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ACQUISITION RESEARCH PROGRAM SPONSORED REPORT SERIES

**Assessing the Manning Options' Impacts on Effectiveness and
Efficiency of Technology Security and Foreign Disclosure
Processes**

31 October 2016

Dr. Johnathan Mun, Professor of Research, Information Science

Graduate School of Business & Public Policy

Naval Postgraduate School

Approved for public release; distribution is unlimited.

Prepared for the Naval Postgraduate School, Monterey, CA 93943.



ACQUISITION RESEARCH PROGRAM
GRADUATE SCHOOL OF BUSINESS & PUBLIC POLICY
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Abstract

The U.S. Navy International Programs Office (NIPO) has an imminent full-time equivalence reduction from 44 to 36 personnel within the next fiscal year. As such, NIPO requires a manning options study on effectiveness and efficiency of its Technology Security and Foreign Disclosure decision process within the U.S. Navy. The concern is what the imminent impact on schedule delays of future NIPO production may be on such a reduction. The objectives and desired outcomes of the current research are to address and answer the following:

- What is the current NIPO process for dealing with various product lines?
- In the current NIPO processes, what are the schedule-cost risks and impacts?
- What are the schedule and cost impacts of the imminent reduced manning?
- Would a change in organizational structure or processes assist or deter efficiency and cost effectiveness at NIPO?



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List of Acronyms

CDF	Cumulative Distribution Function
CNO	Chief of Naval Operations
DOD	Department of Defense
ENDP	Exceptions to National Disclosure Policy
FTE	Full-Time Equivalence
IRM	Integrated Risk Management
ITAR	International Traffic In-Arms Regulations
NDP	National Disclosure Policy
NIPO	Navy International Programs Office
PDF	Probability Density Function
PEAT	Project Economics Analysis Tool
ROA	Record of Action
ROV	Real Options Valuation, Inc.
SME	Subject Matter Expert
TS&CPD	Technology Security and Cooperative Programs Directorate
TS&FD	Technology Security and Foreign Disclosure



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Introduction

The Navy International Programs Office (NIPO) manages and implements International Security Assistance programs (transfers military articles and services to U.S. allies and partners), Cooperative Development programs (negotiates, concludes, and implements international research, development, and acquisition agreements), and Technology Security policy (establishes policies and positions on the release of classified and controlled unclassified information). As a reporting unit to the Assistant Secretary of the Navy for Research, Development, and Acquisition, NIPO supports Regional Combatant Commanders' and the U.S. Navy leadership's efforts in building vigorous relationships with U.S. maritime security partners around the world. NIPO teams with a wide network of U.S. defense industry and security community product and service providers, program managers, policy makers, and technical and regulatory agencies to support the defense requirements of U.S. our friends, allies, and coalition partners.

Recently, NIPO's Technology Security and Cooperative Programs Directorate (TS&CPD) has an imminent full-time equivalence (FTE) reduction from 44 to 36 personnel within the next fiscal year (NIPO FY16 Objective 5.7). As such, TS&CPD requires a manning options study on effectiveness and efficiency of its Technology Security and Foreign Disclosure (TS&FD) decision process within the U.S. Navy. The concern is what the imminent impact on schedule delays of future NIPO production may be on such a reduction.

Predictive Modeling of Waiting Time

Using quantitative prediction modeling with Monte Carlo Risk Simulation of future states of nature and the TS&CPD's existing workload, segregated by project complexity and skillset, it is possible to model schedule and cost risks of requests from industry or foreign governments against service completion rates or average time to complete a request. Using risk simulations, we then obtain anticipated waiting time, probability, and amount of delays in days, as well as length of time a request will be in the system.



By mapping out the time-schedule effects and time-to-completion of certain tasks within the TS&FD process, we may be able to pinpoint bottlenecks and rubbernecks in the system, propose alternative strategies or options to mitigate these bottlenecks, and identify the effects on efficiency should these critical paths be removed. The process map was segregated based on complexity and product types. The analysis will provide better insights into the tangible effects, such as time delays, of reducing the FTEs going forward with the existing organizational structure. The results may also present opportunities for additional follow-on analysis with respect to the effects of different organizational structures.

Analysis of Alternatives with Respect to Organizational Structure

Based on historical knowledge and data, we will attempt to forecast and model the levels of efficiency and effectiveness of execution, in terms of certain productivity metrics (e.g., wait time, service completion times, delays, cost to complete, or other relevant metrics), of the TS&FD functions even if operating at a reduced manning level under various organizational structures that the TS&CPD identified as potential for execution.

The potential organizational structure changes may include combining the two divisions into one (i.e., combining policy creation/writing and policy interpretation/execution), cross-training existing and future FTEs to enable them to multitask in different groups, leveraging technology to enhance efficiency, shifting workloads to focus on policy creation in anticipation of future events and needs to minimize rework, and so forth. If such activities can be implemented in phases, we can further analyze their change in efficiency as related to the TS&FD process (i.e., looking at statistical significance in efficiency differences of before and after effects). For each alternative identified by the TS&CPD, we can perform qualitative risk assessments with the help of subject matter experts (SMEs) as well as employ quantitative rigor in applying risk modeling methods (e.g., running millions of Monte Carlo simulation trials on waiting time models and productivity impact models to determine the effects on delays and wait times for incoming requests under each alternative structure).



Research Objectives and Desired Outcomes

The objectives and desired outcomes of the current research are to address and answer the following:

- What is the current NIPO process for dealing with various product lines?
- In the current NIPO processes, what are the schedule-cost risks and impacts?
- How long does it take, and how much does it cost to complete a specific type of request?
- What are the schedule and cost impacts of the imminent reduced manning?
- Would a change in organizational structure or processes assist or deter efficiency and cost effectiveness at NIPO?

Research Steps

The proposed research will use the following steps.

Literature Survey

A review of the existing literature in terms of process mapping and project schedule risk analysis within the U.S. Navy as well as in other private industry applications will be presented.

Recommended Methodology Overview

The recommended decision framework will be briefly explained. This framework will structure NIPO's current processes for various licensing products and models the cost and schedule impacts.

NIPO Process Mapping

Next, the NIPO licensing process will be mapped and modeled according to the following steps:

Step 1: Process Mapping

Step 2: SME Data Gathering (Schedule and Cost)

Step 3: Sensitivity Analysis



Step 4: Monte Carlo Risk Simulation

Step 5: Results Analysis

Step 6: Conclusions

Conclusions and Recommendations

This final section will detail our conclusions and recommendations going forward with regards to the proposed analytical process, data requirements, analyst/engineer training, and modeling tools.



Literature Survey

Using Monte Carlo Simulation methods for cost and schedule estimation and risk modeling is nothing new in the U.S. Navy. In fact, the *Joint Agency Cost Schedule Risk and Uncertainty Handbook* (Cost Assessment Data Enterprise [CADE], 2014) defines “processes and procedures for performing cost and schedule risk analysis” using uncertainty analysis in support of life-cycle cost estimates for major acquisition programs.

The U.S. Navy Center for Earned Value Management (CEVM; Navy CEVM, 2013) proposed using Monte Carlo Risk Simulation to determine the probability of completion for desired schedule risk analysis (SRA) target milestones by desired dates. Individual estimate ranges were required for each:

critical, near critical, and high risk tasks. These estimates should be developed by the responsible Control Account Manager (CAM) or technical lead. Results of the simulation may either be used to prompt changes in the schedule or to revise expectations and/or contract terms.

