

## **A Comparison Between 8 Common Cost Forecasting Methods**

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### **Abstract**

Forecasts, one of the most important tools in a Project Controls Practitioners toolkit, the importance of which cannot be stressed enough. Although it may not be an exact science, analyzing the project data, evaluating the trends and getting the message to Project Team and Stakeholders is an important step in creating a successful project. Yes, creating, successful projects just don't happen by themselves, they are created by a team of competent professionals utilizing the best resources available to them. Nowadays, a high percentage of projects are failing due to several factors, one of which is poor "tracking and analysis. Tracking and analysis cover a large scope in the practitioner's remit, part of which is forecasting. This forecasting needs to be accurate, utilizing as much of the historic and current data as possible to provide the best possible information to allow informed decisions to be made.

The NDIA's "Guide to Managing Programs and Projects Using Predictive Measures" along with the Guild of Project Controls "Compendium and Reference" (CaR) are two sources of information available to practitioners that should be considered when performing such analysis. This paper explores the information contained within these sources and applies their formulas against a live project to determine which methodology provides the best accuracy, before providing some guidelines for fellow practitioners to consider when developing similar forecasts.

**Keywords:** @Risk, Forecasts, Forecasting, Guild of Project Controls, Linear Regression, Monte Carlo Simulation, GAO, MS Excel Best Fit Curve, Mean, NDIA, Normal Distribution, Standard Deviation, Oracle, Crystal Ball

### **Introduction**

Forecasting, a term used to describe a planning tool that helps management to cope with uncertainty of the future, utilizing past and present data in conjunction with analysis of trends.<sup>1</sup> In today's economic climate the importance of dealing with this uncertainty is becoming more and more critical as marginally viable projects strive to achieve tighter budgets amid financial constraints imposed by the stakeholders.

Why marginally viable projects? Well because nowadays projects have a high "failure rate" and projects that were originally viable are resulting in failure. Research shows many studies have been performed to determine why projects fail and what can be done to enhance competitiveness to reverse the trends.<sup>2 3 4 5</sup> The GAO's Best Practices a) Cost Estimating and Assessment Guide

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<sup>1</sup> forecasting. BusinessDictionary.com. Retrieved August 20, 2017, from BusinessDictionary.com website:  
<http://www.businessdictionary.com/definition/forecasting.html>

<sup>2</sup> International Project Leadership Academy. (2012). Facts and figures – Why do projects fail? Retrieved from  
[http://calteam.com/WTPF/?page\\_id=1445](http://calteam.com/WTPF/?page_id=1445)

<sup>6</sup>, and b) Schedule Assessment Guide <sup>7</sup> were developed by the US Government to address the numerous projects that were over-running both schedule and costs,<sup>8</sup> and the several projects the author has worked on since 2005 were not big success stories either, all overran schedule by several months.

There are various causes why projects fail and although they might be given different names by different researchers, there is some commonality between them; goals and visions, engagement of stakeholders, inadequate/poor leadership, team communication, risk management, scope estimation, planning expectations, tracking and analysis, decision making, and for those global projects the added topic of cultural differences appears. It's a wide and varied range of topics that essentially covers most, if not the entire project. This paper is not going to address all the items listed above, but is going to focus on the "tracking and analysis" item, that of forecasting.

In the Oil and Gas sector there is a big emphasis on the use of dashboards and key performance indicators (KPIs) which goes some of the way to assisting the project teams to identify potential trends if the project controls team are doing the correct analysis. However, analysis of the historic trends is only a part of what is required, with the rest attributed to looking forward in the future or forecasting. If a contractor is not meeting the daily objectives set out in the schedule then the chances of meeting the final target is virtually impossible, unless a recovery plan is implemented.

Without the detailed analysis and forecasting techniques to determine where the activity is headed, be it on schedule, ahead of schedule, or behind schedule, there is no knowing whether a recovery plan is required or not. The importance of providing project management not only with forecast ranges but also a proposed recovery implementation for potential schedule busts is crucial to the success of the project. As noted above in the causes for project failure, high on the list was team communication (team issues), tracking and analysis, and making decisions, by performing the correct analysis, communicating it to the team members, allows them to make informed decisions which creates one success after another. Projects are about creating small successes and building on each one to achieve the big success, forecasting is one of the key building blocks.

When starting out in the industry, the author was advised by his mentors that forecasting did not make any sense until an activity was at least 25% complete, a view held until recently, however it is now believed that the "window of opportunity" is between 15% to 33% from the commencement of the project to identify if the project is in trouble and what mitigations can be implemented, failure to act in that time frame reduces the probability to implement an effective recovery if at all.<sup>9</sup>

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<sup>3</sup> KPMG UK. (2016, July). Forecasting with confidence - insights from leading finance functions. Retrieved from <https://home.kpmg.com/content/dam/kpmg/pdf/2016/07/forecasting-with-confidence.pdf#page1>

<sup>4</sup> The Standish Group, & Project Smart. (2014). The Standish Group report - Chaos. Retrieved from <https://www.projectsmart.co.uk/white-papers/chaos-report.pdf>

<sup>5</sup> Symonds, M. (2011, June 13). 15 Causes of project failure. Retrieved from <https://www.projectsmart.co.uk/15-causes-of-project-failure.php>

<sup>6</sup> United States. Government Accountability Office. (2009). *GAO cost estimating and assessment guide: Best practices for developing and managing capital program costs*. Washington, DC: United States Govt. Accountability Office.

<sup>7</sup> United States. Government Accountability Office. (2015). *GAO schedule assessment guide: Best practices for project schedules*. Washington, DC: United States Govt. Accountability Office.

<sup>8</sup> Paterson, S. J. (2017, August). *Scoring model for scheduling - Project Management World Journal*. Retrieved from <http://pmworldjournal.net/article/scoring-model-scheduling/>

<sup>9</sup> 09.5.3.3.3 IEAC1 Example - Guild of Project Controls. (2015, October 3). Guild of project controls compendium and reference (CaR) | Project controls - planning, scheduling, cost management and forensic analysis (Planning planet). Retrieved August 20, 2017, from <http://www.planningplanet.com/guild/gpccar/project-performance-forecasting>

There are numerous methods available to project controls teams when performing evaluation of the trends to provide a forecast, review of the Guild of Project Controls GPCCAR<sup>10</sup>, and NDIA's Guide to Managing Programs and Projects Using Predictive Measures<sup>11</sup> provide several examples to use. So many options but which one provides the answer that will satisfy management. This paper will evaluate the methods available, testing each method against selected data points, and developing a forecasted estimated budget at project completion, and comparing the results obtained.

It is also important to ensure that any forecast uses the three key quality controls attributes of accuracy, precision and reliability. "Accuracy" refers to how close the forecast is to the actual value within an acceptable target range, "Precision" the spread of the forecasted data points is tightly grouped and not dispersed, and "Reliability" relates to the consistency of the results obtained when the process is repeated several times.

