back Energization is to use power from the grid to source the loads in Unit 2 using the unit transformers which feed the MV switchgear to facilitate the commissioning of Boiler Feed Pump motors or the Draught Group Fans on load without the risk of tripping the unit. This milestone is a big stepping stone towards Unit 2 synchronisation and the key milestones required before Unit 2 synchronisation (e.g. Draught Group Run, Boiler Chemical Cleaning, First Fire on Oil, First Fire on Coal and Initial Steam Admission to Steam Turbine).



Figure 1 – Kusile Power Station Aerial Photograph (Dec 2016)

Meeting the Project Milestone Target dates were imperative to the success of the project and the meeting of South Africa's increasing demand for power. It's therefore imperative for the Clients Project Controls Department to ensure that "Best Practice" is followed by the Contractors' planning departments to mitigate the Clients risk exposure to multi-million dollar claims.

After the rigorous evaluation process, the approved Contractors Baseline Schedules are integrated into the Project Master Plan (PMP).

A well-constructed and integrated schedule is a fundamental management tool to assist government programs to use public funds efficiently, by mitigating interface delays. The schedule assists the Clients PM team to effectively coordinate the execution of the construction activities which includes the testing, quality control and engineering activities required for safety clearance. The schedule also acts as a tool to guide the PM team when work must be performed and a tool to measure program performance according to the performance measurement baseline (PMB). Continuous and periodic schedule performance tracking is essential to verify if the set performance parameters are realistic and achievable. A well-constructed schedule facilitates an analysis of how the interface package changes, e.g. other contractor's delays could affect the overall integrated PMP and is an essential basis for managing tradeoffs between cost, schedule, and scope. Ultimately the reliability of the schedule determines the credibility of the programmes forecast dates for decision making.

In the absence of a reliable baseline programme, all EVM methodologies are at risk of failure during the early stages of reporting and would be worthless as a tool to proactively manage and coordinate the scheduled activities.

Research shows, one of the main contributing factors why projects fail is improper scope definition; therefore sufficient effort and time should be spent on developing the WBS by following the 100% rule to cover the full scope. Horizontal and vertical traceability aligned with the PMP will reduce the schedule updating time drastically during the monitoring and reporting phases. Continuous field reporting is another important factor to consider, and serious efforts must be made to have live progress updates to improve the accuracy of the EVM analysis.

Its highly recommended that during the schedule development phase, the use of parametric estimates are employed to estimate activity durations because of the advantage that they take into account, historical rates based on the existing site conditions, external and internal constraints, resource constraints, project risks at the time, labour skills and crew makeup's etc. Verifying Contractors Schedule updates for out-of-sequence activities for immediate corrective action to mitigate skew reporting are imperative to avoid corrupting and misleading EVM forecasts. Skew Reporting is a common strategy employed by contractors to improve their cash flows and support contractual games.

The author of this paper found that the GAO's best practice for project schedule is the most comprehensive document available being tested and proven to be reliable during the project mentioned above.

This paper's focus is on determining the best forecasting method, assuming a reliable baseline schedule for reporting are in place and "best practice" are followed during the updating process. We will furthermore evaluate the accuracy of the original forecast figures and conclude with a set of guidelines of forecasting methods for use by fellow practitioners.

Statistical Forecasting Methods using Historical Efficiency to Mathematically Calculate Future Predicted Cost

Review of the Guild of Project Controls Compendium and Reference (GPCCaR) “Module 9.5 ‘Project Performance Forecasting’ provides five independent EAC’s (IEAC), four coming from NDIA’s Guide to Managing Programs Using Predictive Measures, and one coming from the collective experience of the GPC authors”⁵. The Author has introduced a six method (IEAC6) by taking the average from the IEAC1 to IEAC5.

1. $IEAC1 = ACWP + ((BAC - BCWP) / CPI)$
2. $IEAC2 = ACWP + ((BAC - BCWP) / SPI)$
3. $IEAC3 = ACWP + ((BAC - BCWP) / CPI \times SPI)$
4. $IEAC4 = ACWP + ((BAC - BCWP) / (0.2 \times SPI) + (0.8 \times CPI))$
5. IEAC5 = Detailed Estimate
6. IEAC6 = Average (IEAC1:IEAC5)

The first five (5) formula’s all start with the ACWP as that is a “sunk cost”- This is the cost that has already been spent and adds the Estimated Cost to Complete (ETC), i.e. $EAC = ACWP + ETC$.

The NDIA together with the GPCCaR provides assumptions and outcomes for each cost forecasting method as follows:

IEAC METHOD	ASSUMPTIONS	COMMENTS
IEAC1	Future cost performance is the same as historical cost performance	Best Case when $CPI < 1.00$ Worst Case when $CPI > 1.00$
IEAC2	Future cost performance will be affected by historical schedule performance.	SPI loses accuracy over the last third of the project; therefore alternative methods is advisable during this period.
IEAC3	Future cost performance will be affected by the past schedule and cost performance.	This calculation typically yields the Worst Case when the CPI and $SPI < 1.00$
IEAC4	Similar to IEAC3, except increased weight is placed on the CPI .	Less weight placed on the SPI calculation, therefore, more reliable than IEAC later in the project.
IEAC5	Future cost performance is influenced by productivity	Used when the actual costs or productivity either is not known or is subject to variability and needs to be validated for any specific application or context to provide future outcomes in terms of either time or cost.

Table 1 – IEAC Assumptions and Outcomes^{6 7}

⁵ <https://js-pag-cert-2017.com/blog/page/3/>

⁶ National Defense Industry Association / Integrated Program Management Division. (NDIA) (2014). A guide to Managing Programs Using Predictive Measures. Retrieved from <http://www.ndia.org/>

Criteria Selection

Based on the case study, we will utilise eight (8) months of real historical project data to calculate each of the five cost forecasting methods. The EAC for each month is calculated, and then data is extrapolated to month sixteen (16). Using the MS Excel, “Best Fit” Regression Analysis Curves, the best case, worst case and the most likely case is determined.

Our conclusion is reached by applying the Project or Program Evaluation and Review Technique (PERT) formula, utilising Z-Tables, to identify the model that yields the most accurate predictions. This evaluation is used to determine the probability that predicted values would fall within the ±10% of the target cost estimates (BAC) at the end of month thirteen (13).

To evaluate the effect of the different IEAC’s the actual figures from the eight-month report will be used to allow the generation of each forecast.

With the Unit 3 start date for the E, C&I works of 04-Jul-17, we use the actual historical project data up to the end of Feb-18 totalling eight (8) months.

ACTUAL DATA								
Project Duration	Mnth 1 (Million US\$)	Mnth 2 (Million US\$)	Mnth 3 (Million US\$)	Mnth 4 (Million US\$)	Mnth 5 (Million US\$)	Mnth 6 (Million US\$)	Mnth 7 (Million US\$)	Mnth 8 (Million US\$)
Spreadsheet Field	Jul '17	Aug '17	Sep '17	Oct '17	Nov '17	Dec '17	Jan '18	Feb '18
BAC	50.9	50.9	50.9	50.9	50.9	50.9	50.9	50.9
BCWSed	2.0	3.3	5.6	7.1	10.7	14.3	15.8	21.4
BCWSld	1.5	1.8	3.6	4.6	8.7	12.2	13.2	19.4
ACWP	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0
BCWP	1.8	3.1	5.1	6.4	9.7	12.7	15.6	21.8
SPI	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0
CPI	1.4	1.3	1.3	1.1	1.1	1.0	1.1	1.1
IEAC1	36.9	38.2	40.8	48.3	47.4	49.8	46.1	46.8
IEAC2	57.2	53.9	53.9	54.6	53.5	53.5	49.7	49.0
IEAC3	41.8	41.0	44.0	52.1	50.4	52.6	46.3	46.7
IEAC4	39.5	40.4	42.4	48.9	47.7	49.2	46.7	47.5
IEAC5	36.9	38.2	40.8	48.3	47.4	49.8	46.1	46.8

Table 2 – 8 Months of Real Historical Project Data⁸

Note: All the data in the table is hypothetical for confidentiality reasons given the sensitivity of proprietary project data. All figures in US\$ Millions

IEAC1 Regression Analysis and Applying PERT Formula to Calculate P50, P75 & P90

The summary of the results from the above EVM figures is shown in Figure 1 below.

