Working the "Educated" Plan: How effective is corrective staffing in a typical white-collar project?

John M. Nevison, PMP

Summary Past reports have claimed that earned-value metrics are inadequate to manage a dynamic project. This report shows how a project can use earned-value metrics to respond to the full range of tests that most projects encounter. The tests assume the project goal is to finish on time with full scope and correct the staffing (the cost) to achieve success. The results show how to work through realistic project delays in unplanned-for staffing, and how the "desert of resources" expands Brooks' Law that "adding staffing to a late project only makes it later."

Key Words White-collar project, earned value, earned-value metrics, Cost Performance Index, CPI, Remaining Work Index, RWI, Staffing to Schedule Index, StSI, scope creep, systemic shock, sudden shock, schedule management, staffing management, up-to-speed delay, time-to-teach cost, learning curve, utility horizon, desert of resources, systems dynamics, project delays, system model, Brooks' Law, rookie, professional, unpaid overtime.

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We have met the enemy and he is us.
Walt Kelly

1.0 Introduction: Earned value's delayed effects
Project management literature is full of integrated system models. These models have described useful insights into project behavior and management. [1] Some have detailed how undiscovered rework gradually bloats the scope of the project and overwhelms the initial plan. [2] Others have explored the process of entry learning on a project where the staff passes through the "arriving rookie" pool to the full "professional" pool of team members, able to contribute 100% to the project. [3]

Unfortunately, some reports have disparaged earned-value analysis as a failed tool in managing the project. [4]

The present discussion builds on the lessons of these earlier reports, incorporates the effects of undiscovered rework and entry learning into a basic "educated" plan, and then uses that plan to test the responses of a middle-sized, 12-month, white-collar project. The responses will demonstrate that a project can apply earned-value metrics to corrective staffing and deliver the original scope on the original schedule for the most reasonable cost. [5]

2.0 THE BASIC EDUCATED PROJECT
Planned staffing for the "educated" white-collar project appears in Figure 1. The Written Staff Plan (with a scale from 1 to 24 people per month) indicates the rate at which the staff will work, and the Written Plan to Date (scaled from 0 to 40,000 staff-hours) adds up the staff work into the completed project cost in 12 months. [6]

Figure 1. The Written Staff Plan, Written Cost Plan to Date, life-cycle phases, and discovered rework
Figure 1 depicts a typical, 12-month, white-collar project with a design-build life cycle: The project staffs up during the early phases, works at a steady 14-person level through the middle of the project, and winds down through the testing and deployment. The project's staffing will result in the total staff-hours of work that will reach the planned goal on the desired schedule. Each staff person works 160 staff-hours each month. Most of the activity of the later phases includes the "undiscovered rework" that was highlighted in prior reports.

Prior reports also illustrated how new staff passes through a "rookie learning" period before becoming "full professional contributors." One study chose a 12-month example of a white-collar project with baseline entry-learning values of a 6-week rookie up-to-speed interval, an average rookie productivity of 50%, and a 6 hour-a-week tutorial from the project professionals, to arrive a "cost of entry learning" of roughly 8% of the project total cost. [7]

To create an "educated" plan that includes entry learning, we will run a trial project that includes all three entry-learning variables. All project hiring will be driven by project pressure working through the system delays in a cause-and-effect systems model. (See Figure 4 for details.)

The trial project begins with 0 rookies and 1 professional (to teach the rookies). As the project hires its staff, the project incorporates entry learning into the plan. When we are done, because the project will have combined earlier reports' undiscovered rework and our entry-learning variables, we will call our result the "educated" project plan.

The early entry learning activity in Figure 2 includes the effects of the getting up-to-speed interval, of the average rookie productivity, and of taking time to teach those getting up to speed.

Figure 2 shows how the educated project's Actual Staff rate follows the Written Staff Plan. The entry learning activity occurs in the area between the Actual Staff rate and the Activity Against Plan.

Figure 2. The basic project with Written Staff Plan, Actual Staff, and Activity Against Plan
Plan. The entry learning activity occurs early in the project and lasts until month 7. It has the effect of delaying progress on the project until later than initially planned. After month 4, the project staff adds a few extra staff-hours to make up for the initial learning activities. When the project finishes on time, the staff has worked a total of 22,272 staff-hours (the area under the Actual Staff rate). This figure includes 2,162 staff-hours of entry learning and 20,110 staff-hours of planned project work (the area under the Activity Against Plan rate). The 9.7% cost of learning in this educated project is not too far from the 8% in the example cited in the earlier report.

Figure 3 shows how the project Activity Against Plan rate accumulates as the project's Earned Value to Date to achieve the project's final Project Goal (the scope goal), of 20,110 staff-hours, on schedule, at the end of 12 months. The Actual Staff rate feeds the cumulative Actual Cost to Date to arrive at the total cost of 22,272 staff hours. The total cost exceeds the goal by the 2,162 staff hours, the cost of entry learning.

If you return to Figure 1 you will notice that the Written Plan to Date lines up with the Actual Cost to Date, not the Earned Value to Date. This is because Figure 1 shows an adjusted Written Staff Plan, with its details revised so that the Written Plan to Date covers the 2,162 staff-hours of entry learning. After the entry-learning work was covered in the adjusted plan with extra staffing, the adjusted Earned Value to Date in Figure 3 reached the planned project goal of 20,110 staff-hours.

