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FORECASTING COST TO COMPLETE ON **MEGA CONSTRUCTION PROJECTS**

This whitepaper demonstrates the importance of regularly and accurately calculating forecasted cost-to-complete for mega construction projects.

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01 | ABSTRACT

This paper demonstrates the importance of regularly and accurately calculating forecasted cost-to-complete for mega construction projects. The objective is to assist project controls professionals achieve better cost control, oversight of their projects and to deliver accurate projections of cash flow to all project stakeholders. Calculating forecast-to-complete is a critical aspect of project controls. It demands a careful process of budgeting, data gathering, progress measurements, change order management, time-phasing and detailed forecasting, to achieve a reliable result.

This paper will dive into the processes and methods required to be able to deliver consistent, accurate results for predicting remaining project costs over a timeline and early identification of critical issues. It will clearly delineate the difference between forecast-to-complete (FTC) and the commonly used industry metric, estimate-to-complete (ETC) and the best practices for the use of each. Where ETC is a calculated metric based on past performance, FTC is a predictive metric made by project controls that forecasts remaining costs based on empirical evidence of work remaining. What's equally significant to this method, is that it is practical and achievable and the result of working with many project controls professionals in a variety of industries over the past 10 years.

02 | INTRODUCTION

Mega construction projects withstand a level of complexity like no other. More than ever, organizations are searching for ways to increase efficiencies, reduce costs, increase productivity, collaboration and automation on their construction projects. To achieve this, the project team needs to apply a significant level of rigor in the planning and management of projects and deliver key metrics and projections to all project stakeholders throughout its execution.

When, for example, it's 9-months into a 2-year facility construction project, and the CFO has asked the team to provide a month-over-month projection of costs to complete, simply subtracting cost-to-date from the original budget is far from an accurate response. The reality is, nothing ever goes exactly to plan. Things change, budgets can be wrong, subcontractors aren't as speedy as initially hoped, material prices get inflated, fabrication delays, incorrect drawings, weather, etc., all factor into the forecast. Calculating a reliable month-over-month forecast requires that the project team has not only done sufficient upfront project planning, but they're also performing ongoing monitoring, measurement and management of the project in order to produce an accurate report.

03 | WHY FORECASTING IS IMPORTANT ON MEGA PROJECTS

Knowing where a project is at on any given day is a critical project controls function for mega projects. However, knowing where it's going is arguably even more important. Any project stakeholder with a financial interest in the project will live and breathe by cash flow projections and spend forecasts; and whether the project will end up on time and on budget. Project controls professionals need to feed that hunger for predictive information. Nobody likes surprises, so continuous and active management of expectations is a fundamental requirement to keep in good standing with all stakeholders. Forecasts are also instrumental for early identification of trends and issues. This gives the project team decision-making power to continuously tweak and reset the course of the project to maximize its potential for success.

04 | IT STARTS WITH GOOD PLANNING

To properly prepare for effective forecasting during project execution, the project planning stage is vital. The nominal extra effort that goes into planning will make things run smoothly and far more streamlined while the project is underway. Shifting more effort to the planning stage has a sizable payoff, as projects are often overly resourced for an execution phase that could be simplified with better planning.

4.1 | Planning for Forecasting

It's at the planning stage that the project needs to be setup so that it can be first measured, then forecasted. The necessary structure will therefore need to be in place to streamline the process of iteratively measuring current progress and performance so that the remainder can be forecasted from there.

4.2 | Set it up so that it's Easy to Measure

It's impossible to predict where a project is going if it's not known where the project is currently at. Measuring project progress is consequently the starting point for forecasting. Measuring progress is essentially calculating how far along the project hs come – in terms of physical progress – at any given time during its execution. This is typically represented as percent complete and should be measured incrementally at regular intervals over the life of the project.

4.3 | Determine What to Forecast

A progress measurement is clearly a valuable snapshot in time. However, it only provides indicators of past performance and current state. These indicators can of course then be used to predict future outcomes if productivity continues as it was. But what if past performance is a misleading indicator of where the project is going? Future performance can often be based on a different productivity factor. Standard EVM calculations for predictive values such as estimate-to-complete (ETC) use past performance to forecast the future state. While this is good information, it doesn't consider any upcoming factors that may influence the future. This is where the forecast comes in. It acts as the early identification of trends and changes that may or may not play out as the project is completed.

4.4 | Iterative Reporting and Forecasting Periods

The project team needs to define an iterative, repeatable process for how and when progress measurements and forecasts are going to take place. This is similar to how a finance department works in continuous reporting periods. The charts in Figure 1 and Figure 2 below show some example metrics and how they trend over several progressing & forecasting periods. Each date on the X-axis represents a progress measurement and reporting period.