The problem statement to be reviewed is "Which forecasting method provides a better level of accuracy?"

Specifically, this paper wants to conclude with a set of guidelines for use of the forecasting methods available to practitioners.

## Forecasting Methods Available

As mentioned in the introduction there are a several methods available when developing a forecast or should it be forecast range as trying to pin-point an exact figure could be likened to trying to find a needle in a haystack. Review of the GPCCAR and NDIA's guide provide five available methods, further research provides another three methods, all methods will be reviewed in this paper.

The available methods are:

- $IEAC1 = ACWP + ((BAC - BCWP) / CPI)$
- $IEAC2 = ACWP + ((BAC - BCWP) / SPI)$
- $IEAC3 = ACWP + ((BAC - BCWP) / CPI * SPI)$
- $IEAC4 = ACWP + ((BAC - BCWP) / ((0.2 * SPI) + (0.8 * CPI)))$
- $IEAC5 = ACWP + ((BAC - BCWP) / (EV / AC))$
- MS Excel's "Best Fit" regression analysis curve
- Monte Carlo simulation using MS Excel
- Monte Carlo simulation using Oracle's Crystal Ball

For this paper, the author suggests that IEAC1 to IEAC5 be evaluated as one method and use the forecast range provided to develop the probability figures. The group will be called IEAC methodology.

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<sup>10</sup> Guild of Project Controls. (2015, October 3). Guild of project controls compendium and reference (CaR) | Project controls - planning, scheduling, cost management and forensic analysis (Planning planet). Retrieved August 20, 2017, from <http://www.planningplanet.com/guild/gpccar/project-performance-forecasting>

<sup>11</sup> National Defense Industrial Association / Integrated Program Management Division. (2014). *A guide to managing programs using predictive measures*. Retrieved from <http://www.ndia.org/>

## Criteria Selection

To evaluate the methods the following criteria has been used.

- 10 Data points from a live project (Weeks 1 to 10)
- Project Duration is 26 weeks.
- Control Estimate budget is \$49,795 (includes \$3,720 Contingency / without Contingency \$46,075)

Project Background: A 26-week distance learning AACE/GPC mentoring course in preparation for achievement of desired certification. The course required development of a detailed schedule of resource loaded activities along with an estimated control budget to monitor and report weekly progress against. Due to unforeseen circumstances, the original project scope was de-scoped in week 4 and a re-forecasted schedule and budget developed to maintain the project completion in week 26.

Figure 1 shows; the control budget (including contingency) as the top blue line in the chart reflecting the \$49,795, the early (blue dashed) and late (red dashed) curves (excluding the contingency = \$46,075), ACWP, and BCWP progress at week 10.

Ah, that word “Contingency”. Just to clarify here, the performance measurement baseline (PMB) includes contingency and can be used to cover items such as Internal risk events or known unknowns. It should not be confused with “Management Reserve” which is not included in the PMB and is used to cover the unknown unknowns or External risk events.

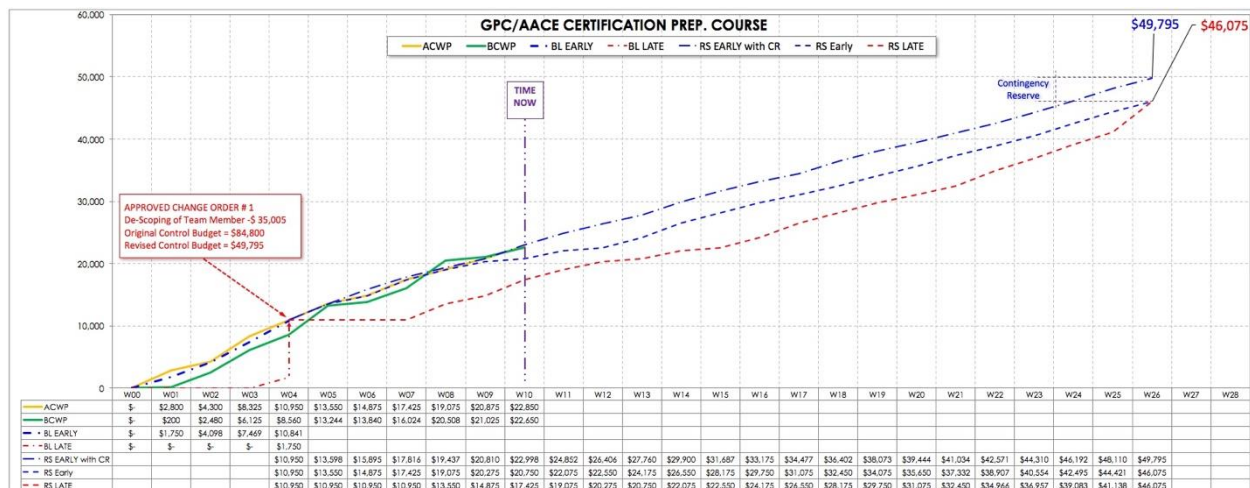


Figure 1 – Live Project Progress at week 10<sup>12</sup>

Table 1 shows the project status at week 10, the CPI and SPI figures will be used in the IEAC methodology calculations.

<sup>12</sup> By Author

GROUP PROJECT ACTIVITY	BAC	BCWS	ACWP	BCWP	CPI	SPI
WBS 1	\$ 1,000	\$ 600	\$ 600	\$ 600	1.00	1.00
WBS 1.3	\$ 4,550	\$ 4,550	\$ 4,550	\$ 4,550	1.00	1.00
WBS 1.4	\$ 3,000	\$ 975	\$ 975	\$ 975	1.00	1.00
WBS 1.5.1	\$ 23,675	\$ 10,475	\$ 12,175	\$ 12,175	1.00	1.16
WBS 1.5.2	\$ 3,900	\$ -	\$ -	\$ -	1.00	1.00
WBS 1.5.3	\$ 4,750	\$ 1,750	\$ 2,150	\$ 1,950	0.91	1.11
WBS 1.5.4.1	\$ 1,300	\$ -	\$ -	\$ -	1.00	1.00
WBS 1.5.4.2	\$ 1,500	\$ -	\$ -	\$ -	1.00	1.00
WBS 1.6.1	\$ 1,150	\$ 1,150	\$ 1,150	\$ 1,150	0.00	0.00
WBS 1.6.2	\$ 100	\$ 100	\$ 100	\$ 100	0.00	0.00
WBS 1.6.3	\$ 1,150	\$ 1,150	\$ 1,150	\$ 1,150	0.00	0.00
WBS 1.8	\$ 3,720	\$ -	\$ -	\$ -	0.00	0.00
<b>Total</b>	<b>\$ 49,795</b>	<b>\$ 20,750</b>	<b>\$ 22,850</b>	<b>\$ 22,650</b>	<b>0.99</b>	<b>1.09</b>

Table 1 – Weekly Report Status for week 10<sup>13</sup>

Table 2 shows the data values from the figure 1 chart. The evaluation process will use either the ten ACWP values or the Control budget (\$49,795) during the analysis process.