The basic educated project's Earned Value to Date defines the full project scope goal at the end of 12 months. Figures 1, 2, and 3 show how the integrated educated project activities work when everything goes according to plan.

Figure 3. Earned Value to Date, Actual Cost to Date, and Project Goal of the basic educated plan
2.1 Cause-and-effect diagram of the basic educated project following the written plan

Figure 4 links the variables that are active in the educated project, based on the written staffing plan. (The system elements enclosed in boxes will be added later when the "educated" project is tested.) If you froze the action of this set of variables, you would be able to look at the current size of the Written Staff Plan; the Actual Staff and the Actual Cost to Date; the basic Activity Against Plan and the Earned Value to Date. [8]

Figure 4 maps the causal links between the system variables. Staff members devote time to learning activities and project activities. Activities are accumulated in the Actual Cost to Date and Earned Value to Date. These metrics combine with the Written Staff Plan to create Project Pressure on the project staff. [9]

In the educated project, entry Learning Activity increases the Actual Cost to Date (but not the Earned Value to Date). The difference creates a mild positive Project Pressure to make up for the lagging earned value. (Details on the formulas will appear later in the discussion.)

Mild Project Pressure combines with the project's Written Staff Plan to grow the planned staff along with a few extra part-timers. (See Figure 2.) The staff becomes fully productive over a 6-week, up-to-speed interval. During that interval the rookies incur an average training cost of 6 staff-hours per week from the professionals already on board. To understand how this 6-week delay affects the educated project, see Figure 5.

Figure 4. Cause-and-effect diagram of the educated project following the written staff plan
The educated project begins with 0 rookies and 1 professional (to teach the rookies). Following the plan, the project staffs up and, after their up-to-speed interval, the rookies become full-time professionals. The rookie 6-week, up-to-speed delay causes the professionals’ growth to follow 1.5 months behind the rookies.

2.2 The Up-to-Speed learning curve
Figures 6 and 7 detail how an individual follows an up-to-speed learning curve.

Figure 6 shows the simplest form of a learning curve, where a new person on the morning of the first day on the project has a productivity of 0 hours/week and at the end of a 6-week, up-to-speed interval has a productivity of 40 hours/week. The individual's average productivity is 50%. The learning curve is the diagonal line that measures the increasing percentage of the working hours that are applied to the planned project work. The diagram also contains the equation for the working rate:

\[ \text{<working rate>} = \frac{40}{6} \times \text{<the week number in the up-to-speed interval>} \]

Figure 7 shows how the learning curve can be modified to include a different arrival pool productivity and the professional time-to-teach rate. First, with a more generous assumption that the arrival's average productivity will be 60%, a planned arrival can immediately contribute 20% (8 hours) to the project. This assumption shifts the dotted-line learning curve rate up a bit.

Second, each person is drawing an average of 6 hours a week of time-to-teach from the professionals already on the project. The time-to-teach rate at the end of the up-to-speed interval will be 0, so to have an average of 6 hours in the middle, the time-to-teach rate at the
beginning must be 12 hours per week. The solid diagonal line represents an adjusted learning curve that begins at -4 hours/week and ascends to 40 hours/week.

When a learning curve begins with a negative rate, it takes a new arrival a while to begin contributing to the project, and then a little while longer until the total contribution covers the initial costs. In Figure 7, the new hire's net contribution turns positive when the rate exceeds 4 hours per week, when the positive triangle of contribution exceeds the negative triangle of cost. The length of time until a new hire "breaks even" and contributes to the project is labeled "Utility Horizon" and is exactly 1.09 weeks. (More on this calculation later.)
The utility horizon has a surprising side effect: it creates a "desert of resources" at the end of the project. Within a week of the end of the project, a new hire cannot learn enough to be helpful to the project. (Unless he or she comes with specific, immediately useful, talents.) This utility horizon will become an important consideration when dealing with the delays in finding and teaching unplanned-for staff.

### 2.3 A variable range's effect on the whole project

Earlier references, information from several surveys, and New Leaf's clients' experience over the past 20 years have led to the current values for a plausible range for each project variable in the 12-month, white-collar project. [10] Given a plausible range of values for a variable, a natural question is "What effect does a variable's range have on the whole project's cost?" And, "How important is this concern to the overall problem of managing the project?"

For the basic, educated project, the total (100%) project baseline cost is 22,272 staff-hours to produce a 20,110 staff-hour scope goal in the required 12 months. The variables that define entry learning are displayed in Figure 8. [11]

The baseline values for these variables were selected to be on the conservative side of the median values of their ranges. [12] Together these three variables define the entry learning for the project. The Up-to-Speed Interval is baselined at 6 weeks and can vary from 2 to 10 weeks, resulting in a project cost spread of 12%. The average Rookie Productivity is baselined at 60% and can vary from 50% to 90%, resulting in a project total cost spread of 7%. The Time-to-Teach Cost Rate is base-lined at 6 hours/week and can vary from 2 to 10 hours, resulting in a project cost spread of 4%.