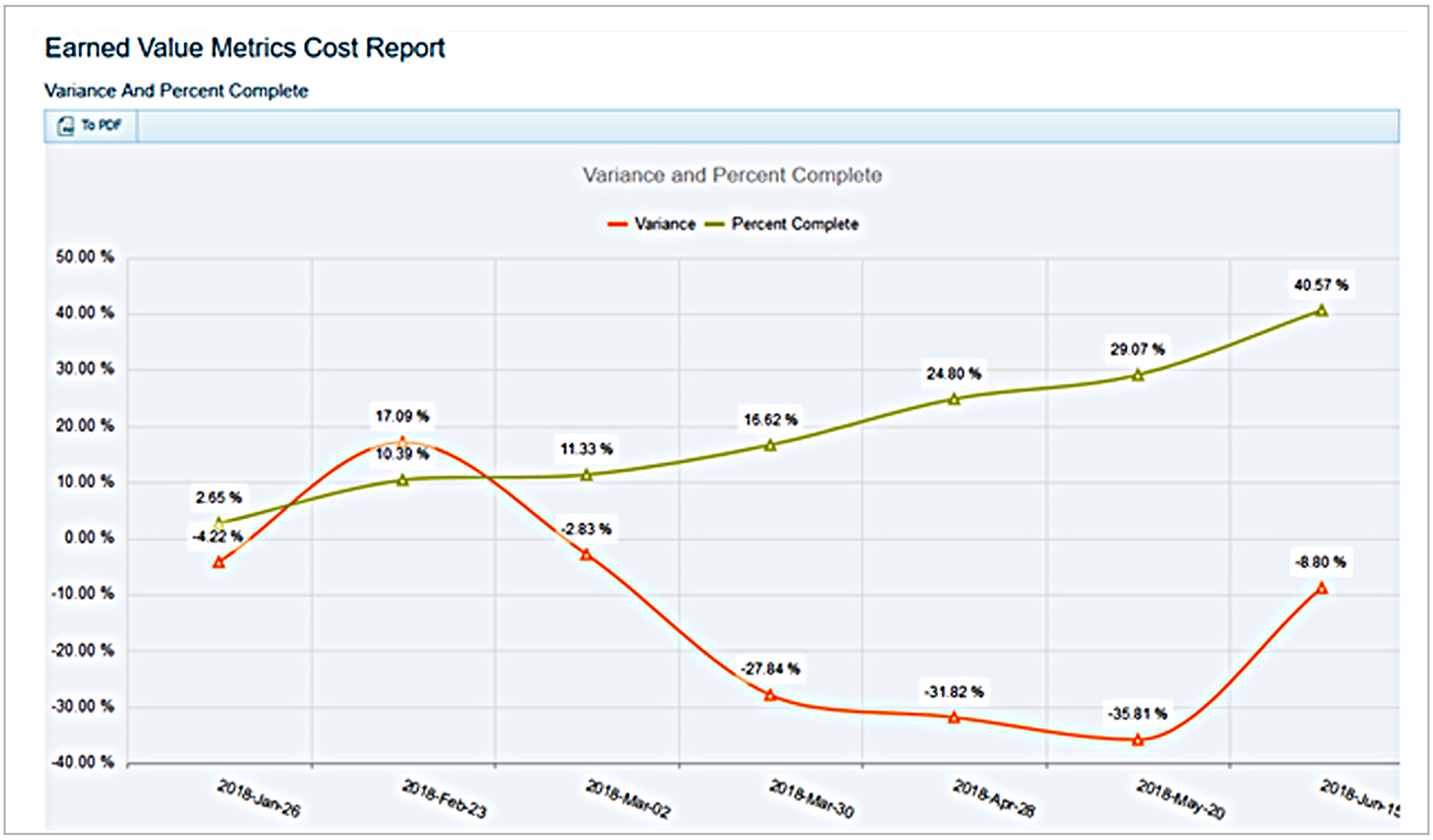


Figure 1 *- Key Project Metrics CV and PC Trended Over a Timeline*

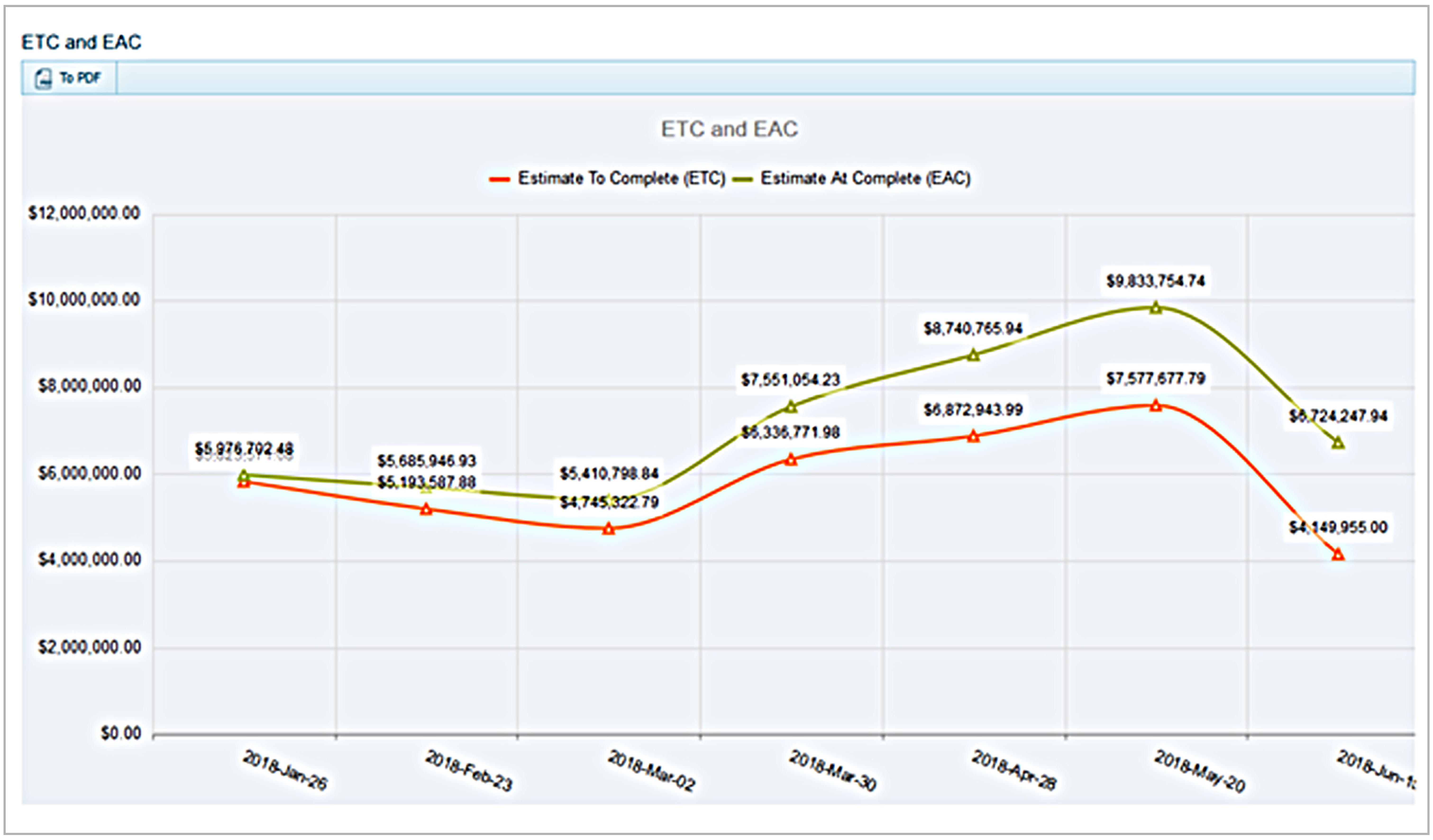


Figure 2 *- ETC and EAC Trended over a Timeline*

05 | PROJECT EXECUTION

To properly prepare for effective forecasting during project execution, the project planning stage is vital. The nominal extra effort that goes into planning will make things run smoothly and far more streamlined while the project is underway. Shifting more effort to the planning stage has a sizable payoff, as projects are often overly resourced for an execution phase that could be simplified with better planning.

5.1 | Tracking

Project tracking should be a rigorous process of capturing every detail of a project that is underway. Hours consumed, items installed, activities completed, materials delivered, etc. should be tracked and routed back to the project management team as cost and progress metrics for the project. This gives early insight into any issues that may be happening that require corrective action and provides the project controls team with core information to determine what to forecast. Figure 3 below demonstrates how actual cost (yellow line) compares against budget (blue line) as the project plays out over time.

