

Project Controls and Management Systems: Forecasting – Promoting Leading Practice



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Executive Summary

Forecasting is a central activity of project controls and management systems (PCMS) and is a key component of measuring and guiding project health. Many risks throughout the project life cycle influence how quickly and cost-efficiently projects can be designed and completed. Forecasting is one of the processes used to help assess and mitigate possible project risks. Without forecasting, projects have no mechanism for estimating the impact of current progress on future completion and, thus, no basis for corrective action.

Despite the importance of forecasting, CII Research Team (RT) 244, Global Project Controls and Management Systems, found that forecasting practices are often deficient. A broad survey of approximately half of the CII membership revealed that forecasting is one of the weakest project controls functions. (See Research Report (RR) 244-11, *Global Project Controls and Management Systems*, for more detail on the survey.) A more specific survey of project controls professionals (along with interviews) from owner and contractor organizations showed that forecasting is all too often carried out in an *ad hoc* manner, with limited integration with other PCMS functions. Moreover, implementation of standard procedures is uneven across projects. These findings are consistent with the experience of the RT 244 industry team members.

While there are many reasons for poor forecasting practice, one of the main causes may be the limited educational resources available on forecasting. In many textbooks and manuals, education about forecasting starts and stops with a presentation of earned value and elementary trending calculations. Company procedures are scattered across various manuals and tools/templates, and they lack an integrated focus on the practice of forecasting. To address this problem, RT 244 created this document to concentrate fundamental knowledge about forecasting in a single place. This effort involved providing context on the reasons for forecasting, presenting basic metrics and methods, discussing the risks and challenges of effective forecasting, and making recommendations for assessment and improvement. This resource is not meant to replace textbooks and corporate manuals, but rather to complement them in the hope of improving both forecasting education and practice.

The intended audiences for this document are the following:

- less experienced practitioners, for whom it will serve as a primer, as well as introduction to good practice
- students and educators who want a review of forecasting
- experienced practitioners who want an update and review of good practice, with implementation guidelines and recommendations for assessment.

The more junior audience should start with the overview of forecasting practice in Chapter 2 and then continue on to Chapter 3, which contains broader considerations, as well as more specifics about developing a forecasting plan. More experienced readers may wish to skim Chapters 2 and 3, and then closely review Chapter 4, which concerns implementation challenges and offers assessment questions for forecasting practice. Chapter 5 concludes with summary recommendations.

Forecasting Basics

1.1 Definition and Overview

CII Research Team 244 defined forecasting as the process of continuously predicting the final outcome of the cost, time, and resources required to complete a scope of work. (See Appendix A for a complete set of project controls definitions.)

By examining the to-date performance history of a project, and applying it to the remaining portion of the project, *along with other applicable knowledge*, a project team can predict the schedule and cost to complete the project. This practice is commonly known as forecasting. A forecast should make allowances for all known remaining items, plus undefined items, based on past experience. With accurate forecasts, project teams can detect issues and problem areas in time to permit effective corrective action. Because forecasting can also identify positive trends, it may enable a project to take further advantage of such trends. It may also suggest useful areas for identification of lessons learned.

The essence of forecasting is “plan versus actual.” This formula implies the need for an established plan, a system of measures, and the resources and procedures to carry out routine assessment of current status. A lack of these fundamentals in any combination will cause the quality of forecasts to suffer.

Forecasting should be performed during all project stages, from front end planning through construction and start-up. Specific forecasting tasks and measures will vary as a project progresses, but all forecasts should be forward-looking, always with an assessment of impact on project completion. This requires that anyone developing and interpreting forecasts should have detailed knowledge of the project and its associated risks. As for all project control functions, early planning for forecasting activities throughout the project will make for better assessment.

Quality forecasting depends on the knowledge of the personnel involved, the quality of the information they have at hand to make decisions, and the

quality of the source data from which initial forecasts are built. In particular, forecasts rely on accurate estimates, schedules, and high quality plans and specifications.

1.2 Cost and Schedule Forecasting Overview

Cost and schedule analysis involves the comparison of the actual performance with the control budget and schedule for the same scope of work. *Early analysis for any given item is critical.* The sampling of bulk material quantities during design and the development of trend curves for engineering and construction labor productivity are both extremely valuable forecasting tools. Project teams should recognize that cost analysis can also identify areas of under-runs and better-than-average performance (e.g., good or creative design work or effective subcontract management). This information is not only valuable for application to future phases of the project, but also on other projects.

Whether during engineering, procurement, construction, or start-up/commissioning, a common element for completing the work is human resources. Having adequate numbers of people with the appropriate skills and operating under optimal working conditions is essential for achieving project cost, schedule, and quality objectives. Hence, labor productivity is a key indicator of a project activity's final cost and schedule outcome.

