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EFFECTIVE CORRECTIVE ACTION: The initial/envelope model for MANAGING PROJECTS

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ABSTRACT

Two of the most important dynamics in planning for projects are the "rookie-professional" up-to-speed delay for new hires, and the "undiscovered-rework" feedback loop. A recent report [Nevison, 2015] used a project model that did not include the undiscovered-rework loop. This report addresses that shortcoming by using a different project model that explicitly includes both the undiscovered-rework feedback loop and the rookie-professional up-to-speed delay. First, the initial system-dynamic model's project plan gets modified to run with a realistic set of fine-tuned parameters and to produce a "best-case" project plan of acceptable scope, schedule, and cost. Then the best-case model's "actual-to-date" staffing pattern becomes the "planned-value-to-date" staffing histogram for an "envelope" earned-value model. The envelope model sets its parameters to the best-case model and then uses system pressures derived from earned-value metrics to "work the plan" two ways:

1. When everything goes according to plan, the envelope model correctly maintains the planned staff and scope to complete the project on time.

2. When extra, unforeseen work is needed, the envelope model detects the need for additional staff or reduced scope and correctly adjusts the project to complete the project on time.

Conclusion: The "envelope" model's earned-value metrics prove completely adequate to manage the project successfully.

Introduction

While small corporate IT and R&D projects are full of unexpected surprises, long-term high-tech projects awarded to private companies by the US state and federal governments are considerably more carefully planned and cautiously executed. Among the measurements required by the federal government are the planned-value-to-date, the actual-to-date, and the earned-value-to-date costs. For most white-collar projects, the major costs are labor costs expressed in staff-hours or staff-months that can be converted to dollars. US federal contracting law requires that these earned-value progress measurements be reported each month and that any change that affects the planned-value-to-date (the project baseline) must be approved by the sponsoring government agency **[1]**.

The systems dynamics community has modeled the changeable, hard-to-plan IT and R&D projects with two major performance dynamics: the undiscovered-rework feedback loop and the rookie-to-professional up-to-speed delay **[2]**.

A recent report demonstrated that a "realistic-case" set of initial assumptions in a system dynamics project plan can be combined with a surrounding "envelope" of traditional earned-value metrics. The "envelope" metrics were able to respond with corrective staffing to the full range of realistic, unforeseen challenges that most large projects encounter **[3]**.

However, that report failed to include an explicit undiscovered-rework feedback loop in the "realistic case" initial model.

The present report addresses that omission by using a *different initial model* of a white-collar project. The new model explicitly includes the undiscovered-rework feedback loop and the "rookie-professional" up-to-speed delay. It was constructed by different author **[4]**. The results show how an earned value "envelope" model can work with a "realistic case" initial systems dynamics model.

Traditional Project

We will begin with a project manager's simple project plan as shown in **Figure 1**. Our traditional manager used tools such as a Work Breakdown Structure, a Network Logic Diagram with a critical path, and carefully delineated task assignments. When our traditional manager was done with his project plan, it called for 4 full-time people working on 100 tasks, each of which was estimated to be about a staff-month of work, with a schedule that stretched over 25 months. The cross training of the staff ensured that everyone could remain productively engaged at all times.

Most Likely Systems Dynamics Project Model

The traditional plan was then expanded by an experienced system dynamics expert to create a realistic project plan that included several familiar dynamics seen in projects and a reasonable initial set of values for the variables. **Figure 2** shows the familiar casual loops of the realistic project plan.

Traditional project plan		
Work to do	100	1-month tasks
Staff (constant)	4	people
Schedule to complete	25	months

FIGURE 1 *Traditional Project Plan*

The model included both a rookie-professional up-to-speed delay, which led to the experience dilution shown in loops R3 and R3A, and an undiscovered-rework feedback loop, which led to compounding errors and additional undiscovered rework (loop R1). The realistic plan also assumed that schedule pressure affected error rate negatively (loop R2) and productivity positively, to the same degree (loop B2A). Additional assumptions in the model included that working overtime led to staff burnout and that slipping the schedule would result in imputed project costs. Specific parameters were as follows: normal error fraction: 15%; time to hire new staff: 4 months; time for rookies to come up to speed: 2.4 months; initial productivity of new staff: 50% of experienced staff; initial error rate of new staff: 200% of experienced staff; and imputed cost of late projects: 10 person-months per month of delay.