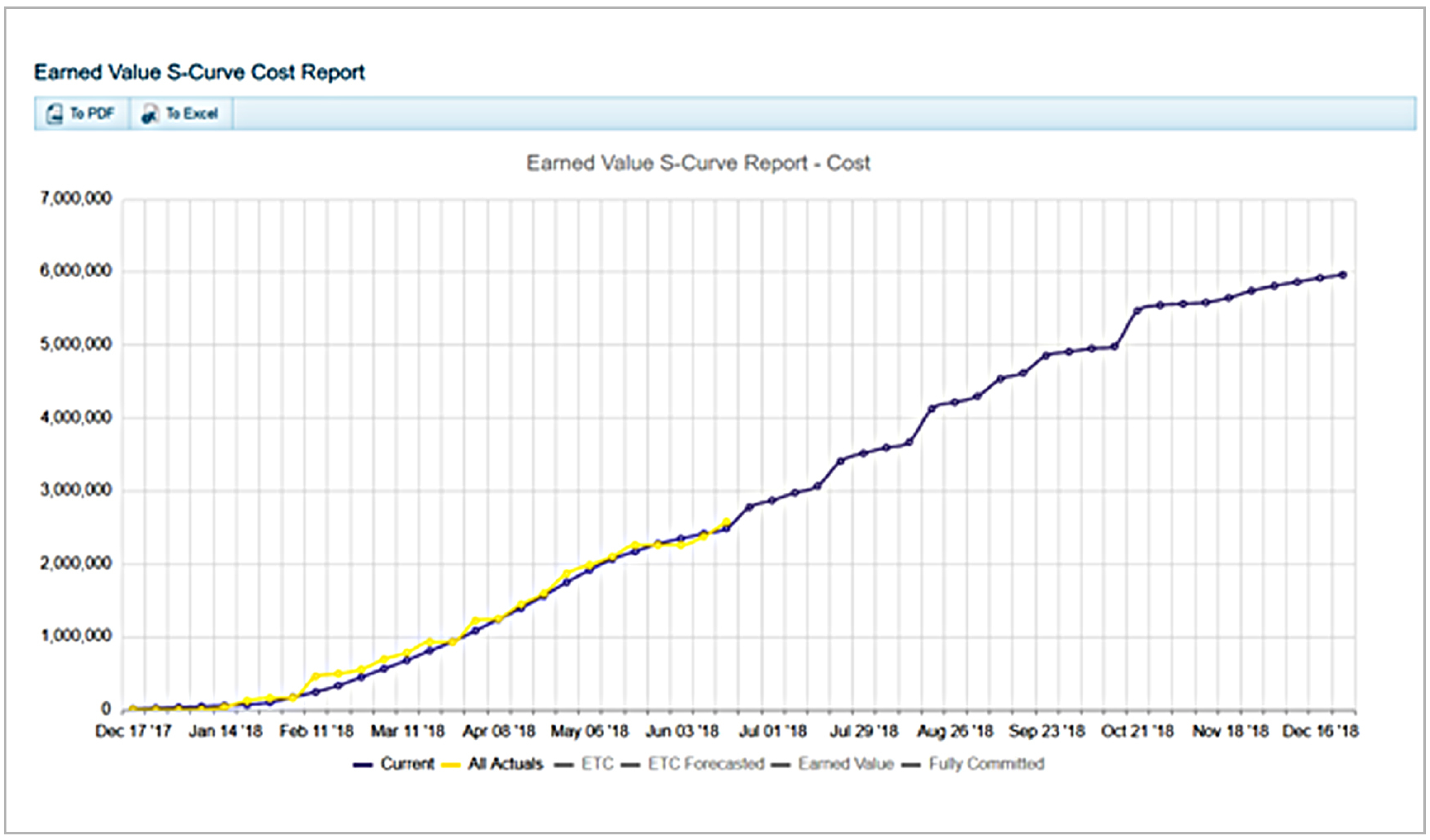


Figure 3 *- Budget vs. Actual Timeline Curve Report*

5.2 | Measuring

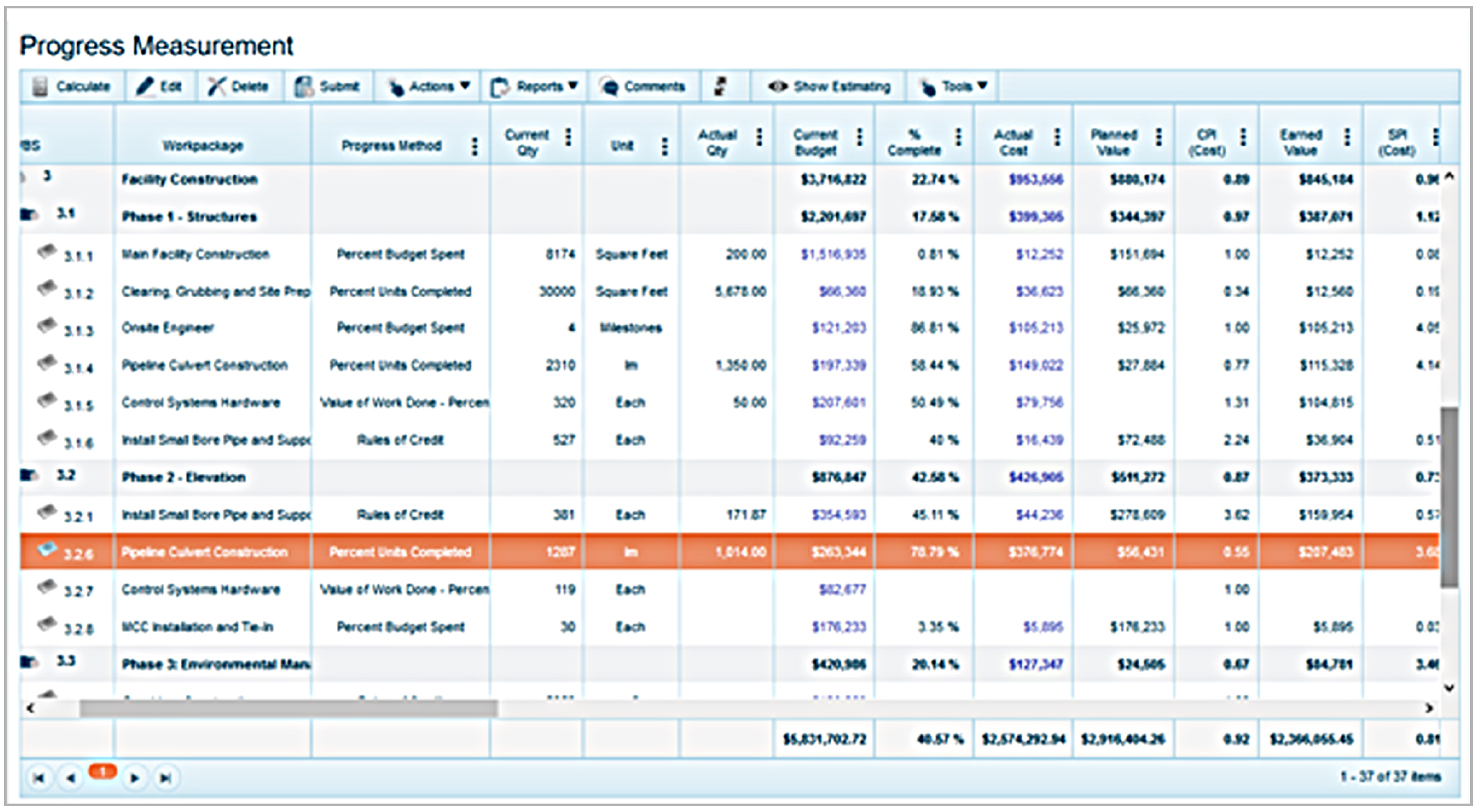
The data that's used to measure a project's progress should be largely derived from the cost tracking and data capture described in 5.1 above. At the time of submitting a progress measurement therefore, all the data that feeds that progress measurement should be already captured and ready for review and analysis. In other words, if the project has been setup so that it's easy to measure – as discussed in section 4.2 – the effort required for the progress measurement should be a relatively straightforward practice of overseeing that the process has been followed, and information capture is complete.

5.3 | Analyzing

It's during the analysis stage that the work of project controls truly kicks in. When tackling the results of a progress measurement that's largely automatically generated, they'll first want to check for any anomalies or outliers and fix any data capture mistakes or gaps.