Using these methods, Monte Carlo Simulation

predicts the completion date of a target milestone by randomly assigning a duration for each task in the schedule from within that task’s predicted range of best, worst, and most likely outcomes. It can iteratively perform this action thousands of times in quick succession and tally the frequency with which each potential completion date is encountered, thereby producing a likelihood of completion for each date. The more iterations that are run, the more statistically significant the result.

Accurate Best, Worst, and Most Likely estimates are obviously vital to the accuracy and usefulness of SRA, as will be used and performed in the current research.

There are various techniques for developing task duration estimates, but they must be “developed with participation from CAMs and technical leads”. In our current research, we will be using subject matter experts (SMEs) within NIPO to help determine these critical input assumptions. Individual estimates must be considered and

carefully crafted for the riskiest tasks. Less risky tasking may be more globally assessed. For example, consider a 20-day task that is among a group of less



risky tasks that are assessed with a 10% band. It would have a best case duration of 18 days, expected duration of 20 days, and worst case duration of 22 days. (Navy CEVM, 2013)

In our current research, we will run tornado and dynamic sensitivity analyses to determine these critical success factors and main drivers, such that their estimates can be further refined to obtain better, more accurate, and more reliable results. According to Navy CEVM (2013), the results of the simulation should be used to “make changes to the schedule that increase the probability of on-time completion”

In the *GAO Schedule Assessment Guide: Best Practices for Project Schedules*, the Government Accountability Office (GAO; 2012) argues for proper schedule and cost modeling and states that

schedule variances are usually followed by cost variances. Because some program costs such as labor, supervision, rented equipment, and facilities cost more if the program takes longer, a reliable schedule can contribute to an understanding of the cost impact if the program does not finish on time. In addition, management tends to respond to schedule delays by adding more resources or authorizing overtime. Further, a schedule risk analysis allows for program management to account for the cost effects of schedule slippage when developing the life-cycle cost estimate. A cost estimate cannot be considered credible if it does not account for the cost effects of schedule slippage.

According to *Schedule Risk Assessment and Analysis* (Stumpo, 2015), the evolution of

CPM [critical path method] as it is known today had its origin in two parallel efforts in project management. In one case, the U.S. Navy was instrumental in developing a method referred to as Project Evaluation and Review Technique (PERT) to help them control cost and coordinate their contracts. PERT is an event-based system that involves a probabilistic approach to time. Although PERT is now antiquated, some aspects of it are being used to provide risk assessments and probability analysis of a project's life cycle as it pertains to probability forecasting. Monte Carlo Simulation will provide a series of probabilities of when an objective can be expected to occur based on the inherent risk associated within the deterministic model.



In *Developing a Methodology for Risk-Informed Trade-Space Analysis in Acquisition*, the RAND Corporation evaluates Cost, Schedule, and Performance Risk Methodologies within the U.S. Army (Bond, Mayer, McMahon, & Kallimani, 2015). According to the authors, the

risk of a program going over budget (i.e., cost risk), going over schedule (i.e., schedule risk), and not performing to a set of originally designated physical characteristics (i.e., performance risk) are three major concerns for any acquisition program. The Army has existing methodologies for calculating such risks with the intention of trying to predict and mitigate them. Three Army organizations perform analyses to calculate different aspects of the cost, schedule, and performance risks of a program under the Army's consideration

In *Schedule Risk Assessment* (Bounds, 2014), the author uses historical data in conjunction with SME-provided information to estimate the probability distribution related to system outcomes through Monte Carlo simulations. These distributions are used to calculate the (discrete) probabilities associated with completion of acquisition phases. Outputs include the cumulative probability distributions associated with completion as a function of time for each phase (Bounds, 2014).

The development of quantitative cost and the schedule risk analysis process describes a quantitative probabilistic risk analysis process able to reveal how one or more cost and/or schedule risks, mapped to any or all linked tasks of a complex integrated master project schedule network, impact a project or program described by the schedule. Technical and programmatic risks are formulated in terms of the salient features that can possibly go wrong and expressed as probabilistic distributions representing the likelihood of occurrence and impact of cost and time (Moses & Hooker, 2005). The authors have successfully used probability methods for NASA projects, as well as the U.S. Navy and the National Reconnaissance Office. From its earliest application to now, this risk analysis process is constantly being refined and improved in parallel.

According to "Project Management under Uncertainty" (Strategy at Risk, 2014), during the project planning phase, a project is broken into tasks that must be



accomplished for the project to be finished. The objectives of the project scheduling are to determine the earliest start and finish of each task in the project. The aim is to be able to complete the project as early as possible and to calculate the likelihood that the project will be completed within a certain time frame. Using Monte Carlo simulation, the two most important questions that can be answered are how long will it take to do the project and how likely is the project to succeed within the allotted time frame?

In *Quantitative Risk Analysis for Project Management: A Critical Review* (Galway, 2004), the author states that the initial deterministic nature of CPM seems not to have been considered a drawback to its users. However, the increasing amount of computing power available led naturally to the inclusion of probability distributions for task durations in CPM. While the analytic simplicity of PERT was lost, rapidly increasing computer power allowed straightforward Monte Carlo simulation to be substituted for the PERT assumptions. The addition of stochastic task durations implies that tasks, in turn, are on the critical path with some probability, also estimated using the Monte Carlo results. With this development, the integral resource allocation enhancements apparently have been largely lost, at least in mainstream practice. Stochastic CPM is now the preferred methodology for assessing schedule risk in project management (Galway, 2004).

In *Schedule Risk Analysis* (Hulett, 2015), the author describes the U.S. Air Force's approach to schedule risk. A most probable schedule (MPS) will be prepared by assessing the durations presented in the offeror's MPS (this means estimating the longest, the shortest, and the most likely duration for each task, activity, event, and milestone) and preparing a network-based Monte Carlo simulation in order to determine a schedule that has a 90% probable completion date. Again, this approach at the Air Force falls in line with the same methodology we describe and prescribe in this current research at NIPO.

In *Schedule Risk Analysis: Why It Is Important and How to Do It* (Book, 2002), the author suggests that the ability to accurately define the duration of a sequence of tasks is challenged by uncertainties similar to those encountered in building an



estimate of a program's future cost, namely, the impact of technical adversity, resource constraints, and programmatic obstacles. Schedule risk analysis is the process of associating a degree of confidence with each schedule-duration estimate. A schedule risk analysis is really a computer simulation of project duration (Book, 2002).

Real Options for Project Schedules (ROPS) is another proposed alternative approach, which has three recursive sampling/optimization shells. An outer adaptive simulated annealing optimization shell optimizes parameters of strategic plans containing multiple projects containing ordered tasks. A middle shell samples probability distributions of durations of tasks. An inner shell samples probability distributions of costs of tasks (Ingber, 2007).

In a research project conducted at the Naval Postgraduate School, cost-constrained project scheduling with task durations and costs in the U.S. Army Future Combat Systems (FCS) was modeled (Grose, 2004). Long-term project schedules subject to annual budget constraints were simulated and optimized. The U.S. Army Future Combat Systems (FCS) is used for illustration. FCS is a suite of information technologies, sensors, and command systems with an estimated acquisition cost of over \$90 billion. The U.S. General Accounting Office found that FCS is at risk of substantial cost overrun and delay. In the proposed research, we analyze three schedule plans for FCS to identify that which can be expected to deliver the earliest completion time and the least cost.