	W00	W01	W02	W03	W04	W05	W06	W07	W08	W09	W10
ACWP	\$-	\$2,800	\$4,300	\$8,325	\$10,950	\$13,550	\$14,875	\$17,425	\$19,075	\$20,875	\$22,850
BCWP	\$-	\$200	\$2,480	\$6,125	\$8,560	\$13,244	\$13,840	\$16,024	\$20,508	\$21,025	\$22,650
• BL EARLY	\$-	\$1,750	\$4,098	\$7,469	\$10,841						
• BL LATE	\$-	\$-	\$-	\$-	\$1,750						
• RS EARLY with CR					\$10,950	\$13,598	\$15,895	\$17,816	\$19,437	\$20,810	\$22,998
- - RS Early					\$10,950	\$13,550	\$14,875	\$17,425	\$19,075	\$20,275	\$20,750
- - RS LATE					\$10,950	\$10,950	\$10,950	\$10,950	\$13,550	\$14,875	\$17,425

Table 2 – ACWP data points for use in analysis<sup>14</sup>

To normalize the results, the use of the P50, P75, P90, P95 values will be used to determine the accuracy of the forecast, along with a comparison as to how each forecast method is looking against the ACWP figure at week 14.

Except for the @Risk Monte-Carlo simulation, determination of the probability values will use the Program Evaluation and Review Technique (PERT) formulas.

## Independent Estimate at Completion (IEAC) Methodology

Although there are five IEAC's listed NDIA's "Guide to Managing Programs using Predictive Measures" provide four of them, and the fifth comes from the GPCCAR based on the collective experience of the GPC authors.

Figure 2 shows information from the NDIA guide regarding the IEAC1, 2, 3 and 4.

<sup>13</sup> By Author

<sup>14</sup> By Author



Figure 2 – NDIA's Four IEAC's<sup>15</sup>

IEAC	Formula	Assumption	Comments
IEAC1	$= ACWP + \frac{BAC - BCWP}{CPI}$	Future cost performance will be the same as all past cost performance.	"Best Case" when CPI is below 1.00, and "Worst Case" when CPI is above 1.00.
IEAC2	$= ACWP + \frac{BAC - BCWP}{SPI}$	Future cost performance will be influenced by past schedule performance.	Use with caution as SPI is diluted by LOE and loses accuracy over the last third of the project.
IEAC3	$= ACWP + \frac{BAC - BCWP}{SPI \times CPI}$	Future cost performance will be influenced by past schedule and cost performance.	In contrast to IEAC1, this calculation typically yields the "Worst Case" (pessimistic) when CPI and SPI are below 1.00.
IEAC4	$= ACWP + \frac{BAC - BCWP}{(0.2 \times SPI) + (0.8 \times CPI)}$	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.

**Note:** "Best Case" is also referred to as "IEAC<sub>min</sub>", while "Worst Case" is also known as "IEAC<sub>max</sub>"

The fifth IEAC comes from the GPCCAR and assumes that future cost performance will be influenced by productivity, and it uses actual costs along with productivity to plus/minus adjust the cost budgets to reflect realistic "real / true" costs.

The formula for IEAC5 is  $ACWP + ((BAC - BCWP) / (EV / AC))$ .

Using the IEAC formulas listed, each one used the information in table 1, and provided the following forecasts.

Week 10 Status						IEAC1 ACWP + ((BAC - BCWP) / CPI)			IEAC2 ACWP + ((BAC - BCWP) / SPI)		
	BAC	BCWP	ACWP	CPI	SPI	BAC - BCWP	CPI	Forecast	BAC - BCWP	SPI	Forecast
WBS 1	1,000	600	600	1.00	1.00	400	1.00	1,000	400	1.00	1,000
WBS 1.3	4,550	4,550	4,550	1.00	1.00	-	1.00	4,550	-	1.00	4,550
WBS 1.4	3,000	975	975	1.00	1.00	2,025	1.00	3,000	2,025	1.00	3,000
WBS 1.5.1	23,675	10,475	12,175	1.00	1.16	13,200	1.00	25,375	13,200	1.16	23,532
WBS 1.5.2	3,900	-	-	1.00	1.00	3,900	1.00	3,900	3,900	1.00	3,900
WBS 1.5.3	4,750	1,750	2,150	0.91	1.11	3,000	0.91	5,458	3,000	1.11	4,842
WBS 1.5.4	1,300	-	-	1.00	1.00	1,300	1.00	1,300	1,300	1.00	1,300
WBS 1.5.4.1	1,500	-	-	1.00	1.00	1,500	1.00	1,500	1,500	1.00	1,500
WBS 1.6	2,400	2,400	2,400	1.00	1.00	-	1.00	2,400	-	1.00	2,400
WBS 1.8	3,720	-	-	-	-	-	-	-	-	-	-
	49,795	20,750	22,850	0.91	1.00			48,483			46,024

IEAC3 ACWP + ((BAC - BCWP) / (CPI * SPI))			IEAC4 ACWP + (BAC - BCWP) / ((0.2 * SPI) + (0.8 * CPI))			IEAC5 ACWP + (BAC - BCWP) / (EV/AC)		
BAC - BCWP	CPI * SPI	Forecast	BAC - BCWP	0.2 * SPI + 0.8 * CPI	Forecast	BAC - BCWP	BCWP / ACWP	Forecast
400	1.00	1,000	400	1.00	1,000	400	1.00	1,000
-	1.00	4,550	-	1.00	4,550	-	1.00	4,550
2,025	1.00	3,000	2,025	1.00	3,000	2,025	1.00	3,000
13,200	1.16	23,532	13,200	1.03	24,960	13,200	0.86	27,517
3,900	1.00	3,900	3,900	1.00	3,900	3,900	1.00	3,900
3,000	1.01	5,118	3,000	0.95	5,313	3,000	0.81	5,836
1,300	1.00	1,300	1,300	1.00	1,300	1,300	1.00	1,300
1,500	1.00	1,500	1,500	1.00	1,500	1,500	1.00	1,500
-	1.00	2,400	-	1.00	2,400	-	1.00	2,400
		-			-			-
		46,300			47,923			51,003

Table 3 – Forecasts using IEAC1, 2, 3, 4 and 5 methods<sup>16</sup>

<sup>15</sup> National Defense Industrial Association / Integrated Program Management Division. (2014). *A guide to managing programs using predictive measures*. Retrieved from <http://www.ndia.org/>

Using the period information from the above developed forecasts and plotted the points on a chart, figure 3 provides an illustration of the range of figures determined. It should be noted that the above forecasts are based on the control budget (excl. contingency reserve) as drawdown of the reserve would be expected until it has been fully utilized.