5.3.1 | Detailed Analysis

Looking at the highlighted row inFigure 4below as an example, the CPI for that activity is calculating to .55 – which indicates significant underperformance.



Progress Measurement

Calculate | Edit | Delete | Submit | Actions | Reports | Comments | Show Estimating | Tools

BS	Workpackage	Progress Method	Current Qty	Unit	Actual Qty	Current Budget	% Complete	Actual Cost	Planned Value	CPI (Cost)	Earned Value	SPI (Cost)
3	**Facility Construction**					**$3,716,822**	**22.74 %**	**$953,666**	**$880,174**	**0.89**	**$845,184**	**0.9**
3.1	**Phase 1 - Structures**					**$2,201,697**	**17.58 %**	**$399,306**	**$344,397**	**0.97**	**$387,071**	**1.1**
3.1.1	Main Facility Construction	Percent Budget Spent	8174	Square Feet	200.00	$1,516,935	0.81 %	$12,252	$151,694	1.00	$12,252	0.0
3.1.2	Clearing, Grubbing and Site Prep	Percent Units Completed	30000	Square Feet	5,678.00	$66,360	18.93 %	$36,623	$66,360	0.34	$12,560	0.1
3.1.3	Onsite Engineer	Percent Budget Spent	4	Milestones		$121,203	86.81 %	$105,213	$25,972	1.00	$105,213	4.0
3.1.4	Pipeline Culvert Construction	Percent Units Completed	2310	lm	1,350.00	$197,339	58.44 %	$149,022	$27,884	0.77	$115,328	4.1
3.1.5	Control Systems Hardware	Value of Work Done - Percen	320	Each	50.00	$207,601	50.49 %	$79,756		1.31	$104,815	
3.1.6	Install Small Bore Pipe and Suppo	Rules of Credit	527	Each		$92,259	40 %	$16,439	$72,488	2.24	$36,904	0.5
3.2	**Phase 2 - Elevation**					**$876,847**	**42.58 %**	**$426,906**	**$511,272**	**0.87**	**$373,333**	**0.7**
3.2.1	Install Small Bore Pipe and Suppo	Rules of Credit	381	Each	171.87	$354,593	45.11 %	$44,236	$278,609	3.62	$159,954	0.5
3.2.6	Pipeline Culvert Construction	Percent Units Completed	1287	lm	1,014.00	$263,344	78.79 %	$376,774	$56,431	0.55	$207,483	3.6
3.2.7	Control Systems Hardware	Value of Work Done - Percen	119	Each		$82,677				1.00		
3.2.8	MCC Installation and Tie-In	Percent Budget Spent	30	Each		$176,233	3.35 %	$5,896	$176,233	1.00	$5,896	0.0
3.3	**Phase 3: Environmental Man**					**$420,986**	**20.14 %**	**$127,347**	**$24,606**	**0.67**	**$84,781**	**3.4**
						$5,831,702.72	**40.57 %**	**$2,574,292.94**	**$2,916,404.26**	**0.92**	**$2,366,055.45**	**0.81**

1 - 37 of 37 items

Figure 4 *- Sample Progress Measurement*

To confirm whether that CPI is a true reflection of that task's current productivity, there are a few things to review prior to assuming any corrective action needs to be taken:

- Ensure that cost and progress have been fully captured and entered
- Compare metrics like percent complete and CPI against the previous reporting period(s) to see how this activity has been trending. Have a look at the trend lines in Figure 5 below for an example of how CPI and SPI can vary over the project's reporting periods.
- Consult with the project management team, who are likely more acutely aware of problem areas, and can shed light on why the productivity is showing that low.

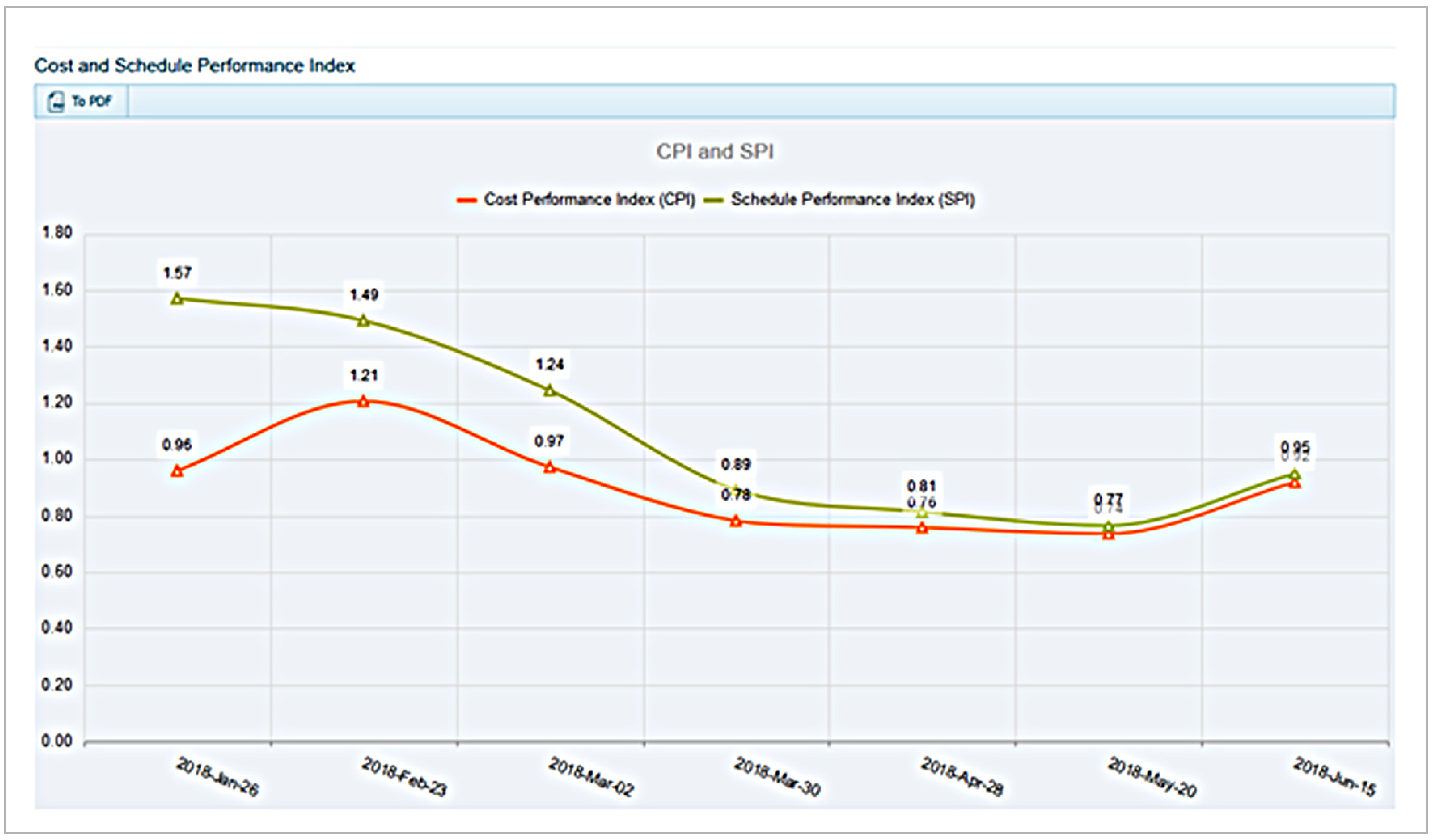


Figure 5 *- Sample Trend Patterns for CPI and SPI*

5.3.2 | Timeline Curves and EVM Analysis

Another valuable way to analyze at both a detailed and summary level is to look at predictive timeline curves. These are instrumental in visualizing past and future trends. The timeline chart in Figure 6 below shows several interesting trends worth examining:

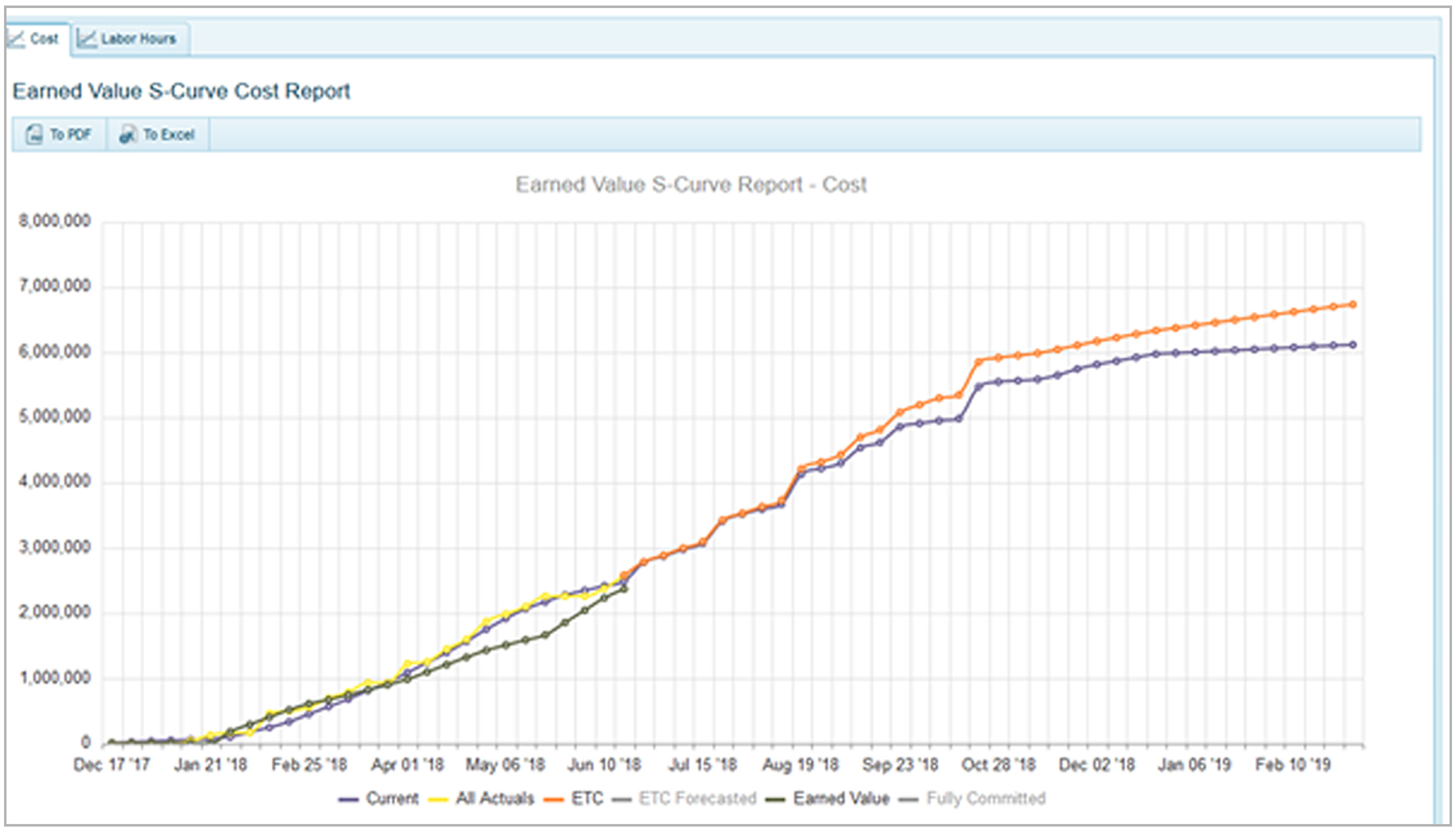


Figure 6 *- Timeline S-Curve showing Current Budget, Actual Cost, Earned Value and Estimate to Complete*

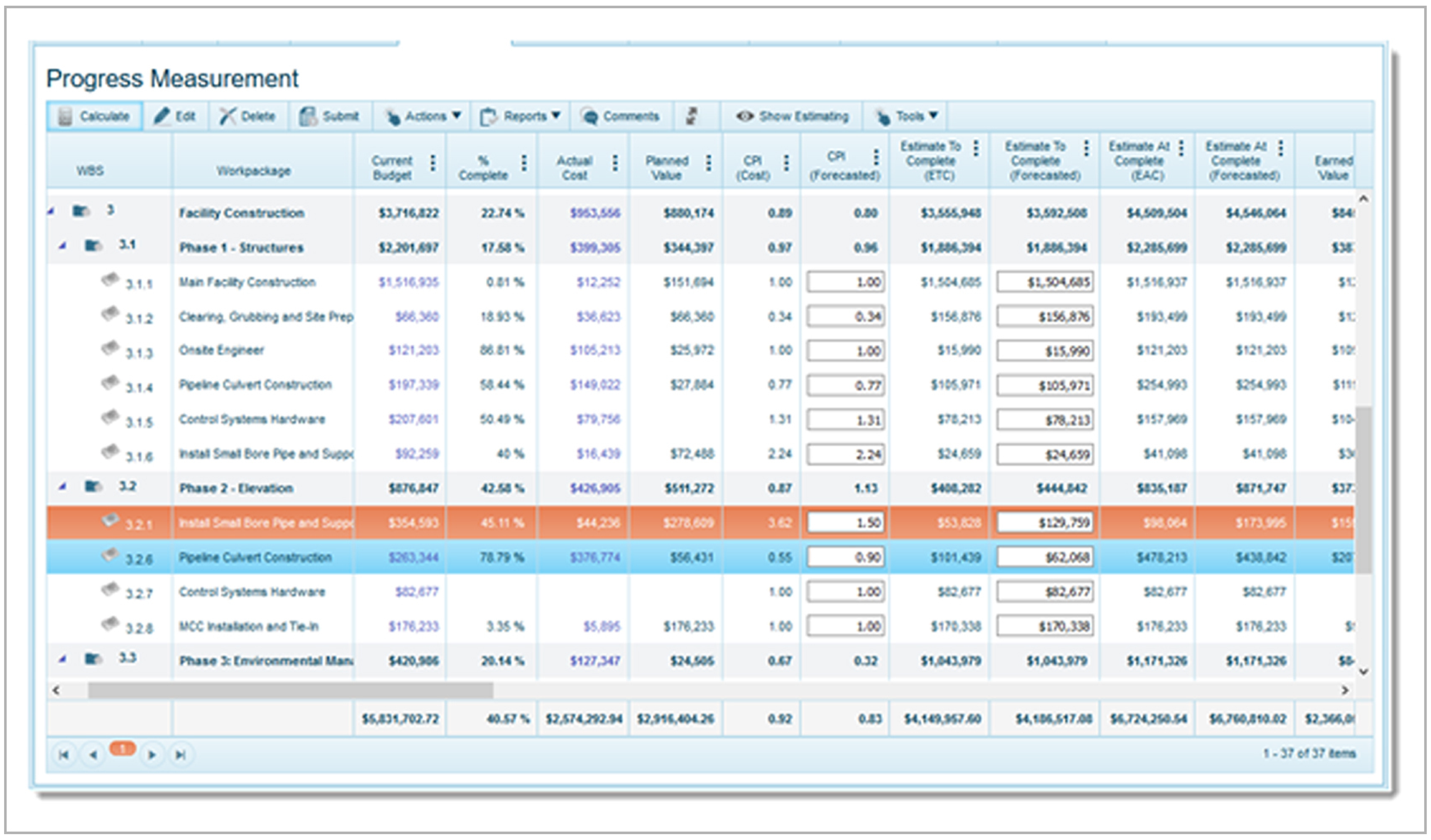
As of the last progress measurement on July 6th, the project appears to be running relatively close to plan. That is determined by looking at how close EV, AC and PV are at that point in time. However, the ETC curve (in orange) diverges from budget starting in September, which shows that the project is trending towards being over budget by its end in February. As a project controls team, this would be something to investigate further as to what is projected to cause that overage.