In the *Department of Defense Risk, Issue, and Opportunity Management Guide for Defense Acquisition Programs* handbook (Office of the Deputy Assistant Secretary of Defense for Systems Engineering [ODASD(SE)], 2015), Schedule Risk Analysis (SRA) is described. The SRA uses task duration uncertainties and program risks affecting schedule execution in combination with a statistical simulation technique (most often the Monte Carlo method) to analyze the level of confidence in meeting selected program dates. Assuming a satisfactory analysis, a probability distribution is established for the duration of each task containing schedule estimating uncertainty and/or various forms of risk. The type of distribution selected



and its corresponding characteristics may vary within the schedule. Probability distributions are developed for the remaining durations of all tasks/activities consistent with the authorized work. The results of an SRA are typically displayed as a histogram (an approximation to a probability density function) providing the frequency of schedule outcomes (dates) and an S-Curve (a cumulative distribution function) providing the cumulative probability of achieving dates associated with given milestones or overall program completion. Other types of outputs include descriptive statistics, a probabilistic critical path, and a probabilistic sensitivity analysis. All of these results should be evaluated for indicators of schedule risk.

In “Stochastic Resource-Constrained Project Scheduling and its Military Applications” (Li & Womer, 2011), the researchers aimed at developing computationally tractable algorithms to obtain near-optimal closed-loop policy for the stochastic resource-constrained project scheduling problem (SRCPS). It has a wide range of military applications, such as mission planning, path planning, and logistics network configuration (Li & Womer, 2011).

In “Probability of Project Completion Using Stochastic Project Scheduling Simulation” (Lee, 2005), project scheduling and simulation were developed to measure the probability to complete a project within a certain time. To deliver a project by a completion date committed to in a contract, a number of activities need to be carried out. The time that an entire project takes to complete and the activities that determine total project duration are always questionable because of the randomness and stochastic nature of the activities’ durations. Predicting a project completion probability is valuable, particularly at the time of bidding. The method calculates the stochastic probability to complete the project in the specified time and can be used to (i) predict the probability to deliver the project in a given time frame and (ii) assess its capabilities to meet the contractual requirement before bidding. The method can also be used by a construction owner to quantify and analyze the risks involved in the schedule. The benefits of the tool to researchers are (1) to solve program evaluation and review technique problems and (2) to complement Monte Carlo simulation by applying the concept of project network modeling and scheduling with probabilistic and stochastic activities (Lee, 2005).



In *Automated Statistical Analysis in Stochastic Project Scheduling Simulation* (Lee & Arditi, 2006), the authors describe a stochastic simulation-based scheduling system that integrates the deterministic critical path method (CPM), the probabilistic program evaluation and review technique (PERT), and the stochastic discrete event simulation (DES) approaches into a single system and lets the scheduler make an informed decision as to which method is better suited to the company's risk-taking culture.

In the *NASA Cost Estimating Handbook* (National Aeronautics and Space Administration [NASA], 2015), the fundamental relationship between project schedule behavior and project cost behavior is explained. Understanding this relationship is essential to the cost estimator. While this cost and schedule relationship seems intuitive to those in project management, it is often difficult for an estimator to quantify or model for the purposes of analysis. To complicate matters further, there is a distinction between the relationship of cost and schedule and the correlation between cost growth and schedule growth. The former (relationship of cost and schedule) is not always obvious, whereas the latter (correlation of cost growth and schedule growth) is mostly self-evident. For example, it is widely observed in a multitude of programs and projects that schedule growth usually leads to cost growth. In addition, the integrated master schedule needs to correspond to cost estimates to ensure that enough resources can be applied to activities to complete them within the expected duration. This should be done before the project schedule is finalized so that the relation between accurate cost and schedule estimates can be verified. Parametric, analogy, and bottom-up estimating methodologies used in cost estimating are also applicable to schedule estimating. Estimating methods for the schedule can be built using historical datasets, comparison to analogy, or detailed grassroots analysis. Estimating schedule durations can be extremely useful at both a high summary level or at the low activity level. The development of SERs, models, and logically linked schedules is a key component of schedule estimating. The level of detail selected will influence all of these key components. The selection of the schedule estimation method is tied to



the relationship between cost and data availability, estimate purpose, data maturity, and program maturity levels.

In *Technology Readiness Level, Schedule Risk and Slippage in Spacecraft Design: Data Analysis and Modeling* (Dubos, Saleh, & Braun, 2007), data from past space programs and the relationship between technology uncertainty and schedule risk in the acquisition of space systems were analyzed. Based on their findings, the authors recommend that the industry adopts and develops schedule risk distribution curves instead of single schedule point estimates, that these schedule risk curves be made available to policy and decision makers in acquisition programs, and that adequate schedule margins be defined according to an agreed upon and acceptable schedule risk level (Dubos et al., 2007).

In “Testing the Validity of Project Schedule Assumptions” (Kennedy, Sherwood, & Droste, 2010), the authors state that understanding the dynamics of project planning will help managers assess the schedule risks of projects, and Monte Carlo simulation was used in the analysis.

In “A Risk-Based Project Schedule Estimation Method to Improve Project Reliability” (Mansoorzadeh, Yusof, Zeynal, & Mansoorzadeh, 2012), the researchers proposed a reliable project scheduling approach that integrates the risk management and critical chain schedule analyses. The project total time was quantified and Monte Carlo simulated as an effective technique in uncertain conditions due to its capability of converting uncertainty to risk judgmentally in projects (Mansoorzadeh et al., 2012).



Recommended Methodology Overview: Dynamic Project Management With Cost and Schedule Risk

In the world of project management, there are essentially two major sources of risks: schedule risk and cost risk. In other words, will the project be on time and under budget, or will there be a schedule crash and budget overrun, and, if so, how bad can they be? To illustrate how quantitative risk management can be applied to project management, we use Real Options Valuation's Project Economics Analysis Tool (ROV PEAT; available from Real Options Valuation, Inc. at www.realoptionsvaluation.com) to model these two sources of risks.

To follow along, start the PEAT software, select the *Project Management—Dynamic Cost and Schedule Risk* module, and *Load Example*. We begin by illustrating a simple linear path project in the *Simple Linear Path 1* tab (see Figure 1). Note that users can click on the *Projects* menu to add projects, or delete, rearrange, and rename existing projects. The example loaded has five sample predefined projects. In this simple linear path project, there are 11 sample tasks, and each task is linked to its subsequent tasks linearly (i.e., Task 2 can only start after Task 1 is done, and so forth). For each project, a user has a set of controls and inputs:

- *Sequential Path versus Complex Network Path*. The first example illustrated uses the sequential path, which means there is a simple linear progression of tasks. In the next example, we will explore the complex network path where tasks can be executed linearly, simultaneously, and recombined at any point in time.
- *Fixed Costs*. The fixed costs and their ranges suitable for risk simulation (minimum, most likely, maximum) are required inputs. These fixed costs are costs that will be incurred regardless of there being an overrun in schedule (the project can be completed early or late, but the fixed costs will be the same regardless).
- *Time Schedule*. This refers to a period-specific time schedule (minimum, most likely, maximum) in days, weeks, or months. Users will first select the periodicity (e.g., days, weeks, months, or unitless) from the droplist and enter the projected time schedule per task. This schedule will be used in conjunction with the variable cost elements (see next bullet item), and will only be available if *Include Schedule-Based Cost Analysis* is checked.