The Up-to-Speed Interval has the largest cost spread because it has a compounding effect: if the interval is shorter, the individual becomes 100% productive faster and the individual uses less of the professional's teaching time. So shortening the rookies’ Up-to-Speed Interval saves a lot of entry-learning staff-hours. Increasing the Rookie Productivity and decreasing the Time-to-Teach Cost Rate also saves entry-learning staff-hours.

All three of these variables can lower the total entry learning and allow for earlier Activity Against Plan. The lesson is clear: **Before starting a project, understand and reduce your average Up-to-Speed Interval.** (For example, by having a clear and complete project plan to show the new arrivals.)

A 1% improvement in our $928,000 educated plan is worth about $9,300 [see note 8]. A simulation not shown here estimates that improving all three of our entry-learning variables to

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**Figure 8. Entry-learning variable ranges and basic, educated project cost spreads**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline Units</th>
<th>Variable Range</th>
<th>Project Cost as Percent of Baseline</th>
<th>Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
</tr>
<tr>
<td>Up-to-Speed Interval</td>
<td>1.5 mths</td>
<td>0.50</td>
<td>1.00</td>
<td>2.50</td>
</tr>
<tr>
<td>Rookie Productivity</td>
<td>.6 (.6 = 60%)</td>
<td>50%</td>
<td>75%</td>
<td>90%</td>
</tr>
<tr>
<td>Time-to-Teach Cost Rate</td>
<td>6 stfHrs/Week</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>
their low-end values could save us 9.4% of the staff-hours, or about $87,300. (Note that the 
sum of the three variables' low-end cost improvements is 13%. However, because the variables 
all affect the same entry-learning costs, the combined yield is only a 9.4% project 
 improvement.)

2.4 The basic educated project: Summary
The educated project plan incorporates important lessons of past work on projects as systems: 
both entry learning and undiscovered re-work. The project integrates baseline variable values 
that are drawn from plausible ranges of values. The project calculates its corrective pressures 
from familiar earned-value variables. The project’s behavior makes a strong argument for 
  hiring high-skilled staff and for pre-project training that can shorten up-to-speed times, 
increase initial rookie productivity, and lessen teaching demands on the working project 
professionals.

2.5 The basic educated project's Planned Value to Date
The educated project's basic Activity Against Plan (that adds up as the Earned Value to Date) is 
pushed later by the early entry learning activities and then compensates later by over-achieving 
the plan to allow the project to finish on time (see Figure 2).

Because the basic Activity Against Plan pattern shows how the project behaves when it 
includes entry learning and everything goes according to plan, this pattern accumulated in the 
Earned Value to Date will become the new reference pattern, the "educated" project's Planned 
Value to Date, that we will use when we explore things not going according to plan. This 
"educated", planned pattern will be the plan to which we will compare our project performance 
as we examine how earned-value metrics can use corrective staffing to respond to sudden and 
systemic shocks.

(The original Written Staff Plan will continue to be used in our diagrams as a reference pattern, 
to make it easier to see how other variables are reacting.)

3.0 THE SHOCKED, EDUCATED PROJECT
What happens when the educated project must make an unexpected, significant adjustment? 
Can we continue to calculate project pressure derived from earned-value metrics? Can we get 
back on track? Can we still reach our project goal on schedule for the lowest possible cost? In 
order to answer these questions, we must take a detailed look at what happens when we 
seriously shock the project.

Our focus will be on the whole project reacting to the worst-case scenario of a systemic shock. 
This systemic shock extends from the beginning to the end of the project. It could be called a 
chronic shock. The shock is that a persistent 25% of our effort goes into unplanned-for work, 
meaning that the staff is only 75% productive!

This systemic shock of 25% unplanned-for work could be caused by some all-too-familiar 
causes: poor requirements definition, bad initial planning, inexperienced staff, challenging 
technical difficulties, interfering senior managers, hostile sister projects, additional 
undiscovered rework, or poor scope management.
A 25% systemic shock will require large adjustments to our initial plan and exercise old and new paths in our cause-and-effect model. The shocked project's behavior may provide valuable lessons for future projects.

3.1 Cause-and-effect diagram of the shocked educated project following the plan

In Figure 4, the shocked project's cause-and-effect diagram splits Project Activity into Activity Against Plan and Unplanned Activity. The Unplanned Activity is where the 25% shock hits the project.

Figure 4 adds Time-to-Find Cost and Time-to-Find Interval considerations for unplanned-for staff. Figure 4 also adds Overtime as a quick-acting response to the need for more staff-hours of work. Note that the Planned Value To Date is based on the basic Activity Against Plan, so that the educated project allows for the early delays that Learning Activity causes and will be reacting to the effects of only the Unplanned Activity.

3.2 Overall performance

First, we'll examine how the educated project behaves when it experiences a systemic shock. Figures 9, 10, 11, and 12 show the educated project responding to a 25% systemic shock—that is, one-quarter of its efforts are spent on work that was not in the original plan but for which the project must pay.

Figure 9 begins with the regular rookies and many more pros. The figure also shows the immediate effects of increased project pressure to hire planned staff and build a pending pool of staff to feed the unplanned rookies into the project. (More detail on these two new pools will appear below.) Notice that the pool of unplanned rookies looks like it has peaked at 4 months. The number of project pros grows until the work has been caught up, then declines as the project slows its pace, finally dropping below than the original plan.