5.3.3 | Estimate to Complete versus Forecast to Complete

The orange ETC line in the S-Curve in Figure 6 is demonstrating how the project's budget is predicted to be spent if past productivity indicators persist for the remainder of the project. ETC is, of course, a type of forecastthat can be thought of as a performance-based forecast; which is the standard earned value method. It takes the historical project performance and determines a productivity ratio based on that performance (CPI). It then uses that ratio to calculate how the rest of the project will play out if it continues to perform at that level. If it's been under-performing historically, it'll end up over budget and behind schedule; and vice versa.

Forecast to complete (FTC) by contrast, is a predictive-based forecast. Predictive forecasting takes the inverted approach by asking the question of what's remaining – as compared to ETC, which asks, what's been done.

Consider the example of an engineer working on a drawing. For an FTC forecast, that person would be asked, "How many hours is it going to take you to complete the drawing?" For example, if 20 hours were originally budgeted, and the engineer has already consumed 10 of those 20 hours. Then, in response to the question, the engineer says, "15 hours". Unlike ETC which uses productivity and percent complete, in this case the FTC requires no calculation – it's simply 15 hours remaining for that activity. The FTC formula will of course calculate a 5-hour cost and schedule variance; but the calculation is not based on the past (like ETC), it's based on what is being predicted for the future – i.e. 15 hours remaining.



WBS	Workpackage	Current Budget	% Complete	Actual Cost	Planned Value	CPI (Cost)	CPI (Forecasted)	Estimate To Complete (ETC)	Estimate To Complete (Forecasted)	Estimate At Complete (EAC)	Estimate At Complete (Forecasted)	Earned Value
3	**Facility Construction**	$3,716,822	22.74 %	$953,556	$880,174	0.89	0.80	$3,555,948	$3,592,508	$4,509,504	$4,546,064	$84
3.1	**Phase 1 - Structures**	$2,201,697	17.58 %	$399,305	$344,397	0.97	0.96	$1,886,394	$1,886,394	$2,285,699	$2,285,699	$38
3.1.1	Main Facility Construction	$1,516,935	0.81 %	$12,252	$151,694	1.00	1.00	$1,504,685	$1,504,685	$1,516,937	$1,516,937	$1
3.1.2	Clearing, Grubbing and Site Prep	$66,360	18.93 %	$36,623	$66,360	0.34	0.34	$156,876	$156,876	$193,499	$193,499	$1
3.1.3	Onsite Engineer	$121,203	86.81 %	$105,213	$25,972	1.00	1.00	$15,990	$15,990	$121,203	$121,203	$10
3.1.4	Pipeline Culvert Construction	$197,339	58.44 %	$149,022	$27,884	0.77	0.77	$105,971	$105,971	$254,993	$254,993	$11
3.1.5	Control Systems Hardware	$207,601	50.49 %	$79,756		1.31	1.31	$78,213	$78,213	$157,969	$157,969	$10
3.1.6	Install Small Bore Pipe and Supp	$92,259	40 %	$16,439	$72,488	2.24	2.24	$24,659	$24,659	$41,098	$41,098	$3
3.2	**Phase 2 - Elevation**	$876,847	42.58 %	$426,905	$511,272	0.87	1.13	$408,282	$444,842	$835,187	$871,747	$37
3.2.1	Install Small Bore Pipe and Supp	$354,593	45.11 %	$44,236	$278,609	3.62	1.50	$53,828	$129,759	$98,064	$173,995	$15
3.2.6	Pipeline Culvert Construction	$263,344	78.79 %	$376,774	$56,431	0.55	0.90	$101,439	$62,068	$478,213	$438,842	$20
3.2.7	Control Systems Hardware	$82,677				1.00	1.00	$82,677	$82,677	$82,677	$82,677	
3.2.8	MCC Installation and Tie-In	$176,233	3.35 %	$5,895	$176,233	1.00	1.00	$170,338	$170,338	$176,233	$176,233	$
3.3	**Phase 3: Environmental Man**	$420,986	20.14 %	$127,347	$24,505	0.67	0.32	$1,043,979	$1,043,979	$1,171,326	$1,171,326	$8
		$5,831,702.72	40.57 %	$2,574,292.94	$2,916,404.26	0.92	0.83	$4,149,957.60	$4,186,517.08	$6,724,250.54	$6,760,810.02	$2,366,0

Figure 7 *- Forecast Example using CPI Forecast Method*

5.3.4 | Pros and Cons of FTC

The nice thing about FTC forecasts is that they're better at taking into consideration subjective knowledge of what's coming. They're also more in-line with how people think; and as a result, more concrete in their accuracy, i.e. evaluating what's remaining rather than what's been completed.

On the flipside, FTC is very subjective and doesn't take advantage of tools like rules-of-credit or weighted steps to calculate the forecast objectively. This subjectivity can be flawed as it relies on the honesty and interpretations of the people involved. When using FTC, it's important to have ETC as a sanity-check of sorts against which FTC can be benchmarked to ensure it's within a realistic tolerance.

5.4 | Forecasting

While it's largely manual and subjective, forecasting must be undertaken using strict and auditable methods to ensure it's defensible. Only those activities that are either not playing-out as initially planned; or those that are at risk of being influenced by previously unforeseen forces need to be forecasted.

To see this in practice, have a look at the forecast shown in Figure 7. To understand how this works, first look closely at 3.2.1 and 3.2.6 in that WBS. In particular, see how the CPI values differ in the CPI-Forecasted (CPI-F) columns from the CPI-Cost (CPI) columns. Also compare the ETC and EAC columns with their companion ETC-Forecasted and EAC-Forecasted columns.