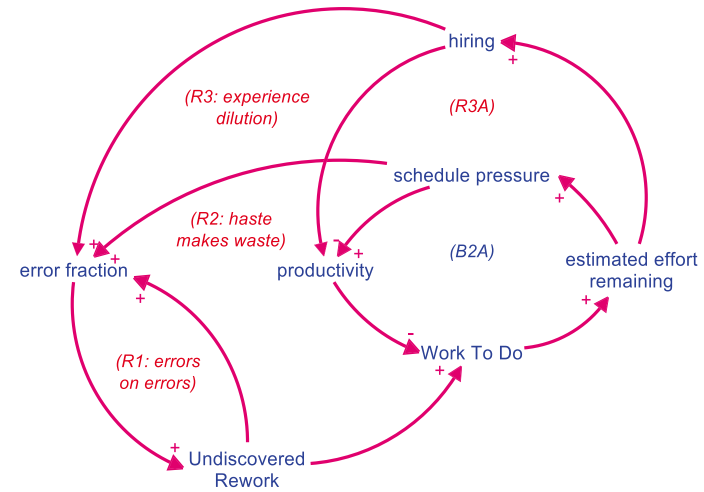

FIGURE 2 . *Causal Loop Diagram of Realistic Project Plan*

Running the initial realistic system dynamics (SD) model helped make decisions for the "most likely" project plan. The system dynamics expert worked with the project team to select the most likely values for variables and the most likely decisions about the dynamics of their particular project. They decided that their most likely project plan would not engage in overtime (not shown) because, in their environment, it led to disruptive burnout. The team also decided that, realistically, schedule pressure could not be avoided when the project fell behind schedule. In this case, schedule pressure isdou-

1. For details on earned-value project management in the real world see Christiansen (1993, 1999, and especially 1992). A complete introduction to the subject is available in Fleming and Koppelman (2010).

2. 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 real world problems.

3. The "envelope" model discussed here was called the "educated" model in the earlier report in Nevison (2015).

4. This model is a simplification of a model presented at a 2007 conference (Chichakly (2007)).

ble-edged sword. It increases productivity, but also increases error fraction to the same extent. However, because of the reinforcing errors on errors feedback (R1 in **Figure 2**), the effect of the increased error fraction is larger than the gain in productivity.

Figure 3 shows how the most likely systems-dynamics model dramatically changed the team's thinking about the traditional project plan. The project cost had risen 78 person-months from 100 to 178, the schedule had extended 6 months from 25 to 31. Clearly, a conference with all the stakeholders was appropriate before proceeding with the plan!

Most-likely system-dynamic (SD) project plan Vary the staffing with 2.4 month up-to-speed time Normal error rate of 0.15 Errors on errors allowed Schedule pressure increases productivity No schedule slip No overtime (so no burnout)		
Work to do 100 tasks	178	person-months
Staff (starting)	4	people (varies)
Schedule to complete	31	months

FIGURE 3 . *Most-Likely Systems Dynamics Project Plan*

The most likely initial plan varied staff as needed to meet more demands for work [See **Fig. 4**].

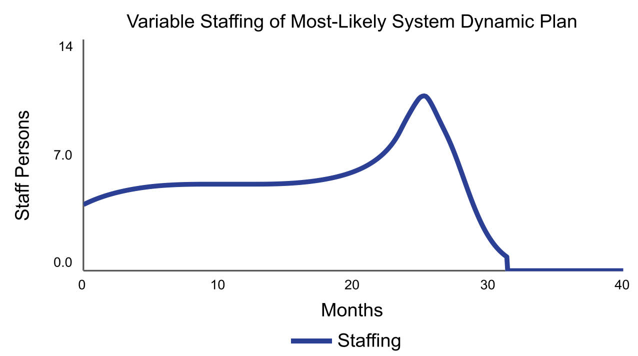

FIGURE 4 . *Variable Staffing of Most-Likely Systems Dynamics Project Plan*

Best Case System Dynamics Initial Project Plan

The system dynamics expert, in consultation with the project manager and the project stakeholders, discussed the dynamic effects of the system's feedback loops on the project's scope, schedule, and cost. The sponsor gave permission to assign one more person to the staff, if necessary, but outlawed the temporary, variable, and disruptive use of outside staff on the project. So the question was, "What did the most likely project look like when staffed with a constant level of 4 (or 5) people?"