⁷ Guild of project controls compendium and reference (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (2015, October 3). Retrieved November 11, 2017 from <http://www.planningplanet.com/guild/gpccar/project-performance-forecasting>

⁸ By Author

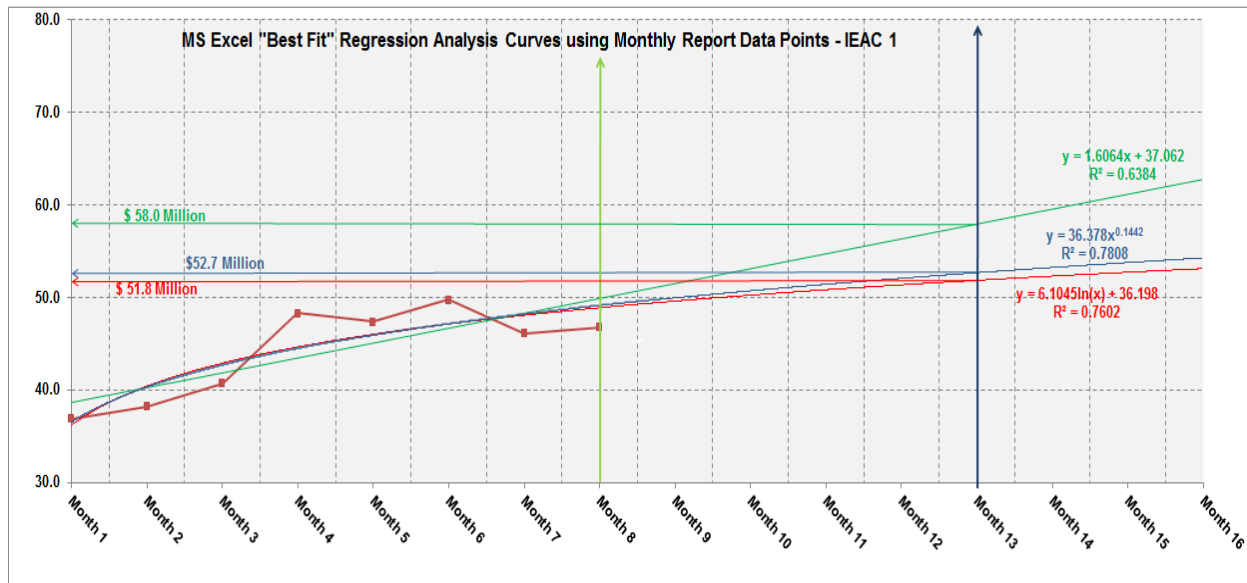


Figure 1 – IEAC1 MS Excel “Best Fit” Regression Analysis Curves⁹

Regression Type	R ² Value	Mandatory Value (Million US\$)	Rank
Linear	0.6384	58.0	Worse
Power	0.7808	52.7	Most Likely
Logarithmic	0.7602	51.8	Best

Table 3 – IEAC1 Regression Analysis Results¹⁰

1. Best Case Projection (Optimistic) - The Logarithmic regression analysis curve, i.e. $R^2 = 0.7602$ intersects at the value of \$ 51.8 Million at the end of month thirteen (13).
2. Most Likely Case Projection - The Power regression analysis curve, i.e. $R^2 = 0.7808$ intersects at the value of \$ 52.7 Million at the end of month thirteen (13).
3. Worst Case Projection (Pessimistic) - The Linear regression analysis curve, i.e. $R^2 = 0.6384$ intersects at the value of \$ 58.0 Million at the end of month thirteen (13).

R^2 values of <0.90 , i.e. $0.6384 > 0.7602$ indicate that the analysis is fairly risky which could produce skewed and inaccurate results. As per our best case, only 76.02% of the points fall within the regression line. A higher coefficient is an indicator of a better quality of fit.

⁹ By Author
¹⁰ By Author

Using the PERT formula (Rounded up/down to the nearest million dollars):

- **Step 1 – PERT (Weighted Mean)**
 (Best Case + (4 x Mean) + Worse Case) / 6
 = ((58.0 + (4 x 52.7) + 51.8) / 6)
 = \$ 53.4 Million
- **Step 2 – Standard Deviation (Sigma)**
 (Largest value – Smallest value) / 6
 = (58.0 – 51.8) / 6
 = \$ 1.03 Million
- **Step 3 – Variance**
 Variance = Sigma²
 = \$ 1.03²
 = \$ 1,067,089 Million

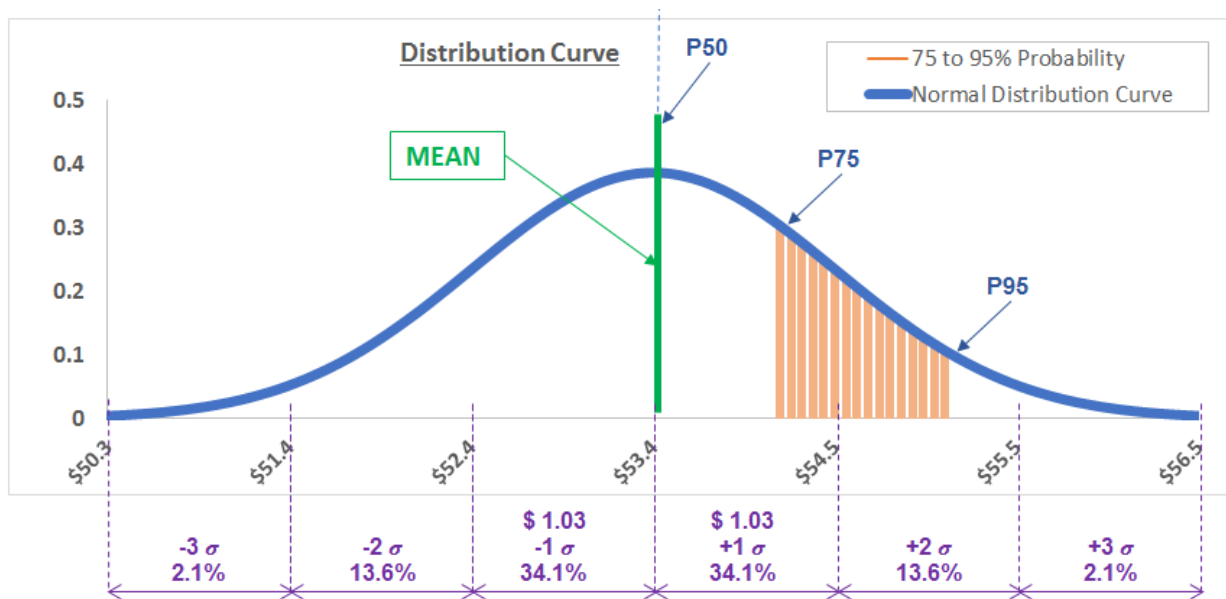


Figure 2 – IEAC1 Normal Distribution Curve Showing ‘Mean’ Value¹¹

Step 3 reveals that the variance falls more than ±3 sigma; therefore it is advisable to recommend to the management that they should choose a higher P, confidence or comfort level.

For this forecasting method the following figures have been determined:

- P50 (Mean) = \$ 53.4 million and;
- P75 = \$ 54.1 million and;
- P95 = \$ 55.1 million

¹¹ By Author

IEAC2 Regression Analysis and Applying PERT Formula to Calculate P50, P75 & P90

The summary of the results from the above EVM figures is shown in Figure 3 below.