Starting with 3.2.1 activity as the first example, CPI calculated out to 3.62, which is well ahead of expected productivity. So, after digging into it a bit, the project controls team decided that, going forward, it's unlikely that CPI will remain that high for that activity, and is likely to slow to 1.50. They therefore manually entered 1.5 into the corresponding CPI-F cell, which then adjusted ETC Forecasted and EAC Forecasted accordingly

5.4.1 | Resource Forecasting

Taking it to the next level, resource forecasting provides a more detailed method for building up the forecast from first principles. This is the technique that enables project controls to enter the physical amounts remaining on initially budgeted items. Like the engineering hours example used in 5.3.3 above, resource forecasting provides visibility into budgeted, consumed-to-date and then enables entry of

Using the example shown in Figure 8 below, activity 3.3.5 has been set to use the resource forecasting option. In that example, one of the takeoff lineitems on the original budget for a project activity was 320 units of 2m lengths of pipe. Then, after a couple months, 55 of those units were delivered and installed. This leaves 265 remaining according to the budget.

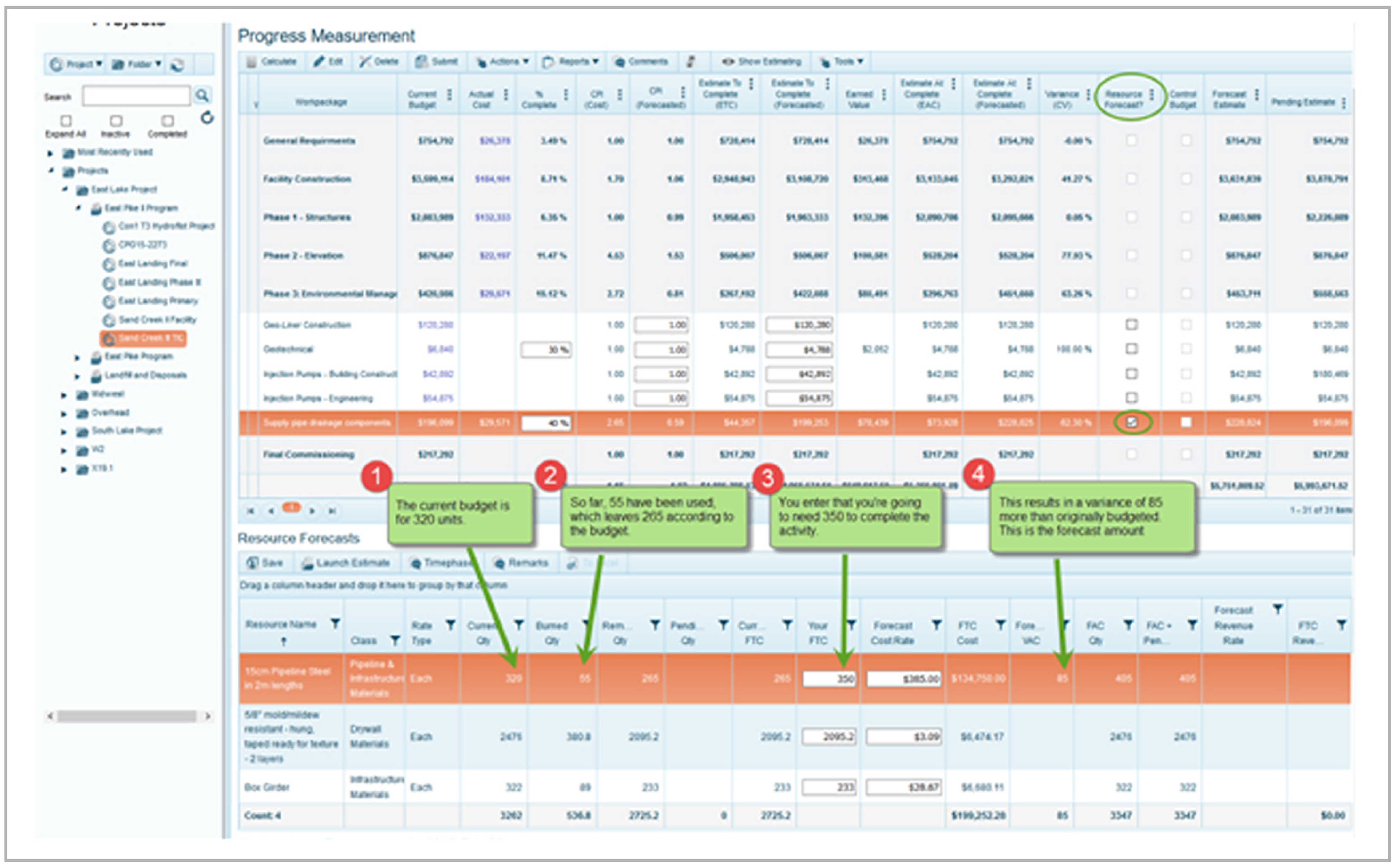


Figure 8 - Example Resource-Level Forecast showing an FTC Override

However, suppose now that the construction manager has sent an update that they're going to need more than that 265 –they're going to need another 350 to complete the activity. To see how this plays out in a resource forecast, have a look again atFigure 8. Entering a forecast to complete (FTC) quantity of 350 will trigger an additional 85 units over the currently budgeted amount. The 85 is shown in the "Forecast VAC" column, which stands for "Variance at Complete". This means that the variance from budget is 85. Notice also that the VAC of 85 units has changed the CPI Forecast to .59 from 2.65 on that activity. The cost of that extra 85 units is clearly going to dramatically change the outcome of that activity.

5.4.2 | Time Phasing the Forecast

Forecasts should also be time-phased in terms of when they are anticipated to be consumed.In addition to specifying an FTC of 350 remaining units in the example above, it's also an opportunity to specify when the incurred cost of those units is going to hit the project

Figure 9 below shows how the forecast curve pulls away from budget and ETC back in July, then takes its own path to ultimately show a significant overage forecasted. Also notice the pattern changes of the different curves based on the differences in time-phasing.