- *Variable Cost.* This is the variable cost that is incurred based on the time schedule for each task. This variable cost is per period and will be multiplied by the number of periods to obtain the total variable cost for each task. The sum of all fixed costs and variable costs for all tasks will, of course, be the total cost for the project (denoted as *Project Total Cost*).
- *Overrun Assumption.* This is a percent budget buffer or cushion to include in each task. This column is only available and used if the *Include Budget Overruns and Buffers* checkbox is selected.
- *Probability of Success.* This allows users to enter the probability of each task being successful. If a task fails, then all subsequent tasks will be canceled and the costs will not be incurred, as the project stops and is abandoned. This column is available and will be used in the risk simulation only if the *Include Probabilities of Success* checkbox is selected.
- *Run.* The Run button will perform the relevant computations based on the settings and inputs, and also run risk simulations if the *Perform Risk Simulation* checkbox is selected (and if the requisite simulation settings, such as distribution type, number of trials, and seed value settings, are entered appropriately). This will run the current project's model. If multiple projects need to be run, users can first proceed to the *Portfolio Analysis* tab and click on the *Run All Projects* button instead.

To see which of these input assumptions drive total cost and schedule the most, a tornado analysis can be executed (see Figure 2). The model can then be risk simulated, and the results will show probability distributions of cost and schedule (see Figure 3). For instance, the sample results show that for Project 1, there is a 95% probability that the project can be completed at a cost of \$398,594. The expected median or most likely value was originally \$377,408 (Figure 1). With simulation, it shows that to be 95% sure that there are sufficient funds to complete the project, an additional buffer of \$21,186 is warranted.