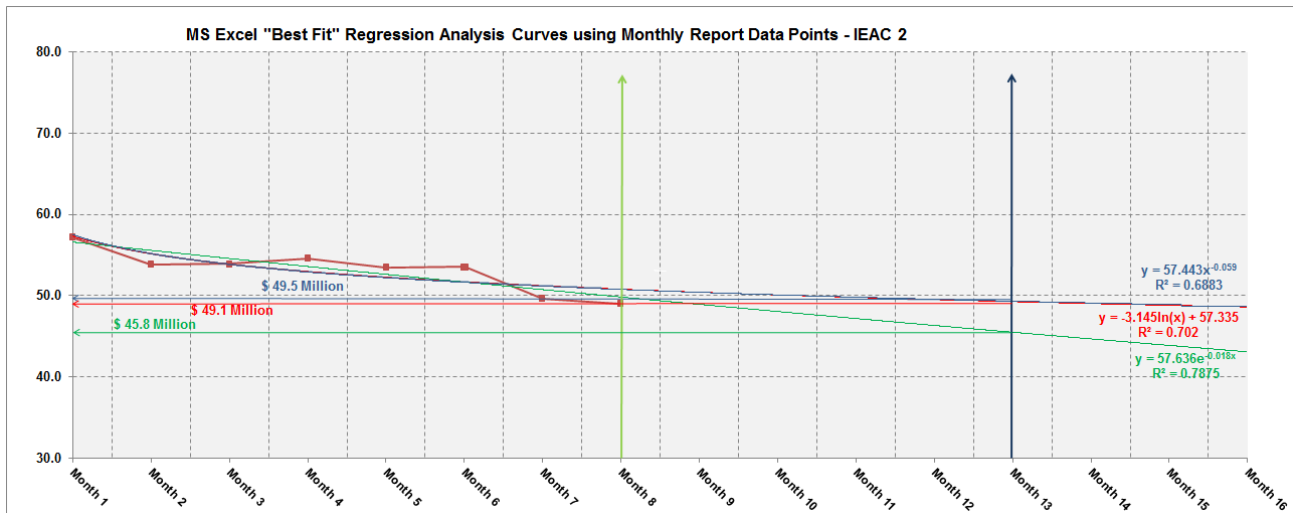


Figure 3 – IEAC2 MS Excel “Best Fit” Regression Analysis Curves¹²

Regression Type	R ² Value	Mandatory Value (Million US\$)	Rank
Power	0.6883	49.5	Worse
Logarithmic	0.7020	49.1	Most Likely
Exponential	0.7875	45.8	Best

Table 4 – IEAC2 Regression Analysis Results¹³

1. Best Case Projection (Optimistic) – This time the Exponential regression analysis curve, i.e. $R^2 = 0.7875$ is the best case projection and intersects at the value of \$ 45.8 Million at the end of month thirteen (13).
2. Most Likely Case Projection (Mean) – This time the Logarithmic regression analysis curve, i.e. $R^2 = 0.7020$ intersects at the value of \$ 49.1 Million at the end of month thirteen (13).
3. Worst Case Projection (Pessimistic) - This time the Power regression analysis curve, i.e. $R^2 = 0.6883$ intersects at the value of \$ 49.5 Million at the end of month thirteen (13).

R^2 values of <0.90 , i.e. $0.6883 > 0.7875$ indicate that the analysis is fairly risky which could produce skewed and inaccurate results. As per our best case, only 78.75% of the points fall within the regression line. A higher coefficient is an indicator of a better quality of fit.

¹² By Author

¹³ By Author

Using the PERT formula (Rounded up/down to the nearest million dollars):

- Step 1 – PERT (Weighted Mean)
 (Best Case + (4 x Mean) + Worse Case) / 6
 = ((45.8 + (4 x 49.1) + 49.5) / 6)
 = \$ 48.6 Million
- Step 2 – Standard Deviation (Sigma)
 (Largest value – Smallest value) / 6
 = (49.5 – 45.8) / 6
 = \$ 0.617 Million
- Step 3 – Variance
 Variance = Sigma²
 = \$ 0.617²
 = \$ 380,689.7 Million

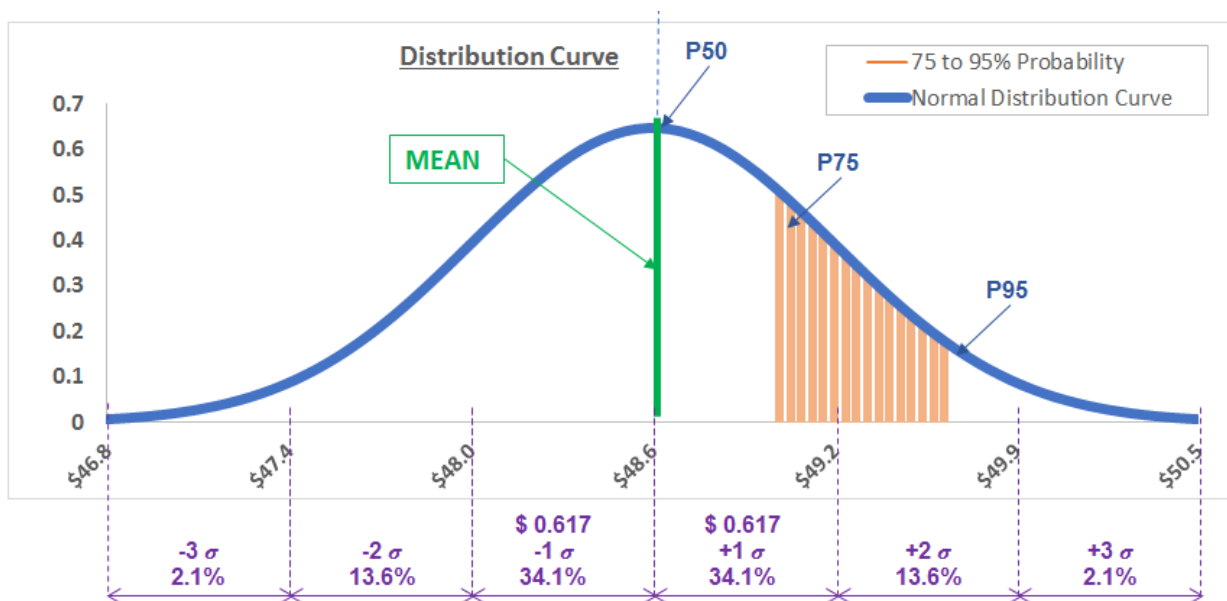


Figure 4 – IEAC2 Normal Distribution Curve Showing ‘Mean’ Value¹⁴

For this forecasting method the following figures have been determined:

- P50 (Mean) = \$ 48.6 million and;
- P75 = \$ 49.0 million and;
- P95 = \$ 49.6 million

¹⁴ By Author

IEAC3 Regression Analysis and Applying PERT Formula to Calculate P50, P75 & P90

The summary of the results from the above EVM figures is shown in Figure 5 below.