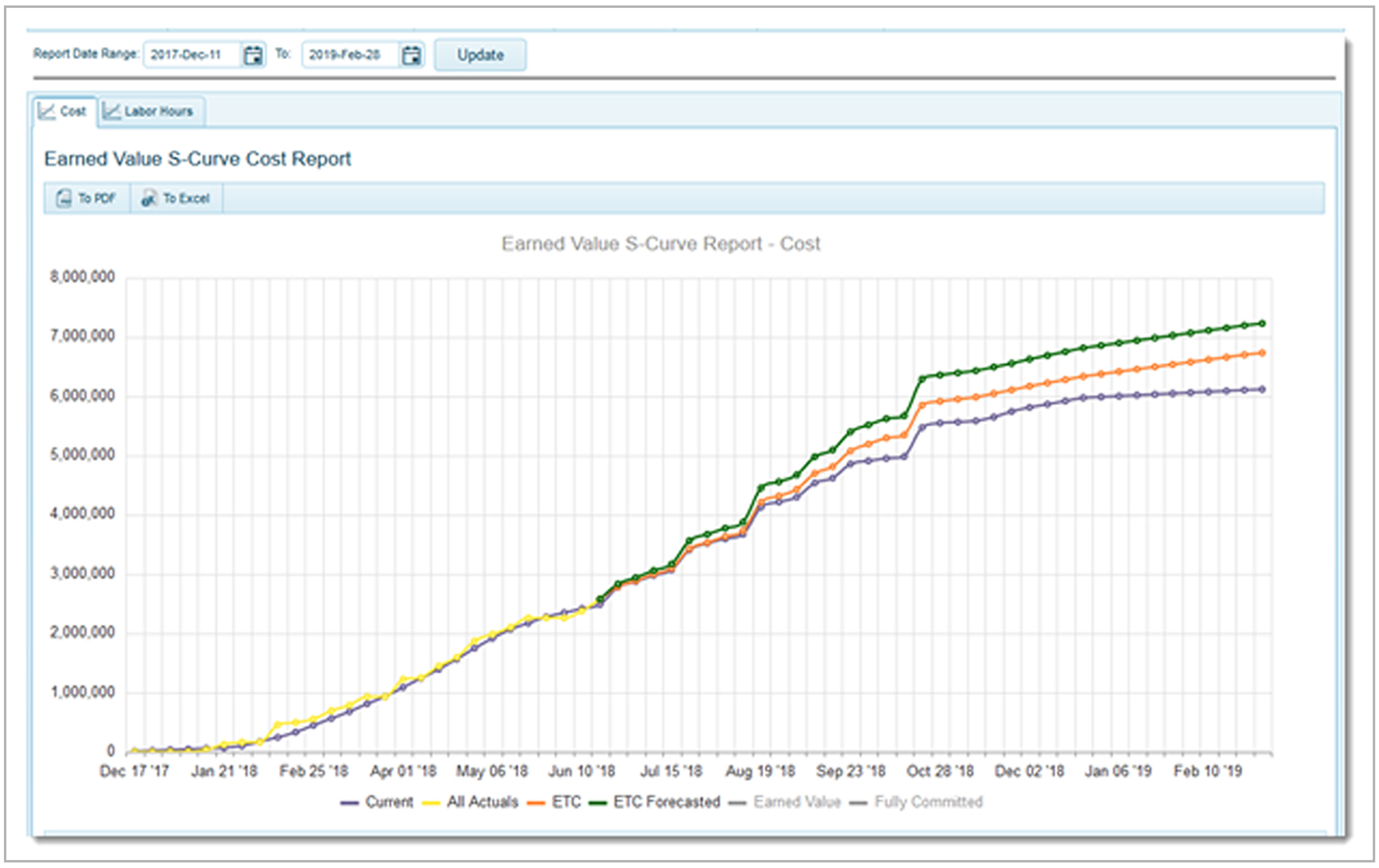


Figure 9 *- Timeline S-Curve with Budget, ETC and Forecasted*

5.5 | Reporting

The final stage in the reporting period is to produce the actual reports themselves. What is chosen to be included in the reports will be specific to each recipient and the preferences of the organization. Once the team has submitted the progress measurement and forecast, there will be an extensive range of metrics and other critical data to choose from for summary and detailed reports, including, of course, forecast data. Forecasts should be documented with explanations and assumptions to ensure the reader fully understands the underlying forces influencing the project.

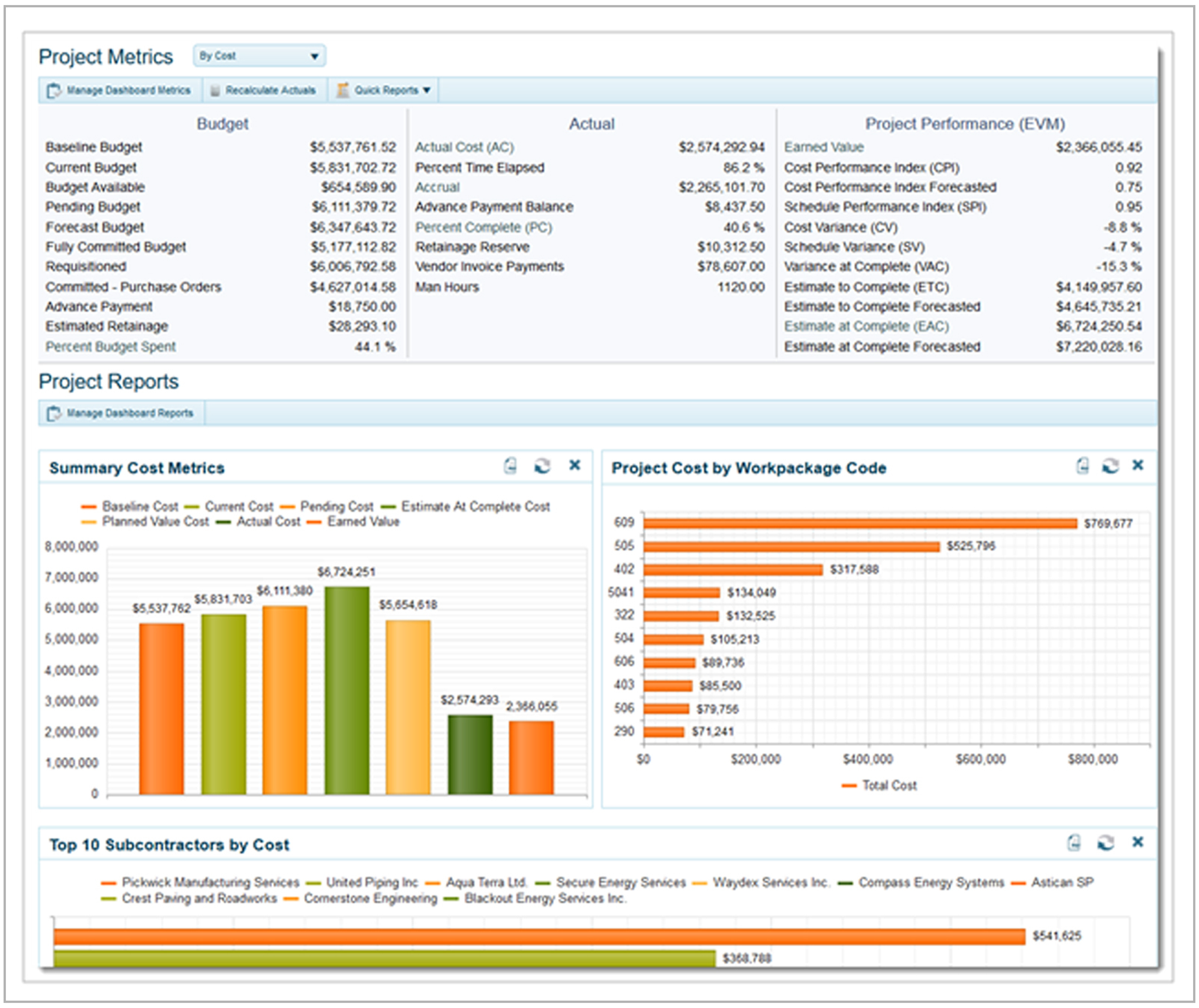


Figure 10 *- A Sample Project Dashboard Summarizing Key Metrics and Indicators*

06 | CONCLUSION

The act of forecasting on an iterative, incremental basis will not only deliver confident numbers to project stakeholders; it will also serve to uncover insidious issues that could compromise the successful execution of the project.

A key takeaway is to emphasize that the methods described in this paper can be done without adding significant extra effort or resources. It will, however, necessitate a shift in where the effort is focused. The ultimate benefit of doing this of course, is that they'll be able to produce far superior project analysis, reporting and controls

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