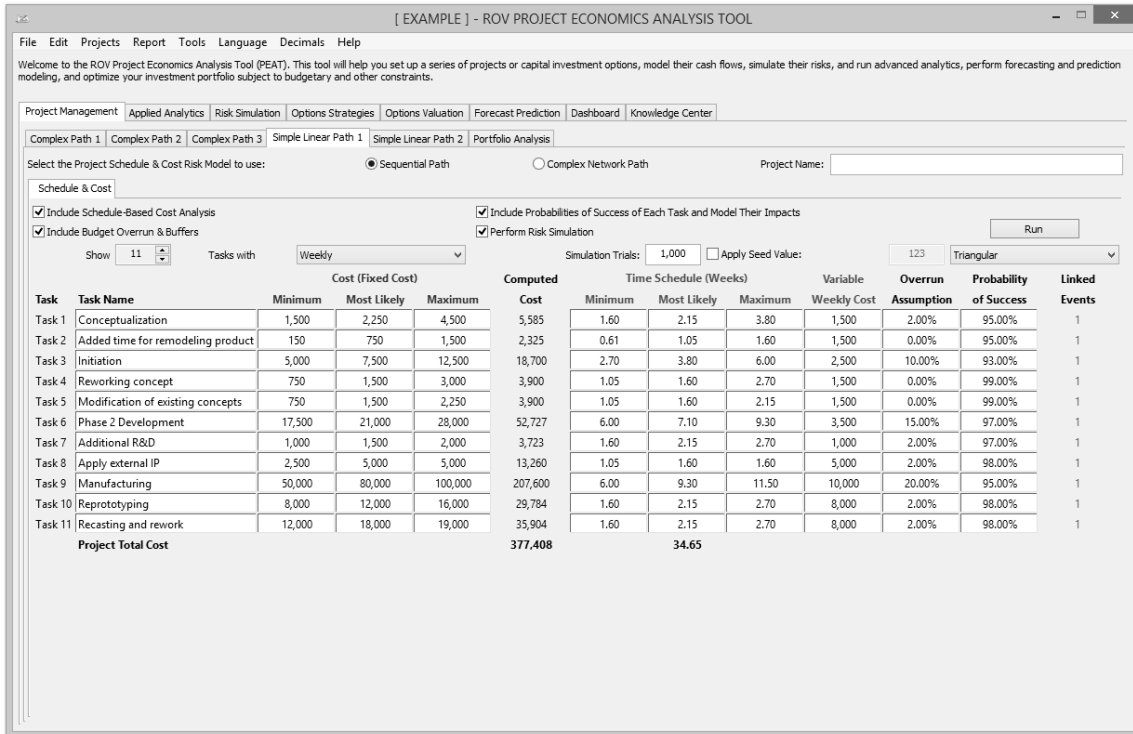


Figure 1: Simple Linear Path Project Management with Cost and Schedule Risk

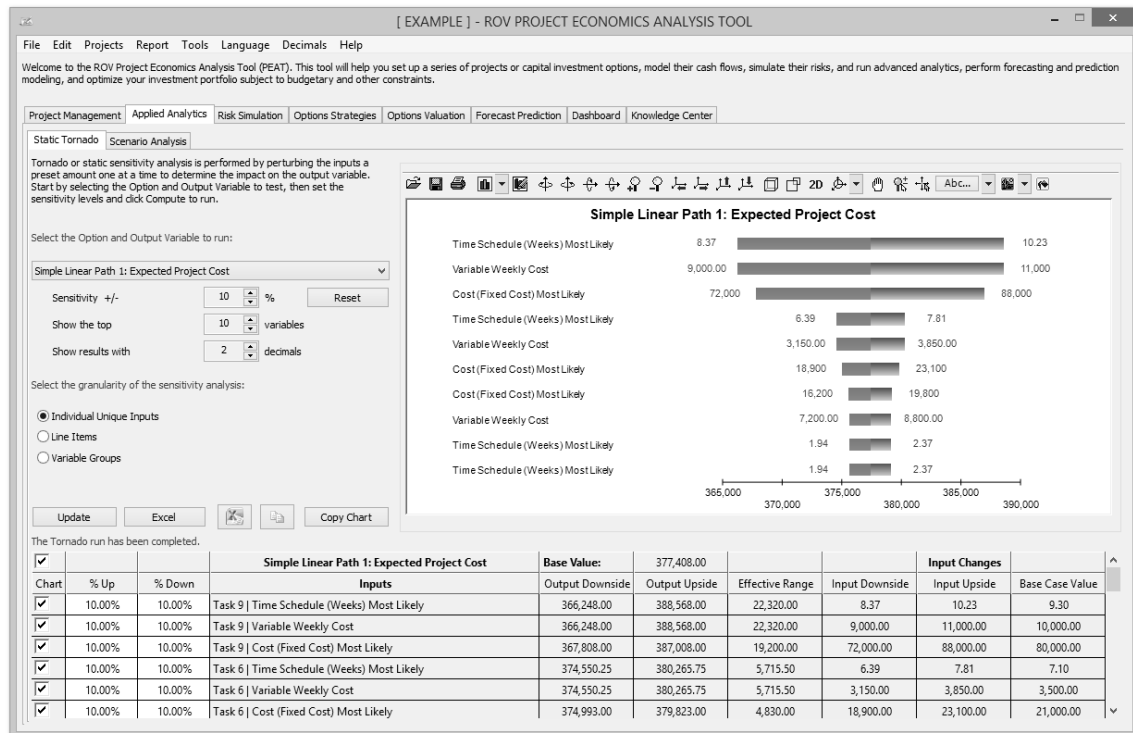


Figure 2: Simple Linear Path Tornado Analysis



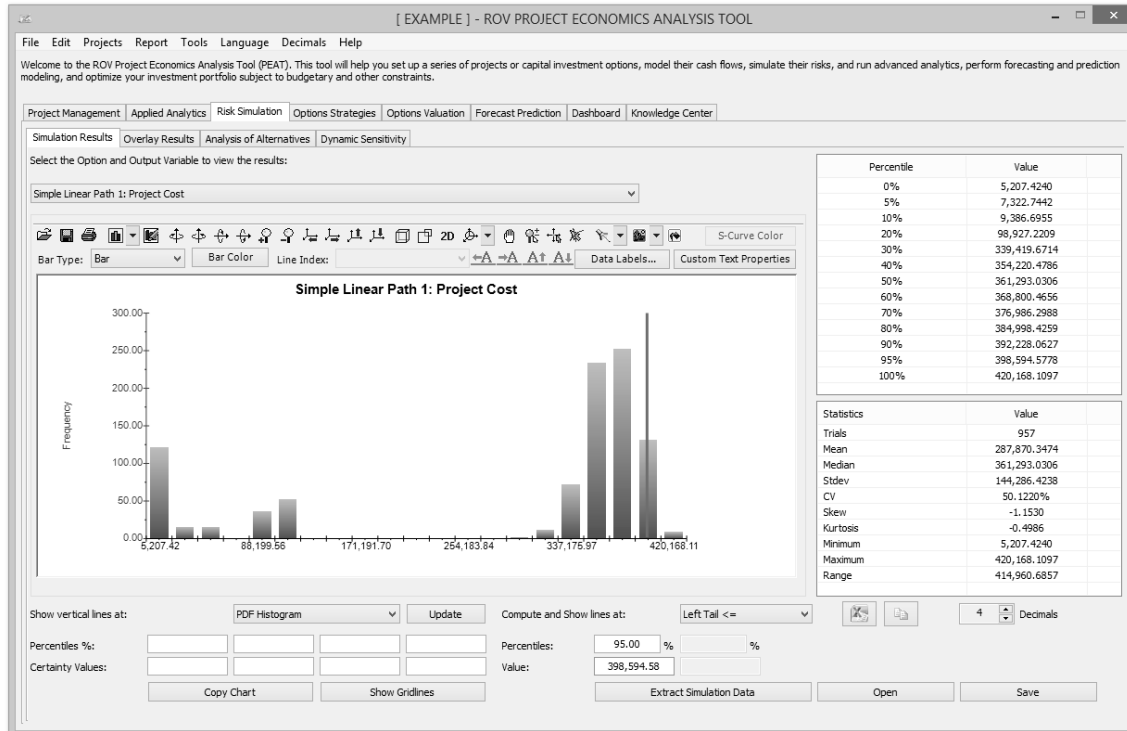


Figure 3: Monte Carlo Risk Simulated Results for Risky Cost and Schedule Values

In complex projects where there are nonlinear bifurcating and recombining paths (see Figure 4), the cost and schedule risks are more difficult to model and compute. For instance, in the *Complex Path 1* tab, we can see that after Task 1, future tasks can be run in parallel (Tasks 2, 3, and 4). Then, Tasks 3 and 4 recombine into Task 8. Such complex path models can be created by the user simply by adding tasks and combining them in the visual map as shown. The software will automatically create the analytical financial model when *Create Model* is clicked. That is, you will be taken to the *Schedule & Cost* tab, and the same setup as shown previously is now available for data entry for this complex model (see Figure 5). The complex mathematical connections will automatically be created behind the scenes to run the calculations so that the user will only need to perform very simple tasks of drawing the complex network path connections. Following are some tips on getting started:

- Start by adding a new project from the *Projects* menu. Then, click on the *Complex Network Path* radio selection to access the *Network Diagram* tab.



- Use the icons to assist in drawing your network path. Hover your mouse over the icons to see their descriptions. You can start by clicking on the third icon to *Create a Task*, and then click anywhere in the drawing canvas to insert said task.
- With an existing task clicked on and selected, click on the fourth icon to *Add a Subtask*. This will automatically create the adjoining next task and next task number. You then need to move this newly inserted task to its new position. Continue with this process as required to create your network diagram. You can create multiple subtasks off a single existing task if simultaneous implementations occur.
- You can also recombine different tasks by clicking on one task, then holding down the Ctrl key and clicking on the second task you wish to join. Then click on the fifth icon to *Link Tasks* to join them. Similarly, you can click on the sixth icon to *Delete Link* between any two tasks.
- When the network diagram is complete, click on *Create Model* to generate the computational algorithms where you can then enter the requisite data in the *Schedule & Cost* tab as described previously.