4-person most-likely SD plan **Constant staffing of 4** Normal error rate of 0.15 Errors on errors allowed Schedule pressure increases productivity No schedule slip No overtime (so no burnout)		
Work to do 100 tasks	145	person-months
Staff (constant)	4	people
Schedule to complete	36	months

5-person most-likely SD plan **Constant staffing of 5** Normal error rate of 0.15 Errors on errors allowed Schedule pressure increases productivity No schedule slip No overtime (so no burnout)		
Work to do 100 tasks	149	person-months
Staff (constant)	5	people
Schedule to complete	30	months

FIGURE 5 . *4-Person Plan Compared to 5-Person Plan*

Figure 5 compares the project consequences of a 4 or 5 full-time person staff. Five people would be marginally more expensive but could complete the project sooner.

The two plans were similar, but after some discussion the stakeholders agreed on their "best-case" initial project plan that was the slightly more expensive (2.8%), but significantly faster (17%), 5-person plan. The level-staffed, best-case 5-person plan appears in **Figure 6**.

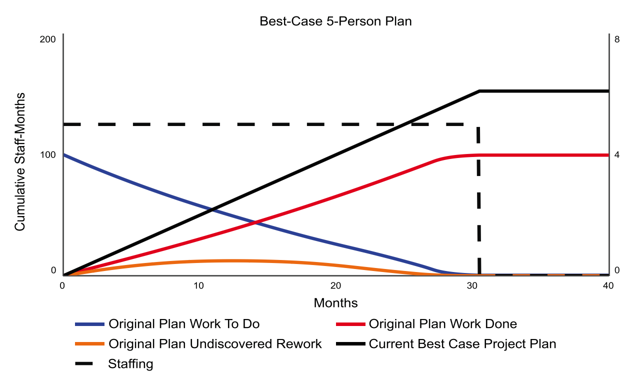

FIGURE 6 . *Variable Staffing of Most-Likely Systems Dynamics Project Plan*

The Best-Case 5-Person Initial Plan has the merit of providing sufficient staffing for the project to proceed smoothly and avoid the necessity of adding additional, unplanned-for staff. The best-case plan allows for enough staff to handle the many anticipated feedback effects, the 15% error rate, the error-on-errors effect, and the schedule pressure effect on productivity and error fraction. The best-case plan will not use overtime to recover schedule and will not include any slipped schedule effects.

The Envelope Plan

The "envelope" model resembles the behavior of large government-sponsored projects subject to federal contracting law. The project is assumed to