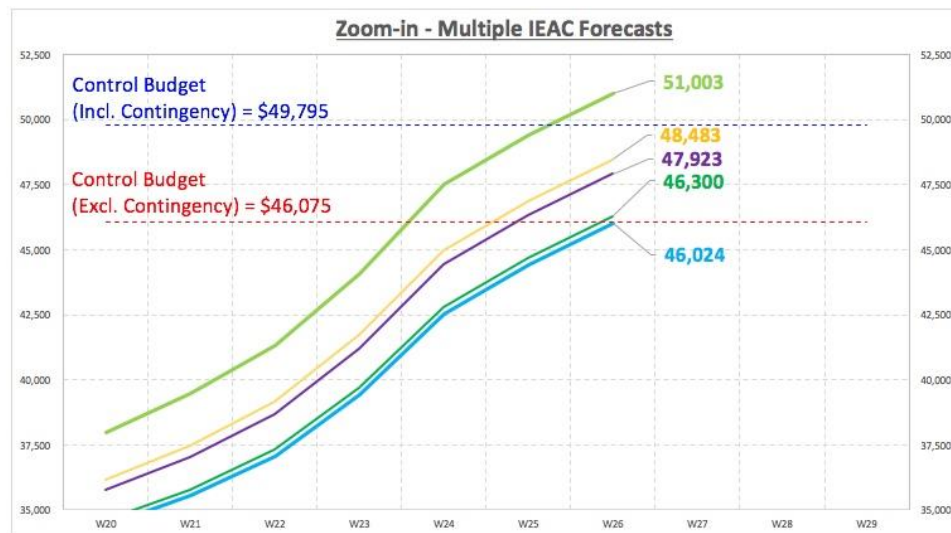


Figure 3 – Multiple IEAC forecasts <sup>17</sup>

From the above, it is possible to determine the “Best Case” (BC), “Worst Case” (WC) and “Most Likely Case” (MLC), so the BC = \$46,024 / WC = \$51,003 / MLC = Average of (46,300, 47,923, 48,483) = 47,569.

The PERT formulas allows determination of:

1. PERT Mean = (Optimistic + (4 x Most Likely) + Pessimistic) / 6
2. PERT Standard Deviation = (Largest value – Smallest value) / 6
3. PERT Variance = Sigma<sup>2</sup>

Therefore, the following results can be obtained by applying the above figures to these formulas.

- Mean = (46,024 + (4 x 47,569) + 51,003) / 6 = 287,303 / 6 = 47,884
- Std. Deviation = (51,003 – 46,024) / 6 = 4,979 / 6 = 829.83
- Variance = 829.83<sup>2</sup> = 688,621

Please note that the variance is large (688,621 / 2) = 344,310 = 414.9 Sigma and reveals that the number is risky, so a higher P number (P90 and above) should be considered when determining forecasts.

Inputting the above PERT information into a normal distribution curve provides the following curve, which allows determination of the P numbers required for the forecast.

<sup>16</sup> By Author

<sup>17</sup> By Author

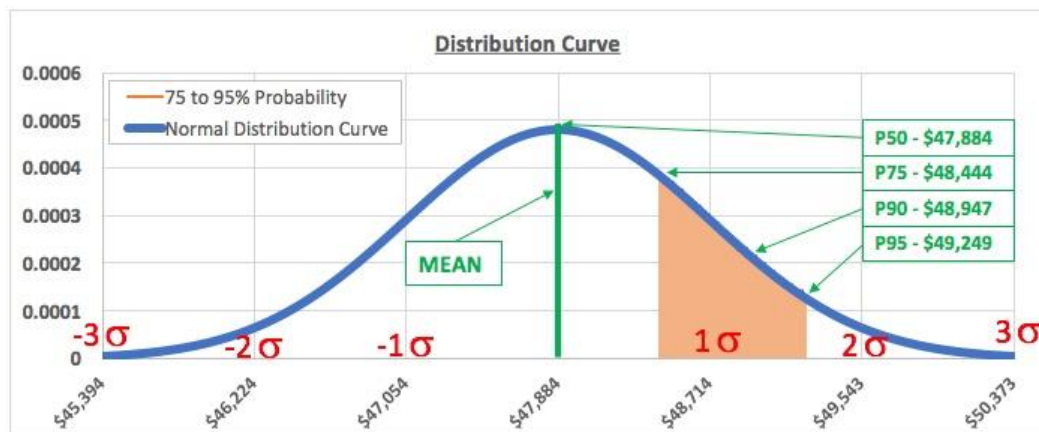


Figure 4 – Normal Distribution curve - IEAC <sup>18</sup>

The figures to be brought forward to the comparison are:

- P50 - \$47,884
- P75 - \$48,444
- P90 - \$48,947
- P95 - \$49,249

### MS Excel “Best Fit” Regression Analysis Curve

MS Excel provides eight options of regression analysis curves; Exponential, Moving Average, Linear, Logarithmic, Polynomial 2<sup>nd</sup>, Polynomial 3<sup>rd</sup>, Polynomial 4<sup>th</sup> and Power. Using the ten ACWP data points in table 2 and all the options available only four trended figures outwards to week 26, these were linear, logarithmic, polynomial 2<sup>nd</sup> and power. The results are shown in figure 5.

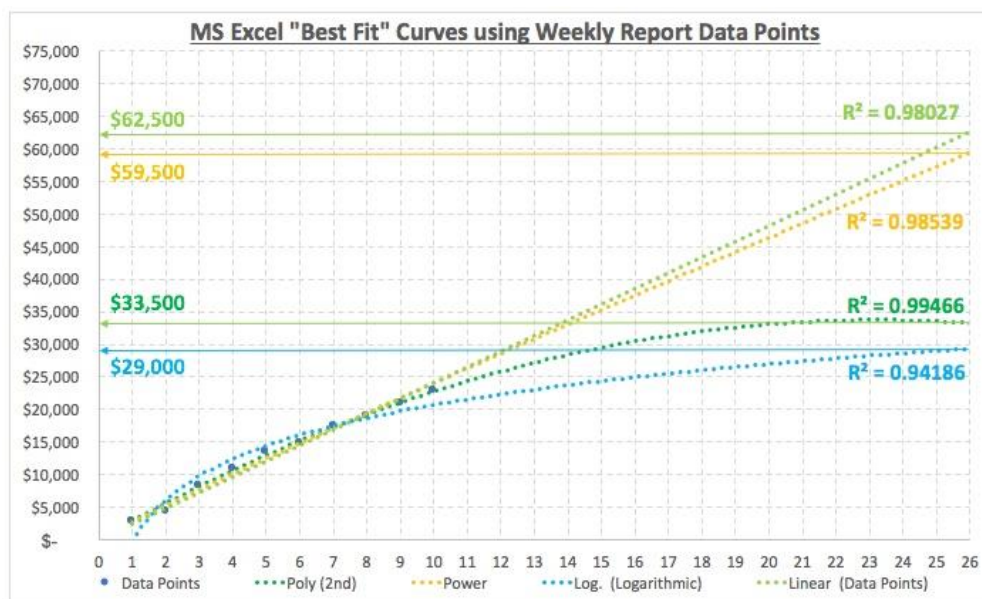


Figure 5 – MS Excel “Best Fit” curves <sup>19</sup>

<sup>18</sup> By Author

<sup>19</sup> By Author



From figure 5, The best case is \$29,000, worst case is \$62,500, and most likely case is the average of \$59,500 and \$33,500, which is \$46,500. The forecast figures to be used in the PERT formulas are shown in table 4.