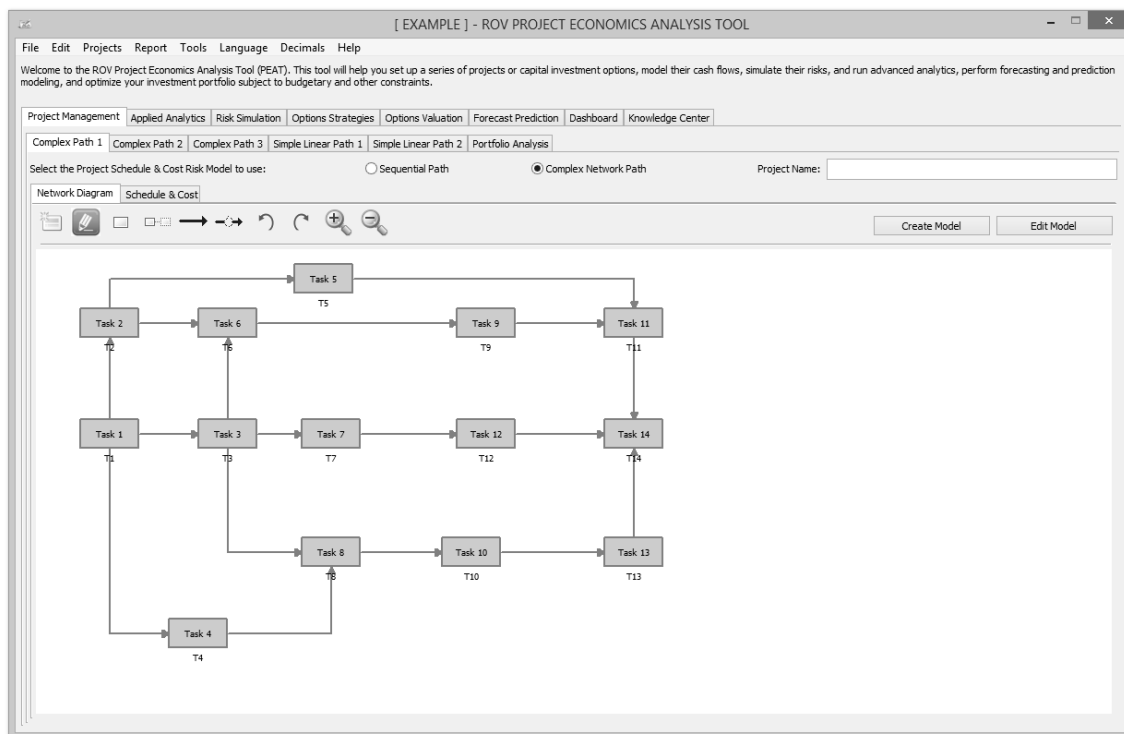


Figure 4: Complex Path Project Management

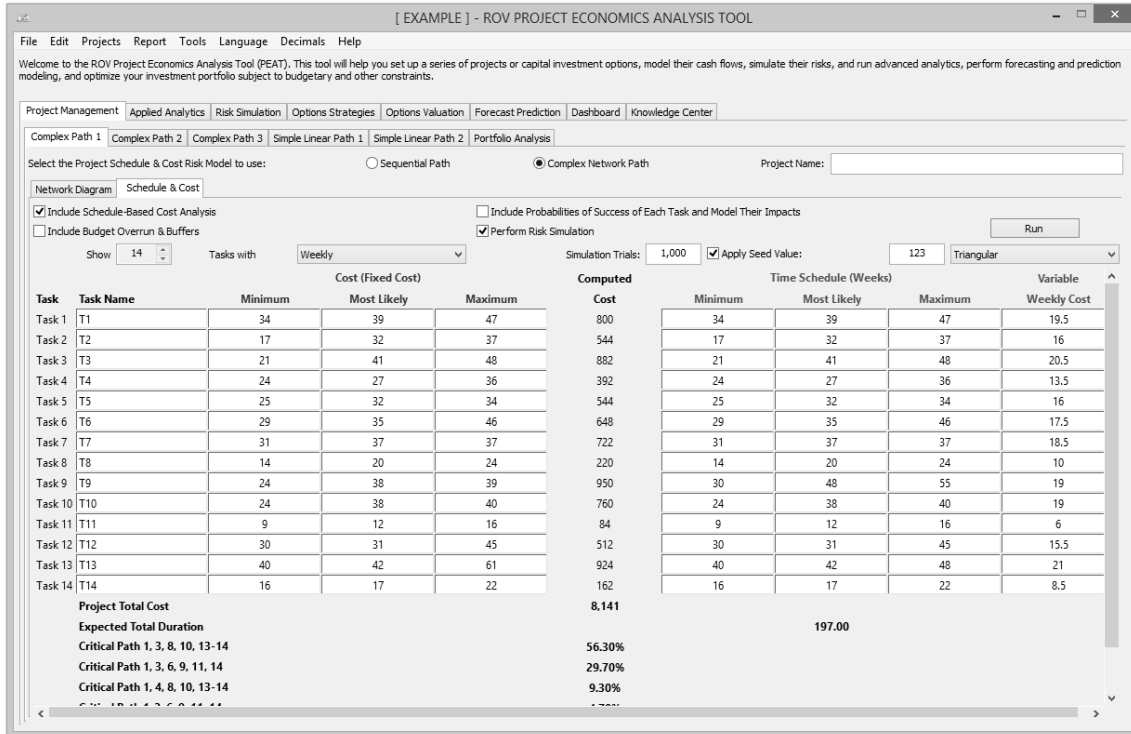


Figure 5: Complex Project Simulated Cost and Duration Model with Critical Path

After running the model, the complex path map shows the highlighted critical path (see Figure 6) of the project, that is, the path that has the highest potential for bottlenecks and delays in completing the project on time. The exact path specifications and probabilities of being on the critical path are seen in Figure 5 (e.g., there is a 56.30% probability that the critical path will be along Tasks 1, 3, 8, 10, 13, and 14).

If there are multiple projects or potential project path implementations, the portfolio view (see Figure 7) compares all projects and implementation paths for the user to make a better and more informed risk-based decision. The simulated distributions can also be overlaid (see Figure 8) for comparison.

Figure 7 allows users to see all projects that were modeled at a glance. Each project modeled can actually be different projects or the same project modeled under different assumptions and implementation options (i.e., different ways of executing the project) to see which project or implementation option path makes more sense in terms of cost and schedule risks. When selected, the *Analysis of*



Alternatives radio allows users to see each project as a stand-alone (as compared to *Incremental Analysis*, where one of the projects is selected as the base case and all other projects' results show their differences from the base case) in terms of cost and schedule: single-point estimate values, simulated averages, the probabilities each of the projects will have a cost or schedule overrun, and the 90th percentile value of cost and schedule. Of course, more detailed analysis can be obtained from the *Risk Simulation | Simulation Results* tab, where users can view all the simulation statistics and select any confidence and percentile values to show. The *Portfolio Analysis* tab also charts the simulated cost and schedule values using bubble and bar charts for a visual representation of the key results.