Productivity is normally defined as the ratio of the hours “earned” (i.e., progress) to the hours expended (i.e., actual) in work done to complete a project activity or group of activities. Work accomplished—i.e., progress—is measured in terms of “earned hours,” whereby the budgeted hours are “earned” as work is completed, until all the budgeted hours are earned (100 percent complete). The relationship between earned and expended hours is productivity. A common productivity calculation is as follows:

$$\frac{\text{Earned Hours (Budgeted Quantity for Completed Activities)}}{\text{Actual Hours Spent to Complete/Progress Activities}}$$

For this calculation, a ratio greater than 1.0 would indicate that productivity was better than planned, since the earned hours of the work completed would be greater than the actual hours that were required to complete it. If the calculation were set up inversely, its ratio of less than 1.0 would represent worse than planned productivity.

A valid and reliable system of measuring progress and related guidelines are essential to accurately determining the earned hours and physical progress of activities. Regardless of the method used for determining productivity, applying the productivity experienced on the project or on any project activity to the remaining work is necessary for effective forecasting.

It is always important to consider the impact of a productivity learning curve, upon which progress starts out as less than planned, gets better, and then falls off as the more complicated activities are completed. More broadly, it is imperative to consider the factors that have influenced the standing trends, whether they are negative or positive. For example, consider field construction activities, among which the productivity for grading work has been found to be poor due to unusually rainy conditions experienced during the initial work progress. Unless these unusual conditions are expected to continue, it would not be prudent to generate a forecast based solely on this calculated productivity value. Also, known conditions that may affect the remaining work should be considered for further improving forecasting accuracy.

The following is a simple example of how productivity is applied to schedule and cost forecasting:

Engineering discipline A has a total budget of 10,000 hours (hrs) and report that they are 33 percent complete with their work 10 weeks into their overall 20 week schedule and having expended 4,000 hrs. Based on 33 percent progress, the earned value = $10,000 \text{ hrs} \times .33 = 3,333 \text{ hrs}$. Therefore the productivity is $3,333/4,000 = .83$. Applying the productivity ratio to the remaining 67 percent work to be completed results in a forecast of 8,000 hrs remaining. The Total forecast at completion = Expended to date + Forecast of Remaining = $4,000 \text{ hrs} + 8,000 \text{ hrs} = 12,000 \text{ hrs}$, compared to the 10,000 hour budget. The associated cost forecast will be the actual cost rate (\$/hr) incurred, multiplied by the total forecast hours.

Likewise, from a schedule perspective, 50 percent of the planned duration of 10 weeks has been consumed in achieving 33 percent progress. Unless there is a significant difference in the execution or the manpower to perform the work, it most likely will require 20 weeks to complete the remaining 67 percent, for a total of 30 weeks to complete all the work.

1.3 Common Forecasting Metrics

This section lists the most common metrics used to monitor, trend, and forecast the cost and schedule of a project. CII companies encounter a vast number of metrics in the range of all work scopes and projects, and unique metrics will be established as appropriate. For each metric, forecasters should determine the contract type in order to understand commercial conditions and their affect on forecast needs and methods throughout the project.

Home Office Labor

Home office labor includes engineering/design/production labor, as well as project management/support labor; this category typically includes project management, purchasing, project controls, administrative, QAQC, IT, area engineers, safety, and other support functions). Common forecasting metrics for home office labor include the following:

Home Office Metrics

Factors that have significant application to forecasting

- cost per hour – average labor rate of expenditures
- hours per unit of time – rate of hours expended, e.g., hours/week or hours/month
- hours per quantity/deliverable – rate of production, e.g., hours/drawing, hours/isometric; also applicable to purchasing, e.g., hours/purchase order
- quantities produced per unit of time – rate of quantities produced, such as 100 drawings per week
- performance/productivity = earned hours (progress)/expended hours
- hours per unit of progress – rate of hours expended to achieve one percentage completion (e.g., 3,000 hours/percent complete)
- percentage split of production engineering hours to project management or project support hours. (e.g., 70/30 or 65/35)
- scope change hours as a percentage of base hours – important at predetermined threshold of growth (e.g., 10 percent); typical necessary “ripple effect” adjustments: additional support, management, and direct supervision

- variances to labor/staffing/progress plans (plan to actual)
- variances to the labor mix (e.g., ratio of senior to junior engineers)

Factors that have limited application to forecasting (benchmarks)

- hours per piece of equipment – ratio that applies to mechanical equipment
- hours per ton – number of hours expended per ton of the facility
- home office as percentage of overall EPC.

Home Office Expenses

- cost of expenses per labor hour – average cost of expenses per labor hour, calculated as cost of expense/HO hours; used for expenses tending to correlate to labor hours, e.g., reproduction, supplies, and computer usage
- cost per unit of time – rate of expenditures for a unit of time, e.g., cost/week and cost/month; useful for any HO expense; applicable to expenses generated by weekly/monthly charges, or related to time more than labor patterns, e.g., office space charges and travel
- variances to third-party agreements, or specific orders
- variances to planned expenditures (plan versus actual).

Equipment & Materials

- cost per quantity of similar equipment/materials – usually monitored by code of account or commodity codes, e.g., \$100/cy concrete, \$100,000 per type of pump, or \$20,000/ of valve
- all units dependent upon valid quantities of materials, and on updated equipment lists
- factoring of risk of quantity growth, pricing escalation, etc. in all forecast indices.