Figure 10 shows the split between the 75% activity worked against the plan and the unplanned 25%. By month 6 in the project, as the increased staff's Activity Against Plan gets fast enough
to match the original plan for 14 people, the project pressure begins its steady decline and the project gradually reduces staff.

Figure 11 shows the workweek with overtime between 40 and 52 hours. The workweek, with only a 1-week delay, increases and decreases with the project pressure. Again, the overtime begins to decrease at the 4-month mark. Also graphed between 0 and 12 hours is the small amount (10%) of *unpaid* overtime.

**Figure 10. Shocked project’s Activity Against Plan and Activity Unplanned**

**Figure 11. Shocked project overtime rate**
Figure 12 shows the project's *Earned Value to Date* achieving the project's final *Project Goal* (the scope goal) of 20,110 staff-hours, on schedule, at a cost of 31,779 staff-hours (a 43% cost increase over the basic project's 22,272 staff-hours).

### 3.3 Variable ranges and their effects

Figure 13 details the important set of the shocked model's variables, their baseline values, their range of values, and the consequent spread of the project costs.

**Figure 12.** Shocked project's *Earned Value to Date* and *Actual Cost to Date*

![Graph showing earned value and actual cost to date](image)

**Figure 13.** Variable ranges and shocked project cost spreads

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline Units</th>
<th>Variable Range</th>
<th>Project Cost as Percent of Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
<td>High</td>
</tr>
<tr>
<td>Up-to-Speed Interval</td>
<td>1.5 mths</td>
<td>0.50</td>
<td>1.00</td>
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<tr>
<td>Time-to-Teach Cost Rate</td>
<td>6 stfHrs/Week</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Unplanned-to-Planned Factor</td>
<td>1.0 ratio</td>
<td>1.00</td>
<td>1.10</td>
</tr>
<tr>
<td>Time-to-find Interval</td>
<td>2 mths</td>
<td>0.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Labor-to-find Cost</td>
<td>22 hours</td>
<td>15.0</td>
<td>22.0</td>
</tr>
<tr>
<td>OT Adjustment Interval</td>
<td>.25 mth</td>
<td>0.25</td>
<td>0.50</td>
</tr>
<tr>
<td>Percent Paid OT</td>
<td>.9 (.5 = 50%)</td>
<td>10%</td>
<td>50%</td>
</tr>
<tr>
<td>Leading Staff</td>
<td>0 time</td>
<td>0 time</td>
<td>.5 desert</td>
</tr>
<tr>
<td>Monitor Frequency</td>
<td>continuous</td>
<td>cont.</td>
<td>.5 mth</td>
</tr>
<tr>
<td>Phased Up-to-speed Interval</td>
<td>none</td>
<td>none</td>
<td>mild</td>
</tr>
<tr>
<td>Scope Creep</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Sudden Shocks</td>
<td>none</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Systemic Shock</td>
<td>25% unplanned</td>
<td>none</td>
<td>25%</td>
</tr>
</tbody>
</table>
The shocked project begins with the basic educated project baseline values for all the project variables and changes only one value, the Systemic Shock, from 0 to 25%. The 25% Systemic Shock stresses the whole system. The increased cost spreads on the far right of the table show that, when the project is responding to stress, most of the variables have broader effects on cost.

The cost spreads of the first two variables have gone up from the basic educated project to the shocked project: Up-to-Speed Interval from 12% to 14%, and Rookie Productivity from 7% to 14%. This increase in the cost spreads comes from the big increase in required project activity driven by the 25% shock. When the project activity goes up, the difference in costs between the high and low setting of a variable often expands. The shocked project makes remedial work necessary and can magnify the effect of each variable setting.

3.4 Overtime
A 25% shortfall in the project's planned activities usually results in an immediate increase in overtime for the current project staff. Depending on how fast a project manager can detect the problem and adjust the staff's workload, the delay can be from 1-4 weeks. The OT Adjustment Interval has such a small difference in its range that its delays from 1 to 4 weeks make no significant difference to the project cost spread! (See Figure 13.)

Some of the research on overtime indicates that by restricting the overtime hours to less than 12 hours a week, burnout can be avoided. [13] By adopting this 12-hour limit, the shocked project sought to avoid the stop-and-start dynamics of burnout. The shocked project assumes that a wise manager would detect individuals suffering from chronic overtime burnout and rotate them off the project until they could return refreshed.

As the shocked project's Project Pressure varies between 1.00 (no change) and 1.99 (99% change), Overtime varies between 0 and 12 hours. The formula is:

\[ <\text{Average workweek}> = 40 + 12 \times (\text{Project Pressure} - 1), \]
when Project Pressure is between 1 and 2.

Otherwise, \[ <\text{Average workweek}> = 40, \text{ when Project Pressure} \leq 1, \text{ or } 52, \text{ when Project Pressure} \geq 2. \]

3.5 Paid versus unpaid overtime
Unfortunately, in many white-collar professions, overtime is considered "part of being a professional" and is not paid for.