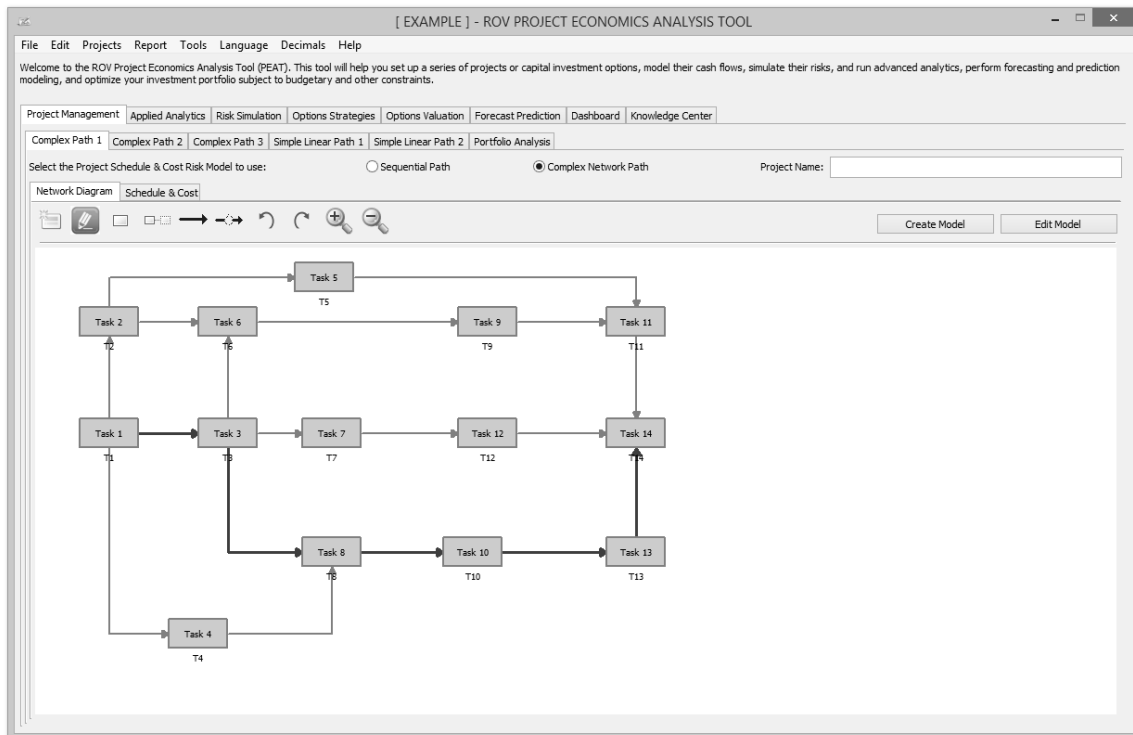


Figure 6: Complex Project Critical Path

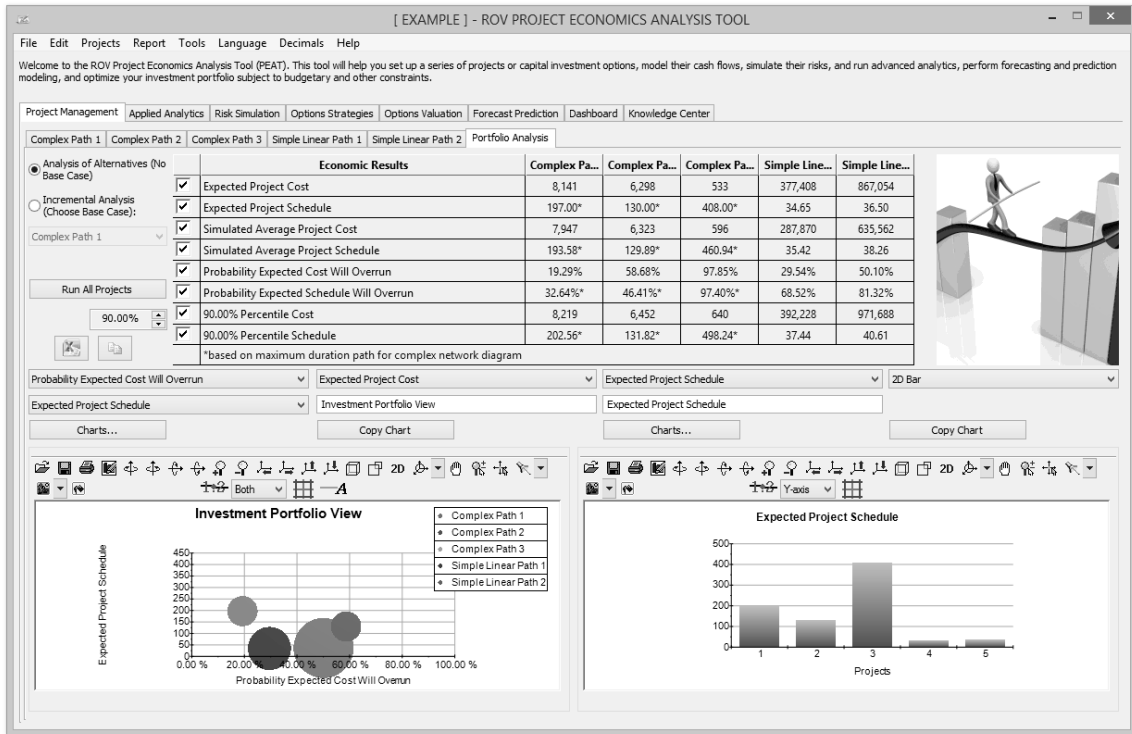


Figure 7: Portfolio View of Multiple Projects at Once

The *Overlay* chart in Figure 8 shows multiple projects' simulated costs or schedules overlaid on one another to see their relative spreads, location, and skew of the results. Users can clearly see that the project whose distribution lies to the right has a much higher cost to complete than the left, with the project on the right also having a slightly higher level of uncertainty in terms of cost spreads.

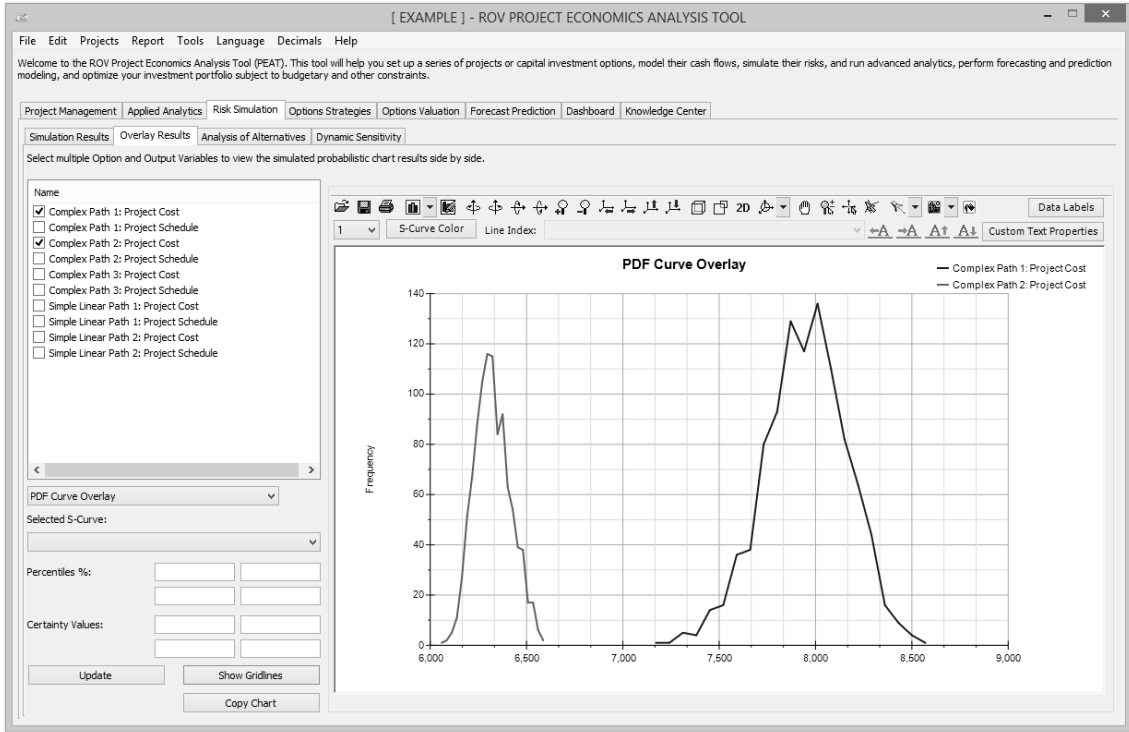


Figure 8: Overlay Charts of Multiple Projects' Cost or Schedule

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U.S. Navy International Programs Office Models

NIPO has many “product lines” that come through as requests from the Navy as well as industry. For instance, NIPO would be responsible for the following critical product lines: TTSARB; CBC, BTT, FDD Updates; ENDP Voting; Delegation of Disclosure Authority; Review of Training Material; Processing of Third-Party Transfer Requests; and ITAR Exemption Certifications. To illustrate the application of the proposed methodology, we have selected the Licensing product line for more detailed analysis in this section. Other critical areas are modeled and results are provided in the next section.

Step 1: Process Mapping

Figure 9 shows the process map for the Licensing product line provided by NIPO. Using this process map, we determined that there are multiple distinctive and independent pathways that can be modeled.