Regression Type	R <sup>2</sup> Formula	Value	for PERT Exercise	Rank
Linear	R <sup>2</sup> = 0.98027	\$ 62,500	\$ 62,500	Worst
Power	R <sup>2</sup> = 0.98539	\$ 59,500	\$ 46,500	Most Likely
Poly - 2nd	R <sup>2</sup> = 0.99466	\$ 33,500		
Logarithmic	R <sup>2</sup> = 0.94186	\$ 29,000	\$ 29,000	Best

Table 4 – MS Excel “Best Fit” curve forecasts <sup>20</sup>

Applying the forecast figures in the PERT formulas provides the following:

- Mean =  $(29,000 + (4 \times 46,500) + 62,500) / 6 = 277,500 / 6 = 46,250$
- Std. Deviation =  $(62,500 - 29,000) / 6 = 33,500 / 6 = 5,583.33$
- Variance =  $5,583.33^2 = 31,173,592$

Again, as in the IEAC methods, note that the variance is large  $(31,173,592 / 2) = 15,586,796 = 2,791.7$  Sigma and reveals that the number is risky, so a higher P number (P90 and above) should be considered when determining forecasts.

Inputting the above PERT information into a normal distribution curve provides the following curve, which allows determination of the P numbers required for the forecast.

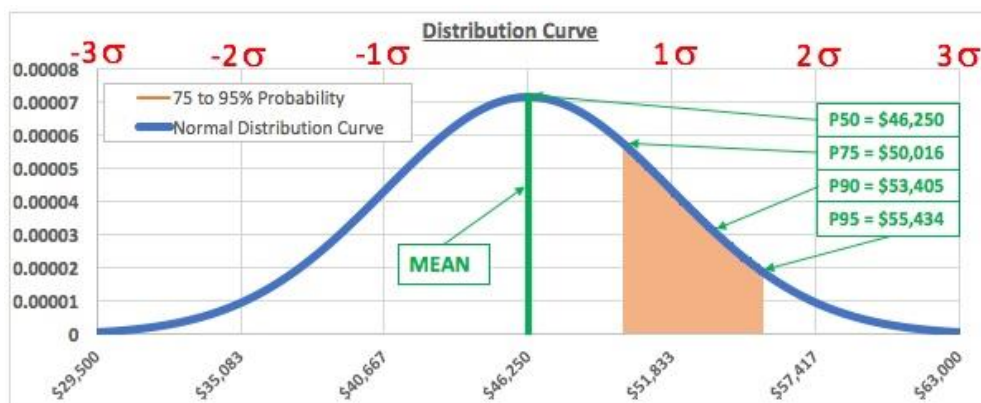


Figure 6 – Normal Distribution curve - MS Excel “Best Fit” curves <sup>21</sup>

The figures to be brought forward to the comparison are:

- P50 - \$46,250
- P75 - \$50,016
- P90 - \$53,405
- P95 - \$55,434

<sup>20</sup> By Author

<sup>21</sup> By Author

## Monte Carlo Simulation Using MS Excel

To evaluate this method, a model (spreadsheet) was developed to evaluate the probability of meeting the original budget of \$49,795. Using 1,000 iterations generated by MS Excel with each step allowing a plus/minus 0.5% deviation depending on the number. In cell, A1 the original budget value was input (A1 = \$49,795) and in cell, L1 the value \$248.98 (0.5% of \$49,795). In cell, A2 a formula used to generate random numbers from 0 to 1 was modified to use the 0.5% value, so if the number generated was greater than 0.5 it would add \$248.98 to the figure above, or less than 0.5 subtract \$248.98 from the figure above. This formula “=IF(RAND()>0.5,A1+\$L\$1,A1-\$L\$1)” was then copied down to cell A1000 to provide the amount of iterations required. To ensure a broad range of results were obtained, 1,000 iterations were performed on five separate lines (see figure 7).

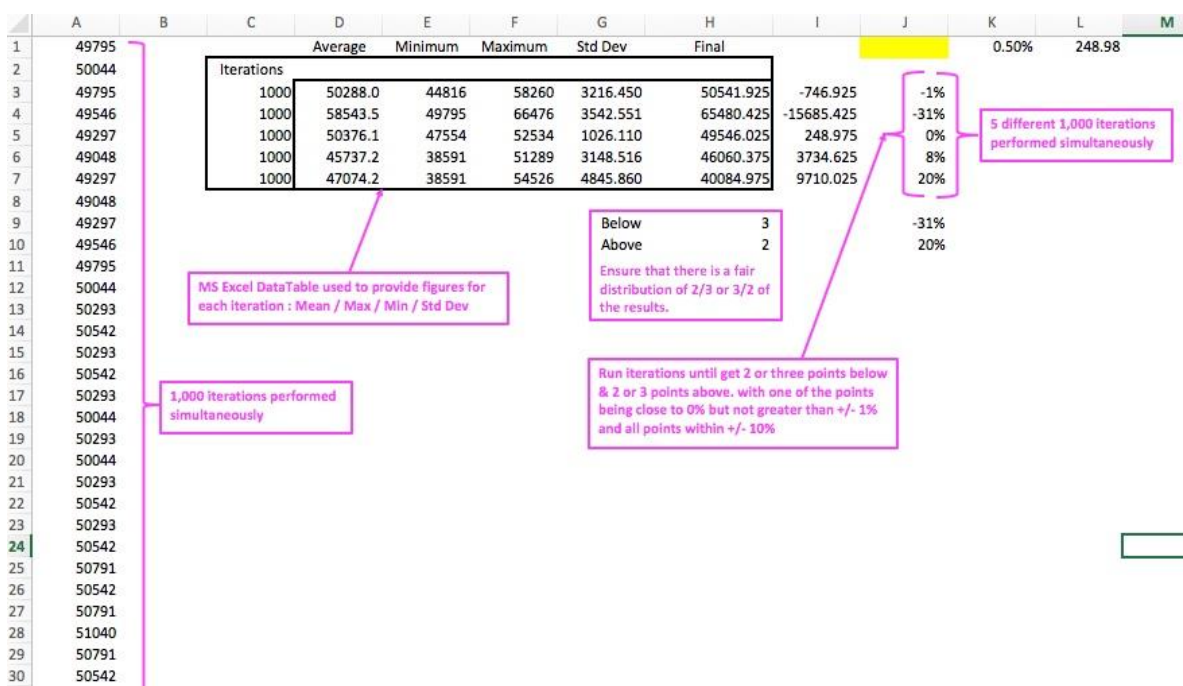


Figure 7 – Sample range of Data iterations using formula above <sup>22</sup>

MS Excel criteria used: 1) Base Figure of \$49,795 budget, 2) 1,000 iteration sets x 5 Sets, providing Average (Mean), Minimum, Maximum and Standard deviation for each set. 3) Ensure all 5 sets are in range +/-10%, 4) Ensure one set has figure close to 0% but no greater than +/-1%, 5) results need to be 2 or 3 below and 2 or 3 above – 1&4 or 5&0 are not acceptable options.