In our shocked project, overtime is set to reflect a good project management practice with a paid overtime value of 90% (in an ideal world, it would be 100%). This good management practice will yield project costs that more nearly reflect the true labor costs of the project. The plausible range of values for paid overtime descends from a commendable 90% to a lamentable 10% and leads to a substantial 11% spread in the shocked project's costs.

Ironically, the bad practice of not paying for overtime often hides another bad practice of allowing overtime burnout to occur. The shocked project baseline values sought to avoid both bad practices. Projects should pay for their overtime and try to avoid staff burnout.
### 3.6 Unplanned-for people

A 25% drop in our productivity creates a need to find and hire extra staff that were not included in the original, educated plan.

The *Time-to-Find* interval ranges from 2 to 14 weeks. For in-house staff, the range is on the shorter end; for outside hires, on the longer end. The baseline value for the shocked project's *Time-to-Find Interval* splits the difference at 8 weeks. [14]

Surprisingly, the range of the *Time-to-Find Interval* has no significant effect on the shocked project's cost spread. Because the project immediately senses the need for unplanned staff and begins a search to identify them, the *Time-to-Find Interval* is covered by the scheduled rookies signing on.

Figure 14 shows that unplanned-for staff adds two pools to our learning-working progression. The first addition is the pending pool with an average length (delay) of 8 weeks. The second is a separate learning pool for unplanned staff. This separate pool allows us to assign different rates for a planned-for staff person and an unplanned-for staff person.

### 3.7 People entering and leaving the project

Figure 14 also allows you to see how staff members might enter or leave the project. When people are needed, the first action is to sign-on the planned staff that is immediately available because they are part of the plan. (This is how the basic plan signed on the planned-for staff.) If unplanned staff members are also needed, the second step is to find them by identifying a pool of applicants for the pending pool. When it becomes possible after a time-to-find delay, the third step is to sign on unplanned staff from the pending pool.

White-collar projects, large and small, all seem able to remove a person from the project payroll in about 2 weeks. Sometimes, 2 weeks is the time required to fire someone; sometimes, it is the time to move a valuable staff talent to a different project. [15]

**Figure 14. Four pools with three delays**
3.8 Unplanned Up-to-Speed Learning Curve
The shocked project distinguishes between planned and unplanned staff with the *Unplanned-to-planned factor*. When the factor is 1.0, both planned and unplanned staff members have the same learning curve; when it's 1.10 or 1.20, the learning curves differ. (For more on the Unplanned-to-planned factor, see the Planned versus unplanned section below.) Figure 15 shows that, in the baseline case illustrated, the factor is 1.0 and the unplanned up-to-speed interval is 6 weeks, with the average productivity of 60%, the same as the planned values in Figure 7.

However, Figure 15 also shows that the average unplanned staff member has a much longer road to travel before joining the ranks of the project professionals. His or her Up-Speed Interval of 6 weeks is preceded by a Time-to-Find Interval of 8 weeks.

Figure 15 includes a new cost, the 22 hours of labor to find a new person, the Labor-to-Find. A plausible range for this variable (from client data) extends from 15 to 30 hours and leads to a project cost spread of 12% (see Figure 13).

Figure 15 also illustrates that when the 22 staff-hours of labor to find each additional person gets included, Net Hours Worked turns positive at 3.05 weeks and the Utility Horizon (also known as the desert of resources) grows to $8 + 3.05 = 11.05$ weeks (or 2.76 months). [16] **So a better, low-cost process to sign up pending, unplanned-for staff could significantly reduce total project costs.**

3.9 The desert of resources
The 2.76-month Utility Horizon stretches over 20% of the project's total duration and creates a desert of resources where it no longer makes sense to hire staff because they will fail to contribute to the project! (See Figure 16.) The only exception to this rule would be a particular person with special talents and a much faster than average up-to-speed time.

Figure 15. Unplanned Up-to-Speed Learning Curve
It's as if the project was a wagon train journey from St. Louis to Los Angeles and the final stage was across Death Valley. When crossing the desert, you don't want to bring on any newcomers who don't have their own water.

So **projects should limit late-project hiring to those contributors with immediate, special talents.** When senior management floods a late project with mediocre talent, the project professionals often ignore them. "If management assigns us people late in the project," one project veteran asserted, "we put them off in a corner reading novels. If we tried to use them, they would only get in the way." [17]

Fred Brooks, the author of *The Mythical Man Month,* proposed in Brooks’ Law that "Adding manpower to a late software project only makes it later." The **desert of resources** means that this law can take effect **well before the project becomes late!** Brooks himself suggested that his rule of thumb was caused in part by the late arrivals' entry learning. [18]

### 3.10 Staff hiring ahead

If, at the end of the project, a late arrival will only harm the project's productivity, it might make sense to hire ahead, before the **desert of resources,** so that when you arrive at the edge of the desert, your staffing is already adjusted for the end of the project. When the project-staffing plan was set to look ahead the full 2.8-month distance, the resulting project costs were less because the project used overtime right away, staffed up more aggressively, and reached a smoothed, steady-state much earlier. This pattern occurred with hiring ahead for either a full desert or a one-half desert. In both cases, the total project cost was 94% of the 100% baseline, for a 6% cost spread. Again, **aggressive early hiring (if the staff can be put to work) can help reduce costs.**