Field Craft Labor/Subcontract Labor

- cost per hour – average labor rate of expenditures
- hours per unit of time – rate of hours expended, e.g., hours/week or hours/month
- hours per quantity/deliverable – rate of production, e.g., hours/cubic yard of concrete or hours/LF pipe
- quantities produced per unit of time – rate of quantities produced, e.g., 100 yards of concrete/week or 20 welds/week
- performance/productivity = earned hours (progress)/expended hours
- hours per unit of progress – rate of hours expended to achieve one percentage of completion
- percentage split of direct hours to indirect hours, e.g., 85/15 or 90/10
- scope change hours as a percentage of base hours – important at predetermined threshold of growth (e.g., 5-10 percent); typical necessary “ripple effect” adjustments: additional support, management, and direct supervision
- variances to labor/staffing/progress plans (plan versus actual)
- variance to the labor mix, e.g., ratio of laborers to pipefitters.

Field Staff Labor & Expenses

- field staff labor cost per hour – average labor rate (dollars/hour)
- field staff labor hours per unit of time – rate of hours expended, e.g., hours/week or hours/month
- cost of expenses per labor hour – average cost of expenses per labor hour, calculated as cost of expense/craft or staff hours; used for expenses that tend to correlate to labor hours, e.g., field office expenses
- cost of expenses per unit of time – rate of expenses expended for a unit of time, e.g., cost/week or cost/month; useful for any field expense; applicable to expenses generated by weekly/monthly charges, or related to time more than labor patterns, e.g., field staff living expenses, office trailer charges, and travel

- expenses cost per hour – average labor rate of expenditures
- variances to field staff labor/staffing plans (plan versus actual)
- variance to the field staff labor mix, e.g., ratio of expatriate versus local hire positions.

Indirect Construction Costs

This category includes temporary facilities, international expenses, craft burdens, construction equipment, and small tools/consumables. Scaffolding and security expenses are often also counted as indirect costs, unless otherwise budgeted as a direct expense. Following are useful indirect cost metrics for forecasting:

- cost per labor hour – average cost of a cost element per labor hour; useful for expenses that tend to correlate to labor hours, e.g., craft burdens
- cost per unit of time – rate of cost expended for a unit of time, e.g., cost/week or cost/month
- cost per hour – average rate of labor expenditures, as appropriate
- relative percentages – indirect costs relative to other project costs, e.g., small tool cost as a percentage of construction labor cost or scaffolding hours as a percentage of total direct construction labor hours
- variances to plans (plan versus actual) – construction equipment, security, safety.

1.4 Example – Control of Labor Hours

Most, if not all, engineering and construction activity requires human resources. Therefore, labor hours can be used as a common measure for work activities. Masonry brick construction provides a useful example of this metric: A standard four-inch masonry brick wall can be constructed at a rate of four square feet per mason worker hour. Therefore a 40,000-square-foot wall will require 10,000 labor hours of effort. Assuming a crew of 20 masons working a 40-hour work week, a forecaster can predict that the construction of the wall will take 12.5 weeks. This calculation provides the starting point, or baseline.

To manage and control any activity, the research suggests that there be a minimum of 10 reporting periods. Thus, with a 12.5-week overall duration, weekly progress assessment and reporting would be optimal. Table 1 presents a plan for weekly progress based on such a metric.

Table 1. Planned Progress

Week	1	2	3	4	5	6	7	8	9	10	11	12	13
sf/ week	1,500	2,000	3,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	3,000	2,000	500
sf Cum.	1,500	3,500	6,500	10,500	14,500	18,500	22,500	26,500	30,500	34,500	37,500	39,500	40,000
Period Hours	375	500	750	1,000	1,000	1,000	1,000	1,000	1,000	1,000	750	500	125
Cum. hours	375	875	1,625	2,625	3,625	4,625	5,625	6,625	7,625	8,625	9,375	9,875	10,000

Table 2 shows how physical progress on the wall would be measured and recorded each week, after three weeks.

Table 2. Actual Progress

Week	1	2	3	4	5	6	7	8	9	10	11	12	13
sf/ week	1,200	1,800	3,000										
sf Cum.	1,200	3,000	6,000										
Period Hours	400	500	800										
Cum. hours	400	900	1,700										

In the above example, at the end of the third week, the actual cumulative progress is 500 square feet behind planned progress. Furthermore, it is evident that the crew has expended 75 more labor hours than planned for the same time frame. Based on this three-period trend, the masons' productivity can be calculated as 6,000 square feet/1,700 labor hours = 3.5 square feet/labor hour, compared to the plan basis of 4.0 square feet/labor hour. Thus, if the trend were to continue, a forecaster could conclude that the construction of the 40,000 square-foot wall would require 11,400 labor hours. That entails a 14 percent overrun of the 10,000-labor-hour budget. Moreover, if crew size were constrained to the number planned (i.e., 25 masons, based on the planned 1,000 labor hours/40-hour week), then the duration will extend by the equivalent of an additional 4,900-square-foot wall, or 1.4 weeks at the calculated productivity