Developing the model was relatively easy, a simplistic approach and all that is required is to meet the criteria set-out for the analysis. As MS Excel recalculates every time a change is made the sheet was set to manual recalculation mode. To meet the criteria guidelines set-out above there is a need to recalculate a few times but the results are achieved very quickly. Figure 8 shows the results obtained which meets the required criteria and being used in this paper.

<sup>22</sup> By Author

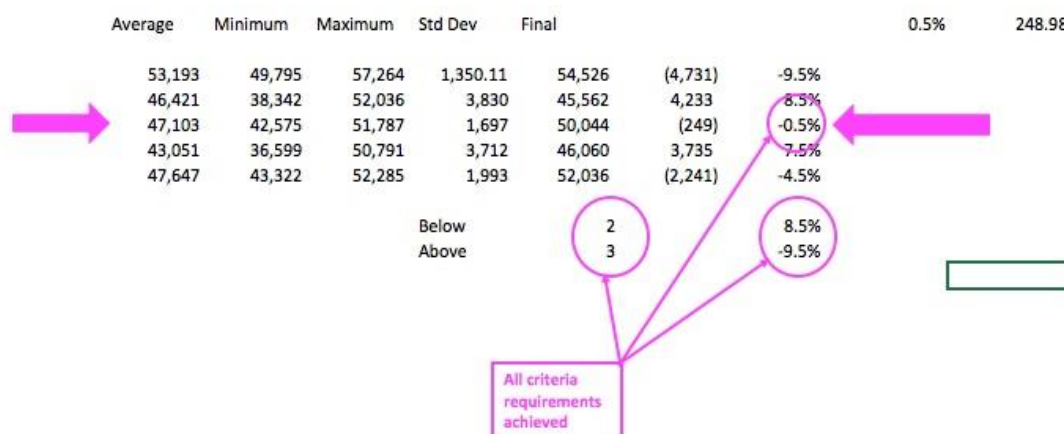


Figure 8 – Simulation results meeting criteria<sup>23</sup>

Taking the information from row 3 (see arrows in figure 8), and applying them to the PERT formulas, the following results are obtained.

- Mean =  $(42,575 + (4 \times 47,103) + 52,036) / 6 = 283,023 / 6 = 47,171$
- Std.Deviation =  $(52,036 - 42,575) / 6 = 9,461 / 6 = 1,576.83$
- Variance =  $1,576.83^2 = 2,486,398$

Again, as in the previous two methods the variance is large ( $2,486,398 / 2 = 1,243,199 = 788.42$  sigma and reveals that the number is risky, so a higher P number (P90 and above) should be considered when determining forecasts.

Inputting the above PERT information into a normal distribution curve provides the following curve, which allows determination of the P numbers required for the methodology comparison.

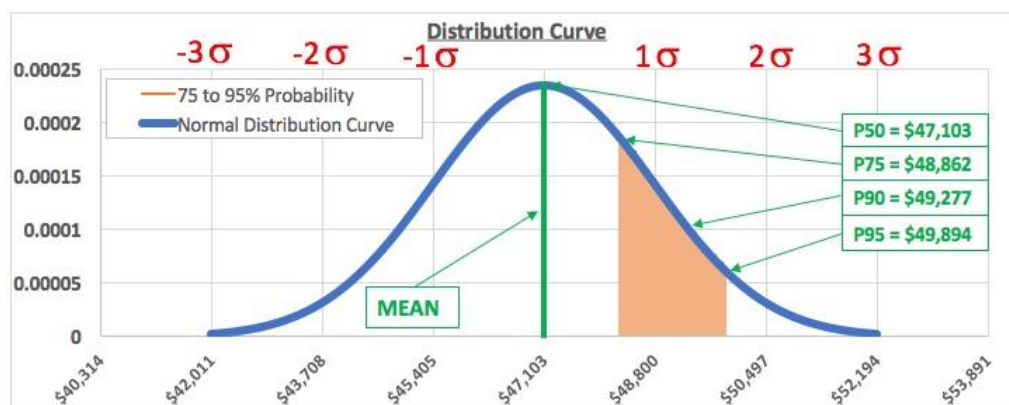


Figure 9 – Normal Distribution curve - MS Excel Monte Carlo simulation<sup>24</sup>

The figures to be brought forward to the comparison are:

- P50 - \$47,103
- P75 - \$48,862
- P90 - \$49,277
- P95 - \$49,894

<sup>23</sup> By Author

<sup>24</sup> By Author

## Monte Carlo Simulation Using Oracle's Crystal Ball Software

Originally the author was going to use @Risk software from Palisade<sup>25</sup> and having obtained a demonstration version, had reviewed several of their tutorials and requested support assistance from Palisade only to be advised that the software was not capable of producing forecasts as required for this exercise. After searching through many other Risk packages, the author came across Oracle's Crystal Ball<sup>26</sup> software which was capable of producing the type of analysis needed for this exercise.

Taking the ten ACWP weekly data points in a spreadsheet, using the "Predictor" feature from the Crystal Ball Tools menu, assigned the "Input Data" cells (cells \$C\$3:\$M\$4 – included the week numbers and the ACWP values). The program advised that it had one data series which contained eleven data points (eleven because we added zero as the starting point). Then working through the other options; Data Attributes, Methods & Options, the following selections were made; non-seasonal, predict 16 more data-points, and provide 75% and 25% probability curves also.

The software returned a predictive curve using ARIMA (2,1,1) as the "Best Method" based on the data points provided (refer to figure 10 below), the forecast for week 26 is \$50,671.