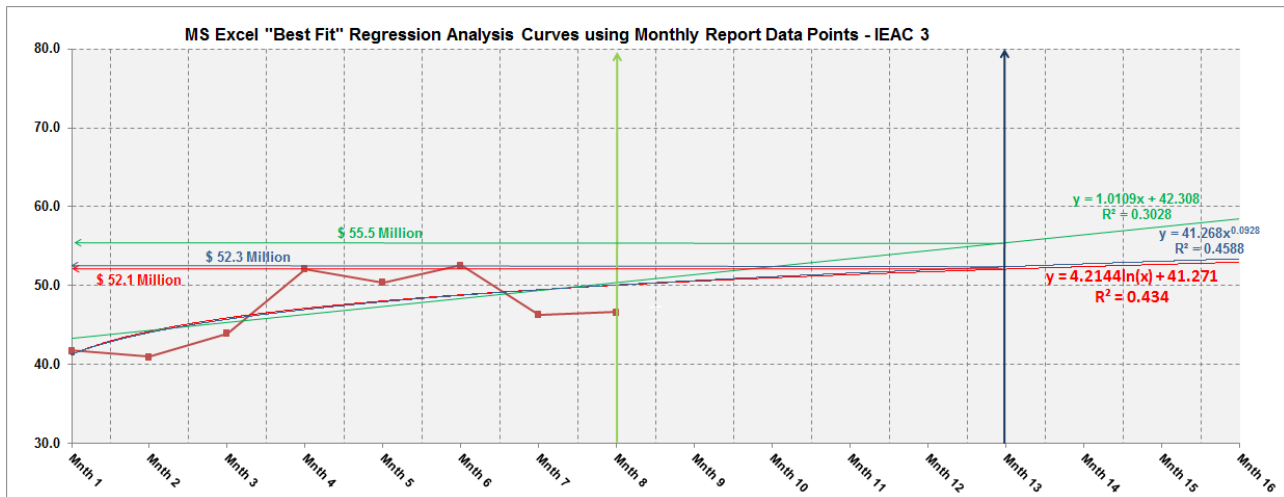


Figure 5 – IEAC3 MS Excel “Best Fit” Regression Analysis Curves ¹⁵

Regression Type	R ² Value	Mandatory Value (Million US\$)	Rank
Linear	0.3028	55.5	Worse
Power	0.4588	52.3	Most Likely
Logarithmic	0.4340	52.1	Best

Table 5 – IEAC3 Regression Analysis Results

1. Best Case Projection (Optimistic) – This time the Logarithmic regression analysis curve, i.e. $R^2 = 0.434$ is the best case projection and intersects at the value of \$ 52.1 Million at the end of month thirteen (13).
2. Most Likely Case Projection (Mean) – This time the Power regression analysis curve, i.e. $R^2 = 0.4588$ intersects at the value of \$ 52.3 Million at the end of month thirteen (13).
3. Worst Case Projection (Pessimistic) - This time the Linear regression analysis curve, i.e. $R^2 = 0.3028$ intersects at the value of \$ 55.5 Million at the end of month thirteen (13).

With the R^2 values of <0.90 , i.e. $0.3028 > 0.434$ indicate that the analysis is fairly risky which could produce skewed and inaccurate results. As per our best case, only 43.4% of the points fall within the regression line. A higher coefficient is an indicator of a better quality of fit.

¹⁵ By Author

Using the PERT formula (Rounded up/down to the nearest million dollars):

- Step 1 – PERT (Weighted Mean)
 (Best Case + (4 x Mean) + Worse Case) / 6
 = ((52.1 + (4 x 52.3) + 55.2) / 6)
 = \$ 52.8 Million
- Step 2 – Standard Deviation (Sigma)
 (Largest value – Smallest value) / 6
 = (55.5 – 52.1) / 6
 = \$ 0.567 Million
- Step 3 – Variance
 Variance = Sigma²
 = \$ 0.6²
 = \$ 321,111 Million

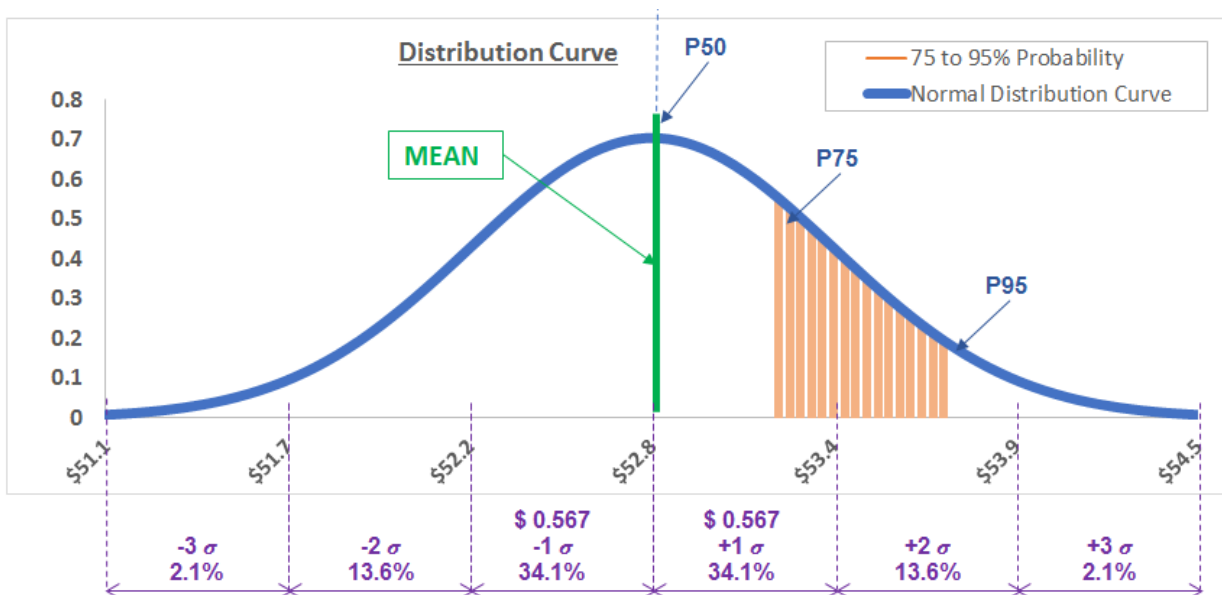


Figure 6 – IEAC3 Normal Distribution Curve Showing ‘Mean’ Value¹⁶

Step 3 reveals that the variance falls more than ± 3 sigma; therefore it is advisable to recommend to the management that they should choose a higher P, confidence or comfort level. For this forecasting method the following figures have been determined:

- P50 (Mean) = \$ 52.8 million and;
- P75 = \$ 53.2 million and;
- P95 = \$ 53.7 million

¹⁶ By Author

IEAC4 Regression Analysis and Applying PERT Formula to Calculate P50, P75 & P90

The summary of the results from the above EVM figures is shown in Figure 7 below.

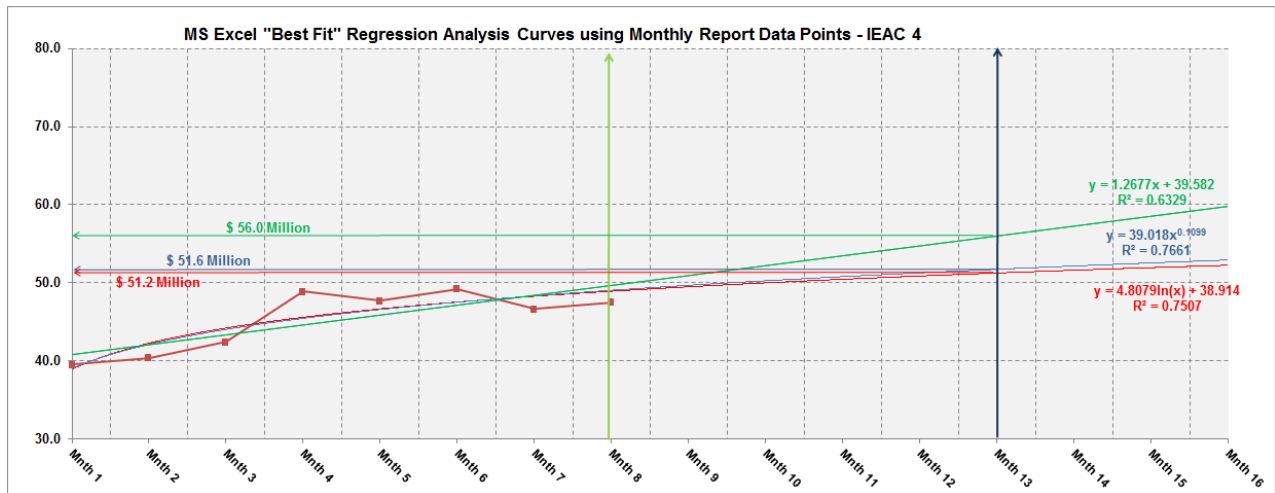


Figure 7 – IEAC4 MS Excel “Best Fit” Regression Analysis Curves¹⁷

Regression Type	R ² Value	Mandatory Value (Million US\$)	Rank
Linear	0.6329	56.0	Worse
Power	0.7661	51.6	Most Likely
Logarithmic	0.7507	51.2	Best