### 3.11 Planned versus unplanned staff

It seems reasonable to assume that, while every rookie is qualified to work on the project, the productivity and skill of the project's **planned** staff might be a little better than the project's **unplanned** staff.
unplanned staff. The shocked project provides three settings, one neutral and two adjustments, for unplanned staff. The adjustments assume that the unplanned-for staff may take little longer to get up to speed and have a lower average productivity while getting up to speed. Both are driven by an Unplanned-to-planned factor that can be 1.00 (no difference), 1.10 (10% difference), or 1.20 (20% difference):

\[
\text{<Up-to-speed of an unplanned rookie> } = \frac{\text{<Up-to-speed of a planned rookie>}}{\text{<Unplanned-to-planned factor>}}
\]

\[
\text{<Productivity of an unplanned rookie> } = \frac{\text{<Productivity of planned rookie>}}{\text{<Unplanned-to-planned factor>}}
\]

The project baseline value is 1.00, with a variable range from 1.0 to 1.2 and a project cost shift of 7%. (See Figure 15.)

3.12 Earned-value metrics

The project pressures that drive corrective actions begin with the fundamental metric of earned-value analysis, the Cost Performance Index (CPI). The CPI is the ratio of the completed planned work, Earned Value, to the actual work expended, Actual Cost.

\[
\text{<Cost Performance Index> } = \frac{\text{<Earned Value>}}{\text{<Actual Cost>}}
\]

Project pressures are the inverse of the indexes, for example:

\[
\text{<Cost Pressure> } = \frac{1}{\text{CPI}}
\]

The project pressures are:

- Exactly 1.0 when project activity should not change,
- Above 1.0 when project activity should increase, and
- Below 1.0 when project activity should decrease.

Two newer information indexes are included in the pressure calculations: the Remaining Work Index (RWI), and the Staffing-to-Schedule Index (StSI). These indexes are reasonable extensions of the familiar earned-value indexes and behave in a fashion similar to the CPI. Their defining formulas are:

Remaining Work Index (RWI)

\[
\text{RWI} = \frac{\text{<Remaining work planned>}}{\text{<Remaining work actual>}} = \frac{(\text{<Total Planned Value> } - \text{<Planned Value to date>})}{(\text{<Total Planned Value> } - \text{<Earned Value to date>})}
\]

Staffing-to-Schedule Index (StSI)

\[
\text{StSI} = \text{CPI} \times \text{RWI}
\]

The formula for Project Pressure is: \(1/\text{StSI}\). [19].
3.13 Other earned-value variables
Other earned-value metrics that were explored but set aside include Cost Variance, Schedule Variance, the Schedule Performance Index (SPI), the Air Force Index, and the To Complete Performance Index (TCPI). The indexes that proved useful were the Cost Performance Index, the Remaining Work Index, and the Staffing-to-Schedule Index. [20] The earned-value pressure allowed the project to respond successfully to a full range of project shocks.

3.14 Monitor Frequency
In most white-collar projects, information on the project's progress is monitored in weekly or biweekly meetings. In the shocked project, the Monitor Frequency ranges from immediate, to biweekly, to once a month. The baseline value for Monitor Frequency is immediate. The re-plan range leads to a project cost spread of only 2%. (See Figure 13.) Other combinations of systems variables (not shown here) had a Monitor Frequency cost spread of 0%, so the project team can manage the project confidently with weekly, biweekly, or monthly frequency.

3.15 Project phases and up-to-speed time
Many white-collar projects get more complicated as they get into their later phases. Team interactions are complex and the half-built product can be challenging. Testing and rework may add additional uncertainty to the project. The complexity of later phases leads many project managers to increase their estimates of the up-to-speed interval for the later phase arrivals. That increase in the overall up-to-speed interval also expands the desert of resources at the project's end.

The baseline, up-to-speed interval was a No Phase, flat 6 weeks (1.5 months). In Figure 17 the other two phase-effect charts are a Mild Phase-effect with an average the same as the No phase, and a Higher Phase-effect chart that begins with the flat rate and goes up.

The range of values for the phase-effect up-to-speeds lead to a huge project cost spread of 18%. The Mild Phase has the lowest project cost percentage of 94% because it has the lowest values for the early phases of the project, when most of the up-to-speed entry learning is occurring. The Higher Phase is at a project cost percentage of 112%, reflecting the early higher up-to-speed times (see Figure 15).

The project's total cost spread was 18%. Also, the utility interval (and the corresponding desert of resources) crept up from 2.76 to 3.18 months, an increase of 1.7 weeks.

**Figure 17. Up-to-speed time by project phase, 3 cases**

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>No Phase</th>
<th>Mild Phase</th>
<th>Higher Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.5</td>
<td>0.5</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>5</td>
<td>1.5</td>
<td>2.5</td>
<td>3.5</td>
</tr>
</tbody>
</table>
We see that, within a phase-driven *Up-to-Speed Interval*, the most important time is *early in the project where the majority of the learning occurs*. We also remember that the *desert of resources* may prevent adding staff in the later project phases.

### 4.0 OTHER PROJECT SHOCKS

Figure 18 shows three possible shocks to the project: *Scope Creep*, *Sudden Shocks*, and *Systemic Shock*.