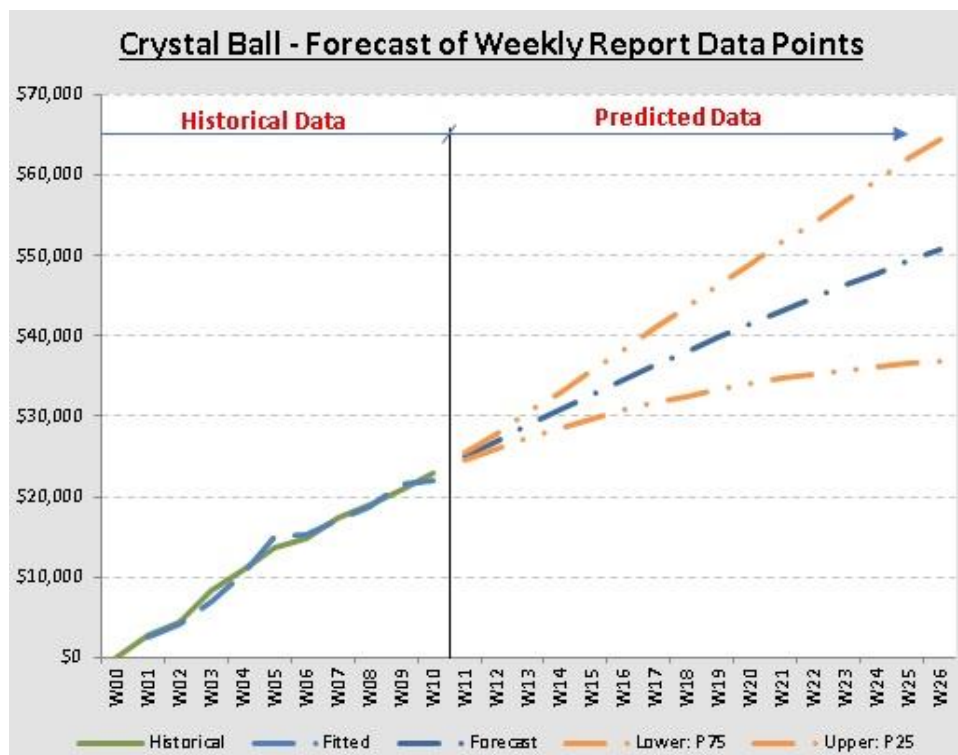


Figure 10 – Crystal Ball ARIMA curve based to Data Points<sup>27</sup>

<sup>25</sup> @Risk [Computer program] v7.5. 798 Cascadilla St, Ithaca, NY 14850, USA: Palisade Corporation (2016).

<sup>26</sup> Crystal Ball [Computer Program] v11.1.2. 500 Oracle Parkway, M/S 507 Redwood Shores, CA 94065, USA : Oracle Corporation (2017).

<sup>27</sup> By Author using Oracle Crystal Ball software



Now that all four methods have been evaluated, summarization of the results is required to make comparisons.

### **Comparison of results and methodology selection**

The summary of the results from the above methodologies is shown in table 5.

<b>Forecast Methodology Results</b>				
<b>Method</b>	<b>IEAC</b>	<b>MS Excel 'Best Fit'</b>	<b>Oracle Crystal Ball</b>	<b>MS Excel Monte Carlo</b>
<b>P50</b>	\$ 47,884	\$ 46,250	\$ 50,671	\$ 47,103
<b>P75</b>	\$ 48,444	\$ 50,016	\$ 64,526	\$ 48,862
<b>P90</b>	\$ 48,947	\$ 53,405	\$ 76,997	\$ 49,277
<b>P95</b>	\$ 49,249	\$ 55,434	\$ 84,460	\$ 49,894

Table 5 – Results from Forecast Methods <sup>28</sup>

Comparing the results in table 5 against the performance measurement baseline budget (PMB) of \$49,795 provides an indication regarding the +/- % accuracy of the results against the budget. Table 6 below shows this accuracy.

<b>% above/below PMB</b>				
<b>Method</b>	<b>IEAC</b>	<b>MS Excel 'Best Fit'</b>	<b>Oracle Crystal Ball</b>	<b>MS Excel Monte Carlo</b>
<b>P50</b>	-3.84%	-7.12%	1.76%	-5.41%
<b>P75</b>	-2.71%	0.44%	29.58%	-1.87%
<b>P90</b>	-1.70%	7.25%	54.63%	-1.04%
<b>P95</b>	-1.10%	11.32%	69.62%	0.20%
<b>Average</b>	-2.34%	2.97%	38.90%	-2.03%

Table 6 – Forecast Methods vs PMB Budget <sup>29</sup>

Analyzing further by using the tracking budget of \$46,075 (developed in Week 9) as a basis, Table 7 provides the results

<sup>28</sup> By Author

<sup>29</sup> By Author

% above/below Week 9 Budget Alignment				
Method	IEAC	MS Excel 'Best Fit'	Oracle Crystal Ball	MS Excel Monte Carlo
P50	3.93%	0.38%	9.98%	2.23%
P75	5.14%	8.55%	40.05%	6.05%
P90	6.23%	15.91%	67.11%	6.95%
P95	6.89%	20.31%	83.31%	8.29%
Average	5.55%	11.29%	50.11%	5.88%

Table 7 – Forecast Methods vs W9 Tracking Budget <sup>30</sup>

The results show that the P50 (Mean) figures are all within 10% of the budget, and with the exception of 'FA3 - Crystal Ball' the P75 figures are within 10% also. There are only two methods which remain within the 10% for all four ranges; IEAC and MS Excel Monte Carlo, with the IEAC providing the closer results. Based on the above, if having to choose an accuracy method at Week 10, the results suggest that IEAC was probably the best method available.

As this paper wanted to look deeper into the four methods available, a proposal to change the philosophy in completing the course was made to the faculty that was running the course, and a decision made to gather as many 'actual' data points as possible prior to the course completion. In week 14, it was decided that the paper could amass 24 data points and still complete prior to course completion, this resulted in a further budget alignment to accurately reflect the revised completion philosophy, as it entailed re-arrangement of the remaining 12 weeks activities. For information purposes, the week 14 budget alignment figure was \$45,075 shifting a further \$1,000 into contingency.

## Forecasting Accuracy Fourteen Weeks On

As mentioned above, at time of writing this paper, the information and data points used in the development of the forecasts were taken from a live mini-project. This project is still ongoing currently just moved in week 25 of a 26-week program, so is approximately 92% through the baseline duration.

When performing the analysis/forecast development, ten data points were available, now there are 24, so there are a further fourteen points in which to review how the forecasting methods compare against the actual expenditures for these additional weeks. Review of these 'actual' points suggests that although there were four probability figures for each forecast method (P50, P75, P90 and P95), it would be best to use the "P50" to compare against the actuals. Figure 11 shows the chart with the 24 data points plotted against the P50 forecasts.