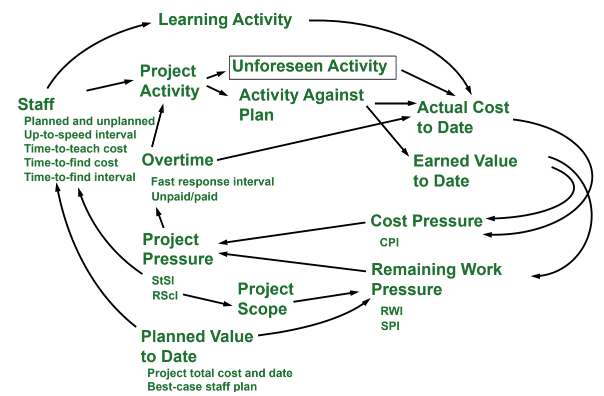

FIGURE 7 . *The Causal Loop Diagram for the Envelope Model*

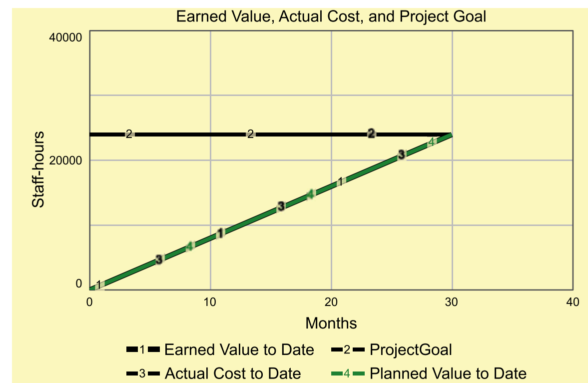

FIGURE 8 *Envelope Model Run With the Project Following the Plan*

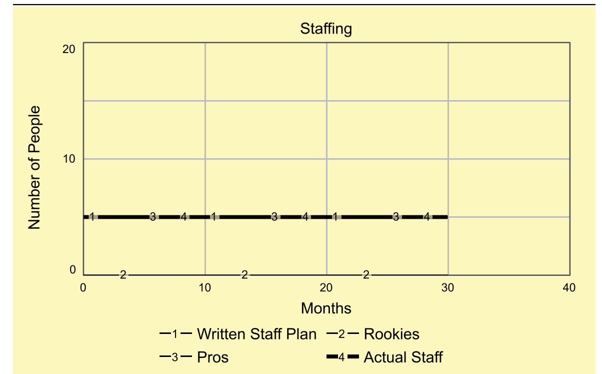

FIGURE 9 *Envelope Model Staffing With the Project Following the Plan*

be well-planned and capable of being continually monitored for performance. The envelope model calculates the standard earned-value ratios of Cost Performance Index (CPI) and Schedule Performance Index (SPI), adds the Remaining Work Index (RWI), and follows that by calculating new systems pressures derived from the Staffing-to-Schedule Index (StSI) and the Reduced Scope Index (RScI) **[5]**. These pressures go through realistic

5. Details on these calculations are in: RWI and StSI, Nevison (2003); RScI, Nevison (2014); derived project pressures, Nevison (2015).
6. Details for several different kinds of unforeseen shocks to the envelope project are in Nevison (2015).
7. 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.

delays and feedback on subsequent performance. **Figure 7** shows the causal loop diagram updated slightly from the Nevison (2015) report.

By using the best-case initial SD model plan's "actual-to-date" results as the "plan-to-date" figures for the envelope model's project plan, the envelope model incorporates all the lessons of the initial model into a smoother performance plan for the larger, envelope model.

Earlier published reports have illustrated how the envelope model plan parameters work together to respond with corrective staffing to projects that have discovered as much as 25% of their work was unforeseen in their best-case initial plan (!). This 25% could be systemic across the whole project or intermittent across one phase of a project, or also scope creep over the life of the project **[6].**

It is no surprise that we expect the envelope model's plan to work well with our 5-person best-case SD Project Plan. The plan has adjusted its schedule to a realistic 30 months with a realistic 150 staff-months of effort that includes all the feedback lessons learned from the professional's dynamic modeling of the project.

The first test of the envelope model is to let the project work the plan and see how the project behaves when all goes according to plan, i.e., when there is absolutely no additional, unforeseen work. **Figure 8** shows the answer in the familiar four lines that appear as two.

As expected, the envelope project's earned-value-to-date follows the planned-value-to date, exceeds the project goal, and stops on the original schedule. The project finishes in 30 months with an actual cost of 23,974 staff-hours. (This is 99.9% of the planned goal of 150 staff-months x 160 staff-hours per staff month and 100% of 23,960 staff-hour goal set in the model).

Because the plan called for a constant staff we observe no effects from any delays in the staffing feedback loops. The actual staffing is a steady, level line [See **Figure 9**].

Envelope Model With Unforeseen Extra Work

What if, even after our efforts to include the dynamic lessons of past projects in our Best-Case 5-Person Plan, unforeseen work still occurs? If that happens the amount of actual work will be more than the planned work, our costs will increase, the pressure to hire additional staff will go up, and the mechanics of hiring will begin to occur with the known organizational delays. Will the response occur in time? Will the project finish on time? How much will the extra people cost? Will the original scope be achieved? **Figure 10** shows what a huge systemic shock of 25% additional unforeseen work does to the project.

The envelope model's staffing has been allowed to vary in order to respond to the unforeseen work. Even with all the delays in the feedback loops of cause and effect, the project adjusts its staffing to complete the project and the extra work on time.

In **Figure 10**, the actual cost of the project is 33,181 staff-hours instead of the original goal of 23,960 staff-hours, a 38.5% increase. The cost increase exceeds the 25% work increase because of the extra costs involved in expanding the staff, such as:

- Working through organizational delays in finding the possible hires,
- Doing the unplanned work to hire additional staff,
- Learning time by the new hires get up-to-speed on the project, and
- Teaching time the professionals spend helping the new hires get up to speed **[7]**.

The extra staffing is shown in **Figure 11**. Because of the necessary increase in staff, we can see how the unplanned-for rookies sign on and, only after they traverse an average 2.4-month up-to-speed delay, do they join the ranks of the "Pros." Also notice that as the project continues, the need for extra staff gradually declines.