#### 4.1 A 40% systemic shock

Our 25% *Systemic Shock* resulted in a project cost of 143% of our educated baseline. If our systemic shock is 40%, the project cost is 193%. This almost doubling in size is consistent with other projects' reported experience. [21] The project's dynamic pattern of behavior was similar in all respects to the 25% systemic shock. The project smoothly concluded on goal and on time. So the *earned-value metrics work on a project up to the point where a complete re-plan would be necessary.*

#### 4.2 Persistent scope creep

A very common project concern is the well-known *scope creep*. If the scope change is an odd one-time event, then its effect is covered in the analysis (below) of a 25% *sudden* shock to a part of the project. However, sometimes scope creep manifests itself as a *persistent* pressure where every project stakeholder seems to want something extra. How much they get depends on the scope control process of the particular project. Persistent scope creep’s effect on the project is relatively simple: it increases the planned work required to reach the final *Project Goal*.

A plausible industry report estimated that two-year white-collar projects contained, on average, about 33% scope creep. [22] The range for the *annual* shock of scope creep in the educated project is: none, 16.5%, and 33%. (The third value is double the industry estimate.)

Figure 19 clearly shows how the persistent scope creep tilts the project goal line upward at a steady rate throughout the project. The *Scope Creep* numbers, while large, are easy to understand as a persistent change in the project goal. Because the earned value and the actual cost are so closely related, it is no surprise that a 16.5% increase in the project scope results in a 17% increase in the project cost (see Figure 18).

Once again, the earned-value metrics smoothly adjust the project pressure to the systemic shock of the steadily changing target and arrive at the goal on schedule.

**Figure 18. Shocks to the basic educated project**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline Units</th>
<th>Variable Range</th>
<th>Project Baseline Cost</th>
<th>Project Cost as Percent of Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
<td></td>
<td><strong>Low</strong></td>
<td><strong>Mid</strong></td>
<td><strong>High</strong></td>
</tr>
<tr>
<td>Scope Creep</td>
<td>none</td>
<td>none</td>
<td>16%</td>
<td>33%</td>
</tr>
<tr>
<td>Sudden Shocks</td>
<td>none</td>
<td>First 1/3</td>
<td>Second 1/3</td>
<td>Last 1/3</td>
</tr>
<tr>
<td>Systemic Shock</td>
<td>none</td>
<td>0%</td>
<td>25%</td>
<td>40%</td>
</tr>
</tbody>
</table>
4.3 A four-month, 25% sudden shock
What about a shock that is not systemic, that is sudden? What happens when a 25% sudden shock occurs at different times during the project year? "In the first 4 months with start-up going on?" "In the middle 4 months when the project is fully staffed?" "In the last 4 months when the project plan is winding down and the desert of resources looms?" How will the earned-value metrics respond to a sudden shock?

4.3.1 First-third sudden shock
When the 25% sudden shock of unplanned work hits at the beginning, the project behaves for the first four months exactly like the fully shocked project. However, at the end of the fourth month, the staff abruptly recovers its ability to produce planned activity. Productivity goes from 75% to 100%. The needed staff drops precipitously, thanks to the short 2-week delay in de-staffing, and the project again ends a bit ahead of schedule. The 25%-unplanned work has resulted in a project cost of only 117% of the basic educated project because it only lasted 4 months.

4.3.2 Second-third sudden shock
When the 25% sudden shock of unplanned work hits the project in month 5, the amount of planned activity abruptly drops (see Figure 20). The drop in Activity Against Plan increases project pressure and leads to a steady increase in the actual staffing. In 2 months the rate of the project work has recovered. In 4 months the total amount of work has almost recovered. Then the sudden resumption of the planned activity boosts the rate so much that some staff can be promptly laid off (with a 2-week delay). Because of the late mid-project jump in the staff and the work, the project actually concludes a week ahead of schedule. The mid-project 25%-extra work resulted in a total project cost of 117% of the basic educated project (coincidentally, the same as the first-third 25% shock).
4.3.3 Final-third sudden shock
When the 25% sudden shock of unplanned work hits the project just as it is beginning to wind down and conclude, the staff stops declining along the written staff line and stays high to fill in the necessary work (see Figure 21). The Total Activity goes up because of Overtime. The project ends on schedule. The 9-12 month, 25%-extra work has resulted in a project cost of 110% of the basic educated plan. (Cost was only 110% because the workers were all professionals, working at 100% productivity).

The project recovered gracefully using earned-value metrics versus all three 25%-sudden shocks. The projects ended on time, or a little early, with their fully completed scope.

Figure 20. 25% Sudden Shock of unplanned activity in months 5-8 (inclusive)

Figure 21. 25% Sudden Shock unplanned activity in months 9-12 (inclusive)
5.0 CONCLUSION: The challenge of the educated project

The educated project has answered the question posed in the title of this discussion: Corrective staffing can be highly effective in a white-collar project. Yet in the real world, white-collar projects continue to get into trouble much of the time. Why is corrective staffing so unsuccessful in practice?

The two big differences between the white-collar real world and our educated project are: real projects cannot find the skilled staff required to do the work and real projects are not permitted to hire the full staff required to get out of trouble.