Table 6 – IEAC4 Regression Analysis Results¹⁸

1. Best Case Projection (Optimistic) – The Logarithmic regression analysis curve (same as Blog W01 and W03), i.e. R² = 0.7507 is the best case projection and intersects at the value of \$ 51.2 Million at the end of month thirteen (13).
2. Most Likely Case Projection (Mean) – The Power regression analysis curve, i.e. R² = 0.7661 intersects at the value of \$ 51.6 Million at the end of month thirteen (13).
3. Worst Case Projection (Pessimistic) – The Linear regression analysis curve, i.e. R² = 0.6329 intersects at the value of \$ 56.0 Million at the end of month thirteen (13).

With the R² values of <0.90, i.e. 0.6329>0.7507 indicates that the analysis is fairly risky which could produce skewed and inaccurate results. As per our best case, only 75.07% of the points fall within the regression line. A higher coefficient is an indicator of a better quality of fit.

¹⁷ By Author
¹⁸ By Author

Using the PERT formula (Rounded up/down to the nearest million dollars):

- Step 1 – PERT (Weighted Mean)
 (Best Case + (4 x Mean) + Worse Case) / 6
 = ((51.2 + (4 x 51.6) + 56.0) / 6)
 = \$ 52.3 Million
- Step 2 – Standard Deviation (Sigma)
 (Largest value – Smallest value) / 6
 = (56.0 – 51.2) / 6
 = \$ 0.8 Million
- Step 3 – Variance
 Variance = Sigma²
 = \$ 0.8²
 = \$ 640,000 Million

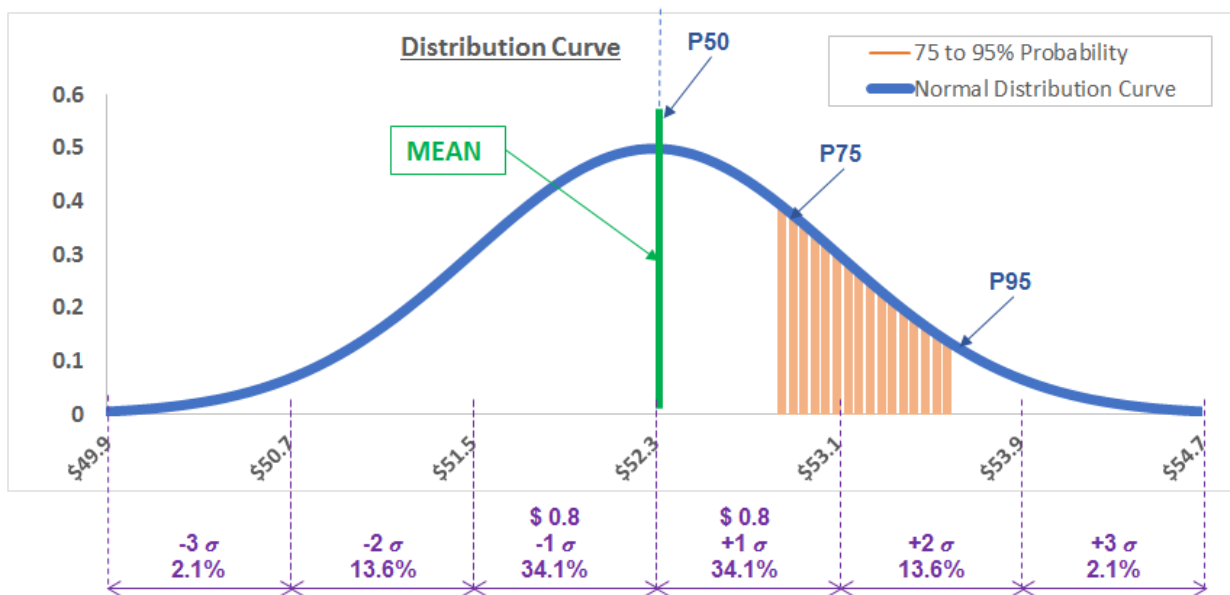


Figure 8 – IEAC4 Normal Distribution Curve Showing ‘Mean’ Value¹⁹

Step 3 reveals that the variance falls more than ±3 sigma; therefore it is advisable to recommend to the management that they should choose a higher P, confidence or comfort level.

For this forecasting method the following figures have been determined:

- P50 (Mean) = \$ 52.3 million and;
- P75 = \$ 52.8 million and;
- P95 = \$ 53.6 million

¹⁹ By Author

IEAC5 Regression Analysis and Applying PERT Formula to Calculate P50, P75 & P90

The summary of the results from the above EVM figures is shown in Figure 9 below.

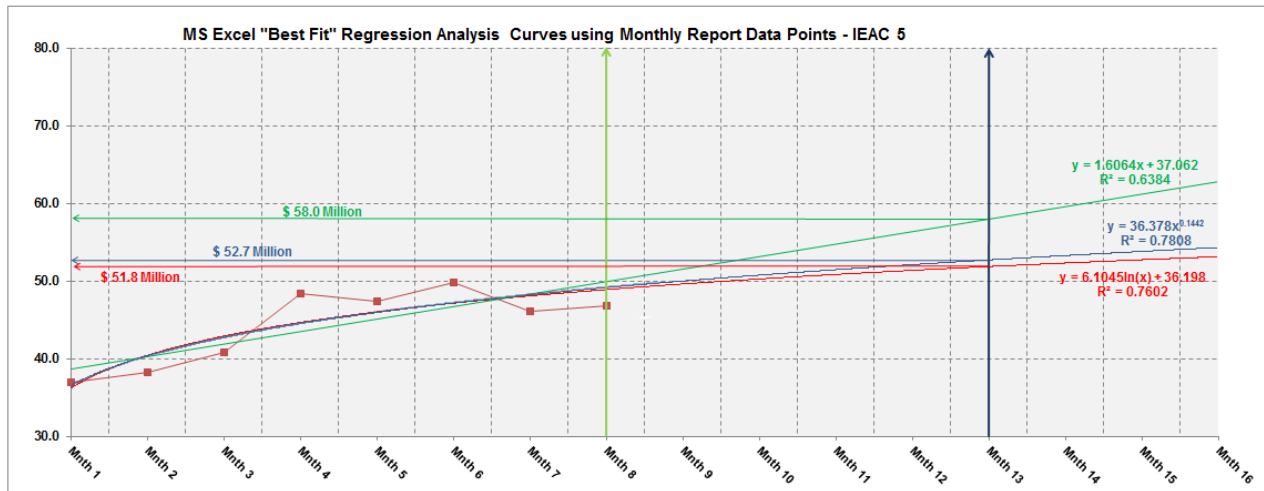


Figure 9 – IEAC5 MS Excel “Best Fit” Regression Analysis Curves²⁰

Regression Type	R ² Value	Mandatory Value (Million US\$)	Rank
Linear	0.6384	58.0	Worse
Power	0.7808	52.7	Most Likely
Logarithmic	0.7602	51.8	Best

Table 7 – IEAC5 Regression Analysis Results²¹

1. Best Case Projection (Optimistic) – The Logarithmic regression analysis curve (same as blog W01, W03 and W04), i.e. R² = 0.7602 is the best case projection and intersects at the value of \$ 51.8 Million at the end of month thirteen (13).
2. Most Likely Case Projection (Mean) – This time the Power regression analysis curve (same as blog W01, W03 and W04), i.e. R² = 0.7808 intersects at the value of \$ 52.7 Million at the end of month thirteen (13).
3. Worst Case Projection (Pessimistic) - This time the Linear regression analysis curve (same as blog 03.1 & 04.1), i.e. R² = 0.6388 intersects at the value of \$ 61 100 Million at the end of month thirteen (13).