<sup>30</sup> By Author

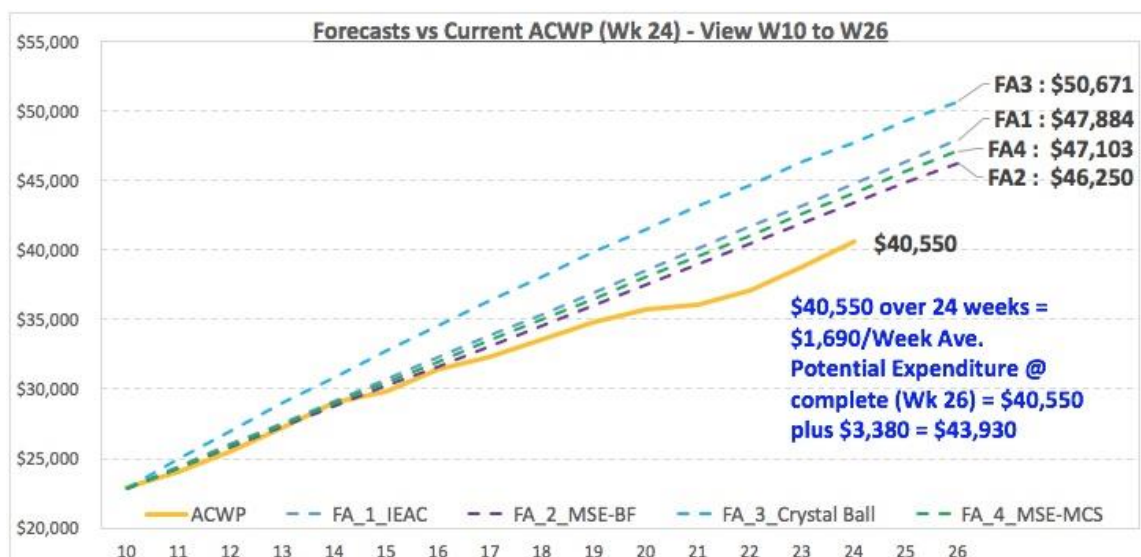


Figure 11 – P50 Forecast Comparisons with Week-24 data <sup>31</sup>

Although there are only two weeks left on the course, it appears that all four forecasting methods appear to be slightly higher than what the final outcome may be. Interestingly enough, three of the forecasting methods provide what could be classed as “good” forecasts based on the \$45,075 budget, refer to Week 14 row in Table 8 below.

P50 - % above/below				
Method	IEAC	MS Excel 'Best Fit'	Oracle Crystal Ball	MS Excel Monte Carlo
<b>PMB</b>	-3.84%	-7.12%	1.76%	-5.41%
<b>Week 9</b>	3.93%	0.38%	9.98%	2.23%
<b>Week 14</b>	6.23%	2.61%	12.41%	4.50%
<b>Average</b>	2.11%	-1.38%	8.05%	0.44%

Table 8 – P50 Forecast Methods vs Budgets <sup>32</sup>

The analysis of the four alternative forecasting methodologies (P50 values) have been charted against the 24 actual data points and show in figure 11, all that remains is to determine the most accurate method used, and by using the Multi-Attribute Decision Making technique, these results will be ranked in order.<sup>33</sup> Remember, this is a forecast and unforeseen risks can occur that can change the current perspective, but at present this there are no signs that such an issue will occur in the final two weeks.

The Feasible alternatives are already identified, all that is required is to identify the attributes; i) Ease of use of the forecasting method, ii) Average of the forecasts vs the PMB as a %, iii) P50

<sup>31</sup> By Author

<sup>32</sup> By Author

<sup>33</sup> 10.3.3.7 Multi-Attribute Decision Making - Guild of project controls compendium and reference (CaR) | Project Controls - planning, scheduling, cost management and forensic analysis (Planning Planet). (2015, October 3). Retrieved August 27, 2017 from <http://www.planningplanet.com/guild/gpcar/managing-change-the-owners-perspective>

Performance against W14 budget, and iv) forecast performance against new data points. Table 4 shows the results of the MADM, along with the ranking of each method.

Attributes	FA1 IEAC	FA2 MS Excel Best Fit	FA3 Oracle Crystal Ball	FA4 MS Excel MCS
Ease of use of forecast method	Excellent	Excellent	Good	Excellent
Forecast Ave. within +/- 5% of PMB	-2.34% Good	+2.97% Excellent	-21.88% Poor	-2.03% Good
P50 Performance against W14 Budget	+6.23% Average	+2.61% Excellent	+12.41% Poor	+4.50% Good
Updated Data points comparison	Above Good	Slightly Above Excellent	Well Above Poor	Above Good
Ranking	3	1	4	2

Table 9 – MADM results for the Forecasting methods

It appears that MS Excel “Best Fit” method provides the most accurate results, but is closely followed by both MS Excel Monte Carlo simulation, and the combination of the 4 IEAC formulas. These three methods provided results within 5% of the PMB, 10% of the W14 budget, and has the potential to be within 10% of the final actual cost. The remaining methodology “Oracle’s Crystal Ball” while providing an answer close to the others, did not rank well against the other alternatives.

## Conclusion

With timing of an accurate forecast key for the success of any project, and the “window of opportunity” being between 15% to 33% of elapsed time to identify if a project is in trouble, determine the root causes and apply corrective action(s), it is imperative that the project controls practitioner select the best methodology or methodologies to provide management with a meaningful analysis. Failure to do so, and allowing the window of opportunity to pass results in the increased probability of effecting a recovery is minimal if at all possible.”<sup>34</sup>

This paper set out eight forecasting methods, which were grouped into four methodologies in order to be tested on a live project, with the results compared against actuals two reporting periods from the completion of the project for accuracy. The author has always advocated that when performing a forecast that the practitioner develops a range that ensures that the periodic reviews do not ‘saw-tooth’, which usually detracts from the message of what the practitioner is telling his/her management.

Determining the correct technique really can be a daunting task, and depends on several factors; accuracy of input data, required accuracy of the output data, and the purpose of the forecast. The above analysis suggested that the use of the MS Excel “Best Fit” methodology provided the closest level of accuracy.

<sup>34</sup> 09.5.3.3.3 IEAC1 Example - 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/gpcar/project-performance-forecasting>



Furthermore, this paper set out to provide a set of guidelines for use by fellow practitioners, and the following should be considered;

- Determine the requirements.
  - Who will use the forecast?
  - What purpose will it be used for?
  - What level of accuracy is required?
- Make use of the data available, testing several of the available methodologies.
  - Results depend on the quality of the inputs, and methodology being used.
  - Where in the project timeline the forecast is being developed?
  - Once developed, challenge the forecast to ensure it makes sense, don't accept the first result as being the right answer.
- Provide a forecast range as opposed to a single value.
  - Determine a realistic range that does not “saw-tooth” every reporting period, failure to do so renders the forecast useless.
  - Practitioners should exercise their expert judgement in determining the range to be presented to management is both credible and defensible.
- Regularly review the forecast to ensure it is still ‘good’ based on current events, including any new risks identified from previous forecast.

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