In one study of 300 project managers, the top 5 ranked difficulties were:

1. Not enough resources are assigned
2. Inadequately skilled resources are assigned
3. An unrealistic schedule is dictated
4. Senior management fails to establish a clear goal
5. We fail to adequately plan [23]

Number 5 is the only item over which a project manager has full control. Project managers have a responsibility to resist items 1 through 4 but they cannot overcome them on their own. Managers require the support of the larger organization.

One project manager who specializes in bailing out troubled projects confessed his "project turn-around" secret, "When senior management asks me to rescue a project, I make it a condition of my help that they give me the number of people I say I need. The truth is, I usually find that number from a look at the original plan (which senior management had never adequately funded). Most of my projects have been successfully rescued by employing the correctly planned staff." [24]

When a project manager begins with the proper organizational support and constructs an adequate, "educated" plan, the project can expect to apply earned-value metrics to corrective staffing and deliver the original scope on the original schedule for the minimum possible cost.

Notes

1. Some earlier system models with real world examples are featured in Roberts (1964), Powell (1987), Abdel-Hamid (1989), Cooper (1993 and 1994), and Nevison (1994). Cooper's work includes many other applications of a systems model to the "real world."
2. For details on the undiscovered rework cycle see especially Cooper (1993 and 1994). Cooper observes that many of his clients' projects have had late surprises caused by "undiscovered rework" in tasks thought completed. On the other hand, research by Christiansen and others find projects with relatively stable Cost Performance Indexes after the first 20% of the project had unfolded. See Christiansen (1993, 1999, and especially, 1992).
3. Two Nevison articles (Project Management Journal and PMNETwork, June 1994) examine entry-level learning along with the results of a white-collar professional survey on projects.
4. In Cooper (1993 and 1994), earned-value tools are discounted as "looking backwards" and ignoring the many feedback activities in real projects.
5. This paper assumes that a shock to the project can be fixed by adjusting staffing levels. Responding to a shock by adjusting the project's scope is discussed in other sources (Nevison 2014).
6. One study by Nevison (2000) scales common white-collar projects at 8 months, another study averaged 21 months (Nevison, 1992). Jones (1991) and Cooper (2004) refer to projects with durations of well over a year. The 12-month white-collar project size maintains continuity with the project in Nevison, (Project Management Journal, 1994), as well as staying in general agreement with other surveys. This paper’s charts were made with the modeling tool iThink from isee Systems.
7. Nevison (Project Management Journal, June 1994) cited this example of entry-learning cost. The example in this paper is scaled to match the one discussed previously, with an additional 2% added for industry-wide turnover.
8. This white-collar project can be modeled using different units. Assuming an $80,000 annual salary for the average project staff member, the Actual Cost of 22,272 staff-hours could be $928,000. Planned value and earned value can be either 20,110 staff-hours or deliverable units such as 25,000 lines of code. Because staff-hours is the resource every project manager must manage, this discussion uses staff-hours.
9. A staff member or full-time equivalent (FTE) works 160 hours per month (when there is no overtime). This work accumulates in the "to-date" figures of the Planned Value to Date, Actual Cost to Date, and Earned Value to Date.
11. The project size can be expressed in several different units. The middle-sized project is: 12 months of duration, 22,272 staff-hours of work, 139.2 staff-months of work, 14 full-time people at its largest staffing, and, at $80,000 per person, an in-house budget of $928,000. When performed for another business, the same project might be priced between $2.32M and $2.78M to cover the organizational overhead.
12. Up-to-Speed Interval and Time-to-Teach Cost Rate have ranges that come from Nevison (1992). The average Rookie Productivity must be between 50% and 100%. None of the values are particularly surprising: they agree with 25 years of New Leaf client experiences. Any of the ranges could be adjusted to reflect the realities of different business environments.
13. For additional details on how 16 managers rated burnout, see Nevison (1992 and 1997). Other details on overtime can be found at Business Roundtable (1980), Cooper (1994), Department of the Army (1979), Department of Labor, and Jensen, et. al. (1997)
14. One project reported a figure of 40 weeks to find an unplanned-for staff person (see Nevison, 1992).
15. One surprising constant in U.S. white-collar projects is the 2-week removal time. This figure comes from 16 respondents (Nevison, 1992). It has been substantiated in New Leaf client experiences over the past 25 years.
16. To arrive at the 3.05 utility horizon, solve for where the Net Hours Worked equals 0, where the individual begins to be a net contributor to the project. The Net Hours Worked is the integral of the Work Rate.
17. Private communication from a very senior project engineer, Joe Gwinn.
19. See Nevison ("RWI and StSI," June 2003) and Nevison (2013) for a careful discussion of these indexes and their handy uses.
20. For details on the Air Force multiplier, see Fleming (2010); for the StSI see Nevison (2003).
21. See, for example, (Cooper, 2004).
23. When 300 U.S. managers were asked what factors caused problems on their projects, the most common answer was "inadequate resources." (See Taylor, 1998.) In a New Leaf Project Management study, 278 respondents doing project work in ten companies said that only "seldom" was it true that "In our organization we have an adequate number of people to work on our current projects." (See Nevison, 2000).
24. Confidential communication from a New Leaf client.

References


27. Private communications from current practitioner Joe Gwinn.