Only two of the parameters that led to the 38.5% cost increase were present in the best-case SD model: the time to hire, and the up-to-speed time. The other two parameters, time-to-teach cost rate and the labor-to-find cost, illustrate the imperfect match between the initial SD model and the envelope model. **Figure 12** compares the important variables between the two models.

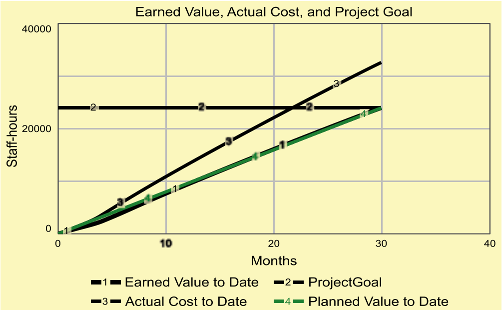

FIGURE 10. *Envelope Model Run Responding to 25% Additional Unforeseen Work: Staffing*

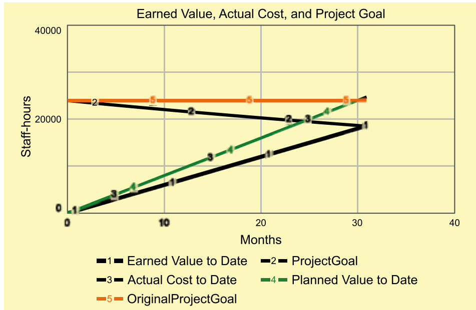

FIGURE 13. *Envelope Model Run Responding to 25% Additional Unforeseen Work: Scope*

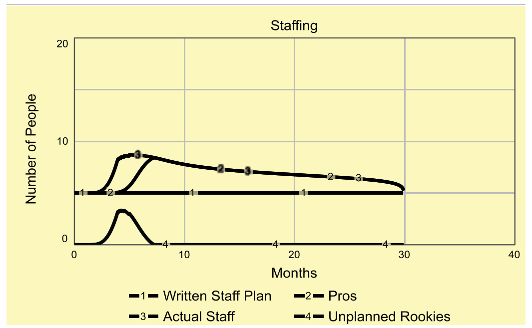

FIGURE 11. *Envelope Model Staffing When the Project Covers an Unforeseen 25% Work Increase*

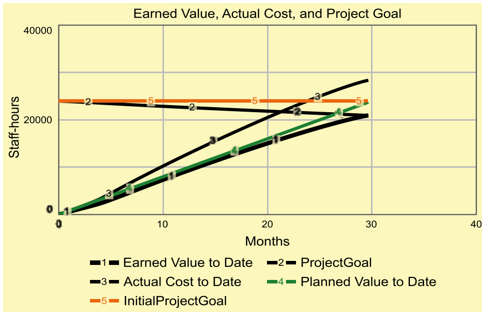

FIGURE 14. *Envelope Model Run Responding to 25% Additional Unforeseen Work: Part Staff Increase, Part Scope Decrease*