With the R² values of <0.90, i.e. 0.6384>0.7602 indicates that the analysis is fairly risky which could produce skewed and inaccurate results. As per our best case, only 76.02% of the points fall within the regression line. A higher coefficient is an indicator of a better quality of fit for the observations.

²⁰ By Author
²¹ By Author

Using the PERT formula (Rounded up/down to the nearest million dollars):

- Step 1 – PERT (Weighted Mean)
 (Best Case + (4 x Mean) + Worse Case) / 6
 = ((51.8 + (4 x 52.7) + 58.0) / 6)
 = \$ 53.4 Million
- Step 2 – Standard Deviation (Sigma)
 (Largest value – Smallest value) / 6
 = (58.0 – 51.8) / 6
 = \$ 1.03 Million
- Step 3 – Variance
 Variance = Sigma²
 = \$ 1.03²
 = \$ 1,067,089 Million

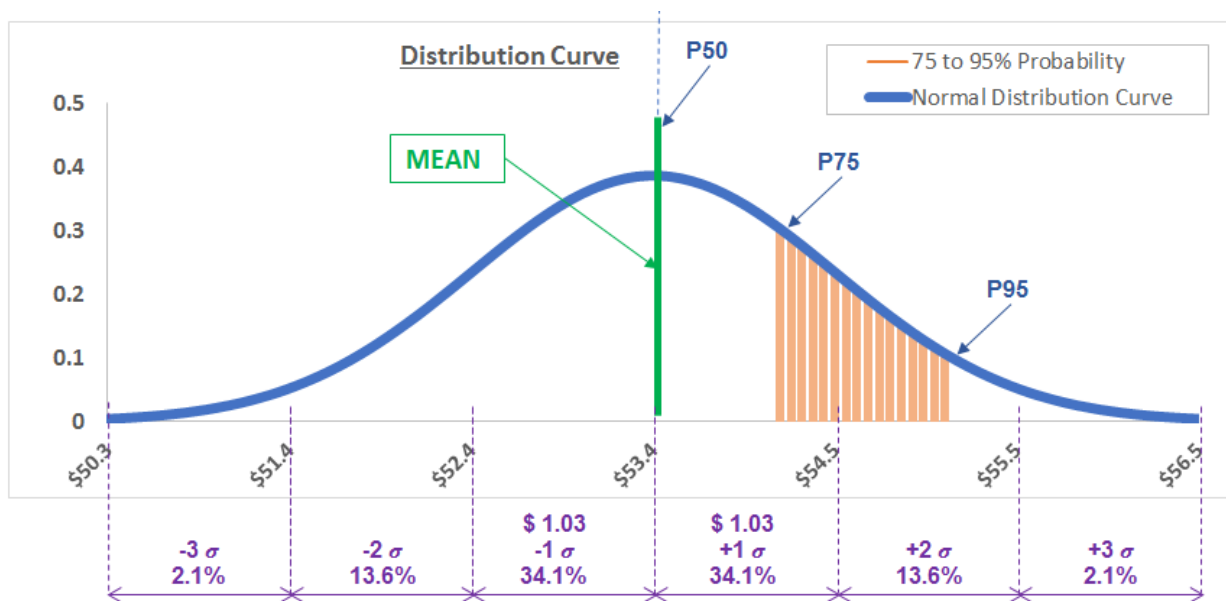


Figure 10 – IEAC5 Normal Distribution Curve Showing ‘Mean’ Value²²

Step 3 reveals that the variance falls more than ±3 sigma; therefore it is advisable to recommend to the management that they should choose a higher P, confidence or comfort level.

For this forecasting method the following figures have been determined:

- P50 (Mean) = \$ 53.4 million and;
- P75 = \$ 54.1 million and;
- P95 = \$ 55.1 million

²² By Author

IEAC6 Analysis - Average (IEAC1: IEAC5)

To evaluate the effect of the different IEAC’s the actual figures from the month eight report will be used to allow the generation of each forecast.

Project Duration	Month 1 (Million US\$)	Month 2 (Million US\$)	Month 3 (Million US\$)	Month 4 (Million US\$)	Month 5 (Million US\$)	Month 6 (Million US\$)	Month 7 (Million US\$)	Month 8 (Million US\$)	Month 13 (Million US\$)
ACWP vs IEAC1@13	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0	46.8
ACWP vs IEAC2@13	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0	49.0
ACWP vs IEAC3@13	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0	46.7
ACWP vs IEAC4@13	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0	47.5
ACWP vs IEAC5@13	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0	46.8
ACWP vs IEAC6@13 (Ave)	1.3	2.3	4.1	6.1	9.0	12.4	14.1	20.0	47.4
	ACWP								IEAC

Table 8 – 8 Months of Actual Project Data and IEAC for Month 13²³

Probability Analysis Utilizing Z-Tables

Using the “Best Fit” regression analysis of each IEAC, we determined the MEAN and Standard Deviation. Now we will analyze the probability that the predicted MEAN values of each IEAC will fall within ± 10% of the TARGET (BAC) cost estimate.

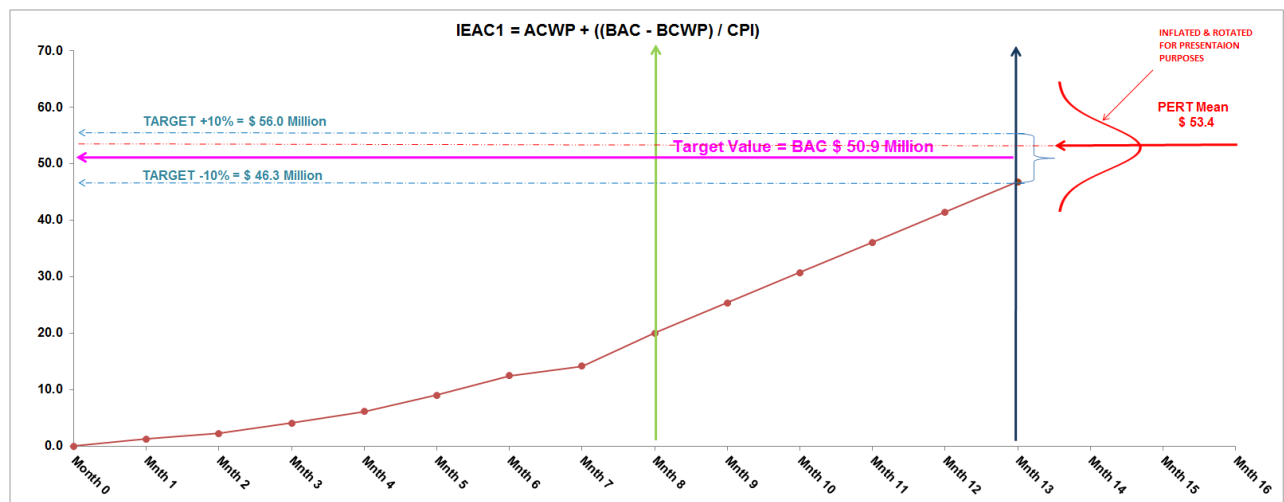


Figure 11 - IEAC1 MEAN = \$ 53.4 and σ = \$ 1.033²⁴

Description	Value (Millions US\$)	Difference \$	Sigma>Mean	Z-Table
BAC +10%	56.0	2.6	2.52	99.41%
PERT MEAN	53.4	0.00		
Target BAC	50.9	-2.49	-2.41	0.79%
BAC -10%	46.3	-7.1	-6.90	0.00%

Table 9 - IEAC1 Z-Table Values²⁵

²³ By Author

²⁴ By Author

²⁵ By Author

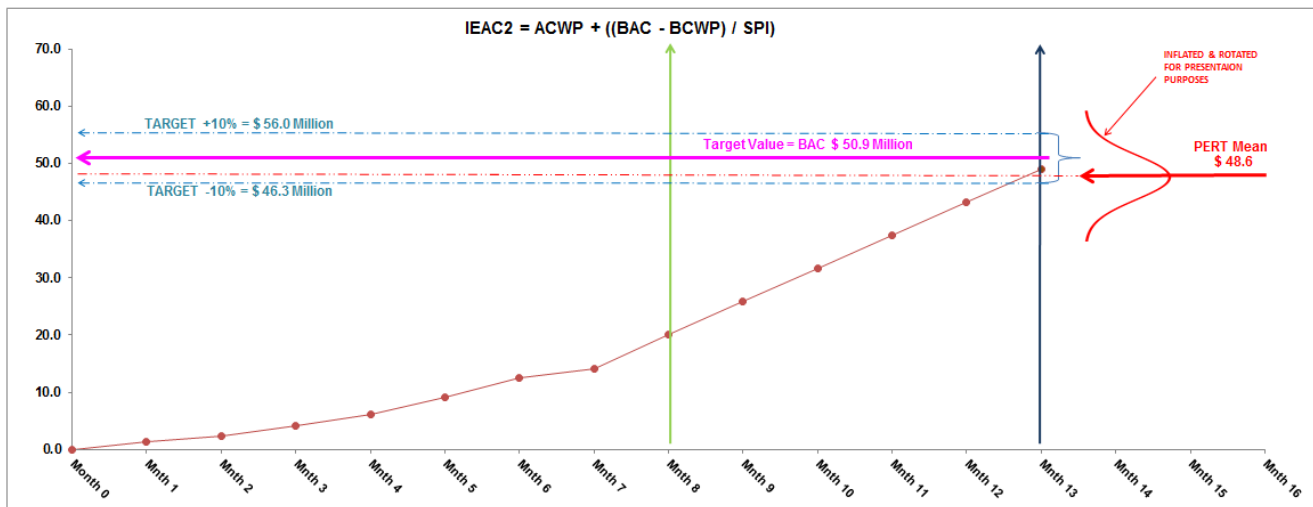


Figure 12 – IEAC2 MEAN = \$ 48.6 and $\sigma = \$ 0.617^{26}$

Description	Value (Millions US\$)	Difference \$	Sigma>Mean	Z-Table
BAC +10%	56.0	7.4	12.03	100.00%
Target BAC	50.9	2.32	3.77	99.99%
PERT MEAN	48.6	0.00		
BAC -10%	46.3	-2.3	-3.74	0.00%

Table 10 – IEAC2 Z-Table Values²⁷

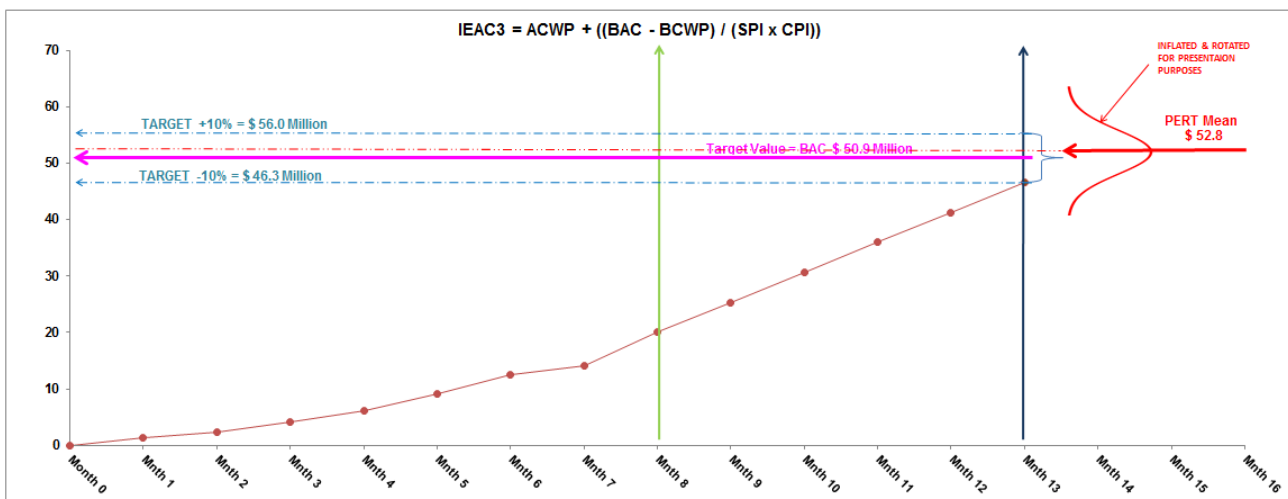


Figure 13 – IEAC3 MEAN = \$ 52.8 and $\sigma = \$ 0.567^{28}$

²⁶ By Author

²⁷ By Author

²⁸ By Author

Description	Value	Difference \$	Sigma>Mean	Z-Table
BAC +10%	56.0	3.2	5.71	100.00%
PERT MEAN	52.8	0.00		
Target BAC	50.9	-1.86	-3.28	5.00%
BAC -10%	46.3	-6.5	-11.46	0.00%

Table 11 – IEAC3 Z-Table Values²⁹

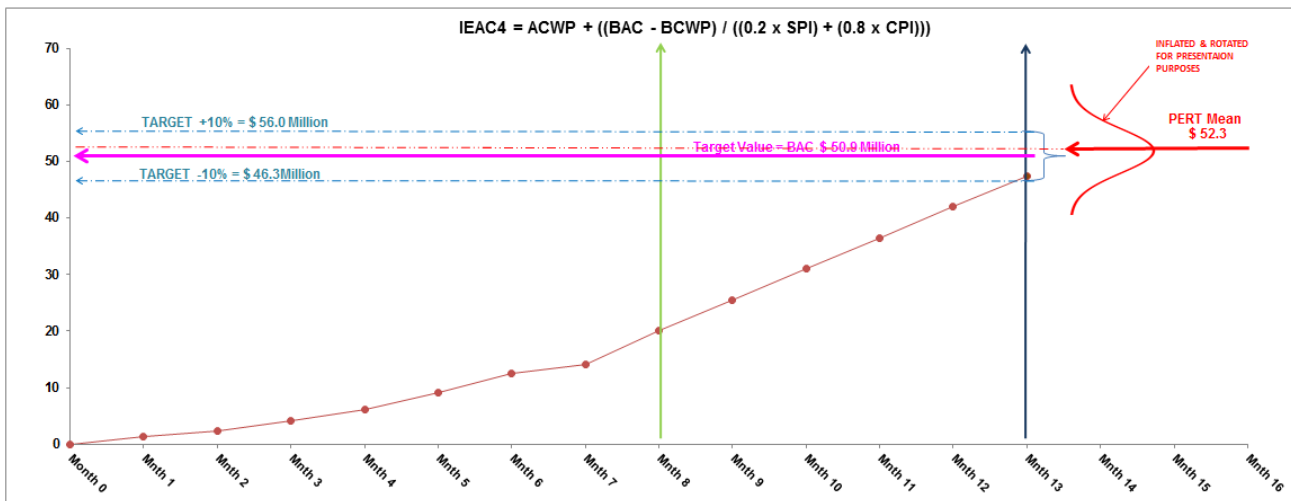


Figure 14 – IEAC4 MEAN = \$ 52.3 and σ = \$ 0.8³⁰

Description	Value	Difference \$	Sigma>Mean	Z-Table
BAC +10%	56.0	3.8	4.71	100.00%
PERT MEAN	52.3	0.00		
Target BAC	50.9	-1.33	-1.66	4.80%
BAC -10%	46.3	-6.0	-7.45	0.00%