Model and Initial Data									
	Best Case Initial System Dynamic Model				**Envelope Earned Value Model**				
Differences marked with ***	**Variable Name**	**Value**	**Units**	**Comments**	**Variable Name**	**Matched Value**	**Value**	**Units**	**Comments**
	Run specs lengeth	40	months		Run specs lengeth		40	months	
	Run specs DT	1/32	time		Run specs DT		1/32	time	
	Integration method	Euler			Integration method		Euler		
	initial scheduled completion date	30	months		Budgeted Duration		30	months	
***	normal error fraction	15%	percent	Leads to rework	Unforseen rework	**25%**	0%	percent	Unforseen work is the result of bad planning or additional erroneous work
***	initial new staff	0	people		Initial rookies		0.001	people	Needs to avoid 0 at start
	initial experienced staff	5	people	Best "remediated" choice	Initial pros		5	people	Best "remediated" choice
***	time to gain experience	2.4	months	Time to become a "pro" (not used in best-case plan)	UpToSpeed Interval	**2.4**	2	months	Time to become a "pro"
***	relative productivity of new staff	50%	percent	Not used in level-staffed plan	Rookie productivity	**50%**	60%	percent	Over the up-to-speed interval
	BLANK		hrs/week	Teaching during up-to-speed interval	Time-to-teach Cost Rate		6	hrs/week	Teaching during up-to-speed interval
	BLANK		units	1.0 is no difference; 1.2 means longer Unplanned uptospeed interval and lower Unplanned Rook Prod.	UnplannedToPlanned Factor		1.0	units	1.0 is no difference; 1.2 means longer Unplanned uptospeed interval and lower Unplanned Rook Prod.
***	average time to hire	4	months	Finding unplanned staff	TimeToFind Interval	**4**	2	months	Finding unplanned staff
	BLANK		stff-hrs	Cost of finding unplanned staff	Labor-to-find Cost		22	stff-hrs	Cost of finding unplanned staff
***	overtime delay	1.00	months	OT begins to happen in a month (not used)	OT Adjustment Interval	**1.00**	0.25	months	OT begins to happen in a week (not used)
	BLANK		units	Unpaid OT is a way to increase productivity	Percent Paid OT		100%	units	Unpaid OT is a way to increase productivity
	BLANK		% people / year	This is industrial turnover (39.2% a year)	Normal TO Rate	0%	39.2	% people / year	This is industrial turnover (39.2% a year)
	Cumulative Person Months (final)	152.5	person-months	Final person-months goes with 100 original tasks and is the goal at planned end date	BudProjectGoal		23,197	stff-hrs	From first run of Planned Value to Date
	Assumed constant staff	5	people	Professionals on the project	Written Staff Plan		5	people	Professionals on the project
	BLANK		people	Professionals on the project early	Leading Staff Plan		5	people	Professionals on the project early
	Cumulative Person Months	Work Done	check	Be sure that work tasks are 100 and = to 152.5 person-months goal at planned end date	Earned Value to Date		BudProject Goal	check	Be sure the two are = to 23,197 at planned end date
***	average time to transfer	1.00	months	Off the project in 4 weeks	SignOutTime	**1.00**	0.50	months	Off the project in 2 weeks

FIGURE 12. *Two Models Variables and Values*

As we can see, in every case where the variables differed in value, the envelope model's plan was adjusted to agree with the best-case SD model plan.

Envelope Model Adjusting Scope

We have already seen in **Figure 11** that the envelope model can correct an error of 25% unforeseen work with additional staff. Whether or not we are permitted to address our project's unforeseen difficulties with additional staff is a difficult question for discussion with our stakeholders. But what if the stakeholders insist that the schedule be met and the original cost be maintained? That is, they insist that no additional project staff be hired? Government projects where the funding comes from Congress sometimes respond this way.

Can the envelope model's project use earned-value measures to achieve the target date by reducing scope? (The original scope of the project can be defined as the staff-hours of the original final goal of the project.) **Figure 13** shows how the envelope model can respond to unforeseen work by reducing the scope (reducing the project goal).

Again, even with all the delays in the feedback loops of cause and effect, the envelope model's project reduces its scope to complete the combined project plus unforeseen work close to the original 30-month schedule (at 32 months, a 6.67% slip) and close to the original 23,960 staff-hours cost (at 24,730 staff-hours, a 3.2% increase). The actual units of the scope are 18,524 staff-hours of scope, a 77.3% reduction from the original goal. (Remember that a 1.25 [5/4] increase in unforeseen work requires a 0.80 [4/5] scope decrease to offset it.) The small errors in cost and schedule performance are attributable to learning costs and the effects of delays in the project's feedback loops.

Stakeholder Choice

The envelope model can also accommodate a stakeholder decision to split the response to unforeseen work between extra staffing and reduced scope. **Figure 14** shows a 25% unforeseen work increase split between the two responses.

The results of the request to split the response to a 25% increase in unforeseen work has the project ending at 30.5 months with 27,765 staff-hours of actual work, or a 15.9% increase over the originally planned 23,960 staff-hours, and 20,209 staff-hours of scope, or a 15.7% decrease to 84.3% of the original project scope.

Our envelope model demonstrates that **earned-value measures can feed earned-value indexes, translate into system pressures, operate with realistic organizational delays, and smoothly address the challenges of unforeseen work.**

Conclusion

Initial system dynamics project models can capture the fine-grained interactions of traditional projects in realistic initial SD plans, which can be combined with envelope models that use earned-value metrics to deal with the large-scale unforeseen changes. These combined project models can provide useful insights to stakeholders and project leaders as they negotiate how best to balance a project's scope, schedule, and cost.

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