Table 12 – IEAC4 Z-Table Values³¹

²⁹ By Author

³⁰ By Author

³¹ By Author

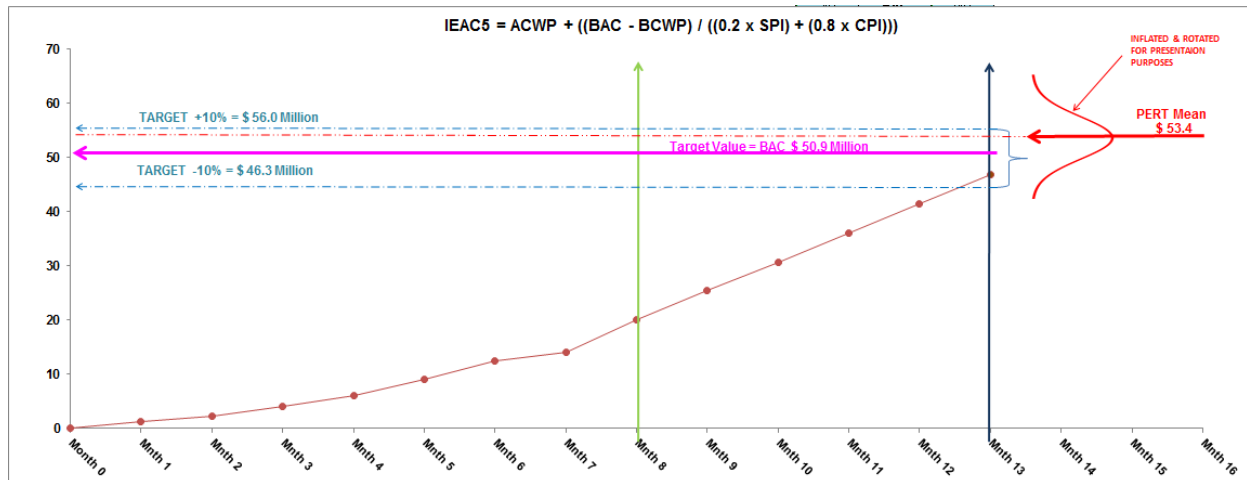


Figure 15 – IEAC5 MEAN = \$ 53.4 and $\sigma = \$ 1.033$ ³²

Description	Value	Difference \$	Sigma>Mean	Z-Table
BAC +10%	56.0	2.6	2.52	99.41%
PERT MEAN	53.4	0.00		
Target BAC	50.9	-2.49	-2.41	00.79%
BAC -10%	46.3	-7.1	-6.90	0.00%

Table 13 – IEAC5 Z-Table Values

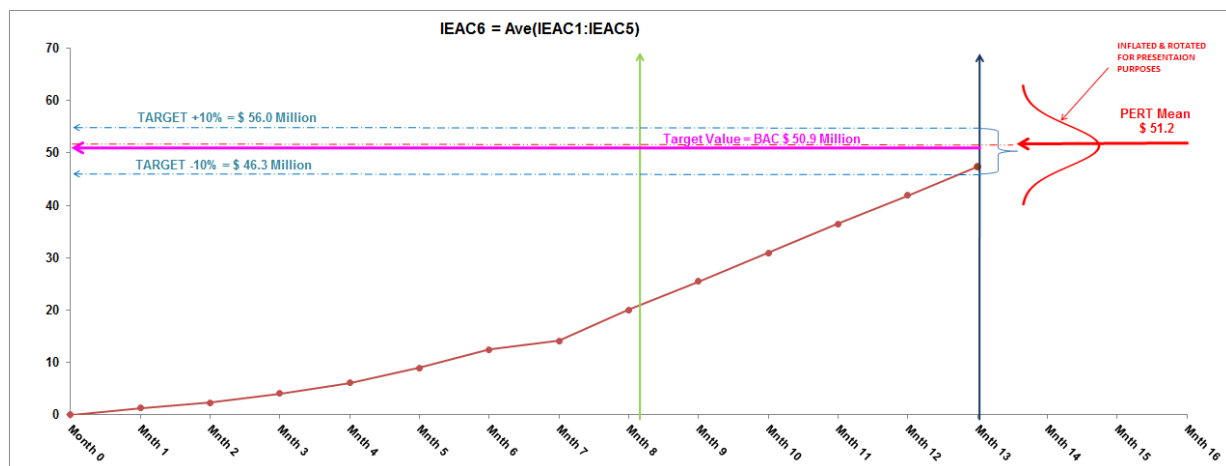


Figure 16 – IEAC6 MEAN = \$ 51.2 and $\sigma = \$ 0.413$ ³³

Description	Value	Difference \$	Sigma>Mean	Z-Table
BAC +10%	56.0	4.8	11.71	100.00%
PERT MEAN	51.2	0.00		
Target BAC	50.9	-0.25	-0.62	26.67%
BAC -10%	46.3	-4.9	-11.82	0.00%

Table 14 – IEAC6 Z-Table Values³⁴

³² By Author

³³ By Author

³⁴ By Author

Preferred Statistical Forecasting Method to Calculate Future Predicted Cost

Comparing the analysis above the following can now be determined:

- Most accurate IEAC prediction which yields the least BAC variance at the end of month thirteen.
- The probability that our predicted values will fall within the BAC to +10% of the target cost estimates (BAC) at the end of month thirteen (13).

Description	IEAC Value	PERT MEAN Value	Target BAC – MEAN Deviation	Most Accurate IEAC Method Using Mean Ranked (1-6)	Probability of falling within $\pm 10\%$ of the Target Value (BAC)
Target Value (BAC)	50.9				
IEAC1	46.8	53.4	-2.49 or -4.9%	5	99.41%
IEAC2	49.0	48.6	2.32 or 4.6%	4	100%
IEAC3	46.7	52.8	-1.86 or -3.5%	3	100%
IEAC4	47.5	52.3	-1.33 or 2.5%	2	100%
IEAC5	46.8	53.4	-2.49 or -4.9%	5	99.41%
IEAC6	47.4	51.2	-0.25 or -0.5%	1	100%

Table 15 – Most Accurate IEAC Method Ranked in Order from No 1 to 6³⁵

The probability of IEAC6 method predictions falling in between the Target BAC and less than +10% from the BAC equals 73.33%.

Monitoring Post Evaluation Performance

During the monitoring and controlling process the most accurate forecasting method must continuously be determined and analysed for management level decisions making and incorporated during the risk review process.

It's recommended that further testing of the forecasting models is required, by using actual data from various real projects, to see if the predictive models are consistent.

Summary and Conclusion

The accuracy of the EVM forecasts is imperative to project success and must be evaluated on a periodical basis to assist management with root-cause identification for corrective and preventive actions during the window of opportunity (between 15% to 30% elapsed time).

³⁵ By Author

Our main responsibility as Project Controls Professionals is to equip the PM team, based on best practice methodologies, with the most accurate and reliable tools to make decisions timeously. Your expert judgement will be required to determine which formula is most appropriate given the specific situation you are experiencing.

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Juan Marcel van Aswegen is a Lead Project Planner and Project Controls Analyst with over 20 years' experience representing the Client, Owners Engineer and Contractor in the Project Management and Project Controls fields, specialising in Mega Projects, and well experienced to add tangible value to any PM team. Juan has gained experience in the following industries: Power Generation, i.e. Hydro Power Generation, Coal Fired Power Station, Mining, Rail and Ports, Roads and Manufacturing in all the engineering disciplines. Understanding the Organizational Strategy with strong attention to detail based on International Best Practice; he has mastered the ability to navigate through complex project environments throughout the entire Project Life Cycle from Pre-Feasibility to Hot Commissioning / Handover. He is currently furthering his education by way of 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 Guild of Project Controls and AACE (CCP) certifications.

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