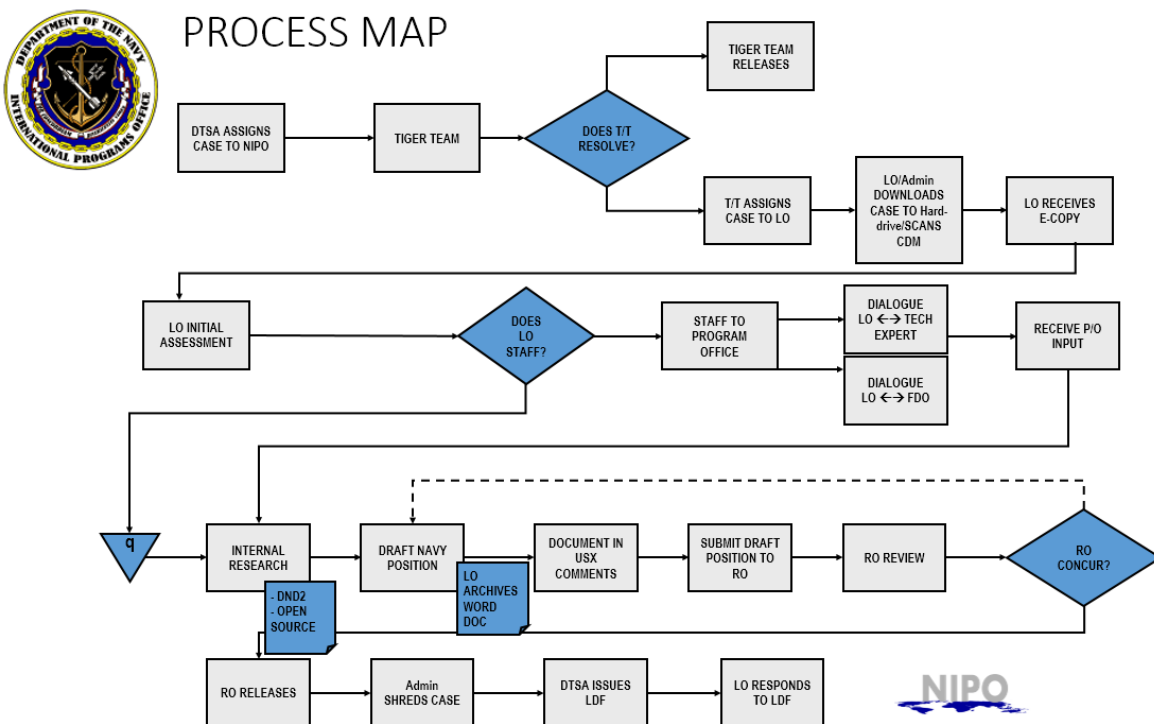


Figure 9: Licensing Process Map From NIPO

For instance, Figure 10 shows the longest possible path, which we termed the *Most Complex Path*. Figure 11 shows the other independent paths, namely, *Higher Complexity*, *Medium Complexity*, *Low Complexity*, and *Simplest Path*. A careful examination of Figure 9 will show that we can “tease out” these various independent pathways.

The modeling assumption is that each path is mutually exclusive and independent from the other paths. A request coming into NIPO will fall into one of these complexity “buckets” and will go through the prescribed path to completion. Each pathway consists of a series of tasks that can occur serially or in parallel. A serial path occurs when one task is linked to another in sequence (e.g., in Figure 10, Tasks 1 to 6 are serially linked). A parallel process will eventually merge back into the sequential path (e.g., in Figure 10, Task 7 splits into Tasks 8 and 9, which eventually merge back into Task 10).

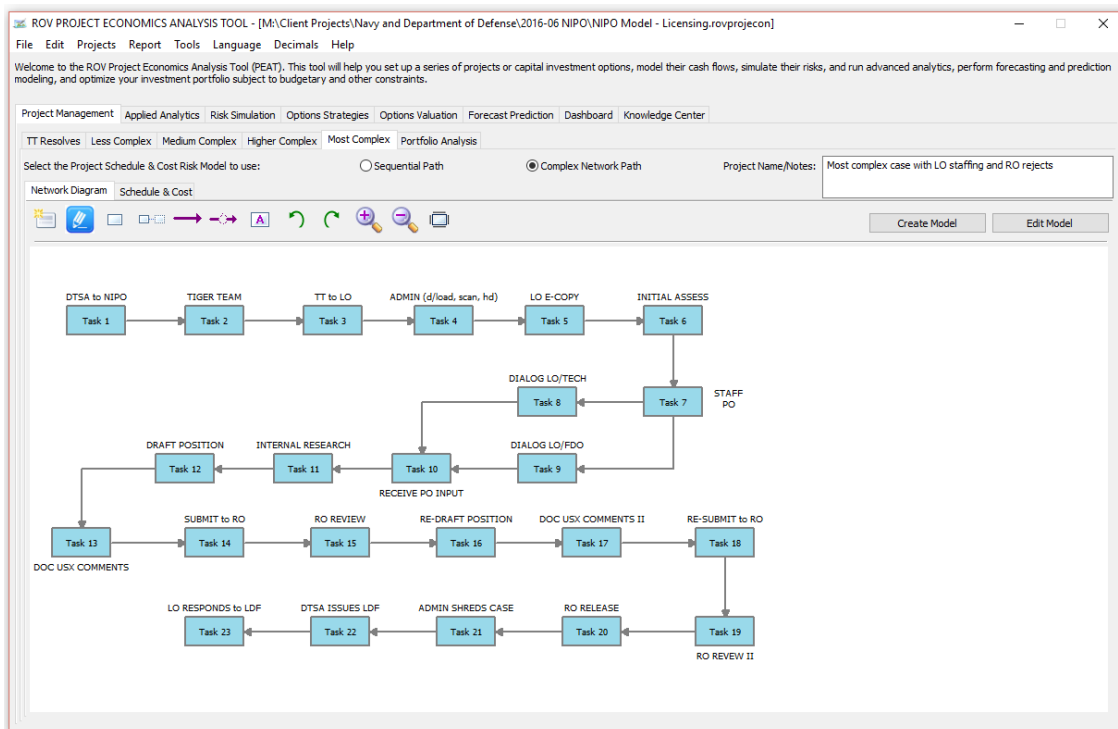


Figure 10: Most Complex Path



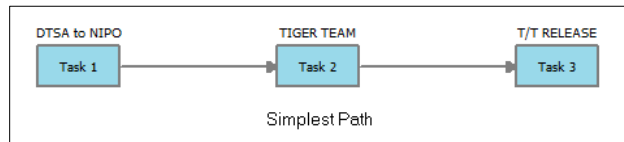
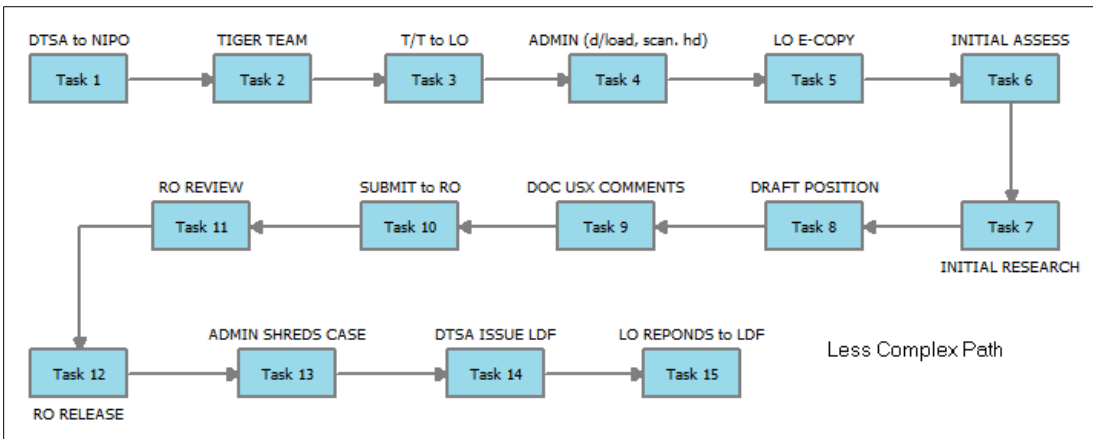
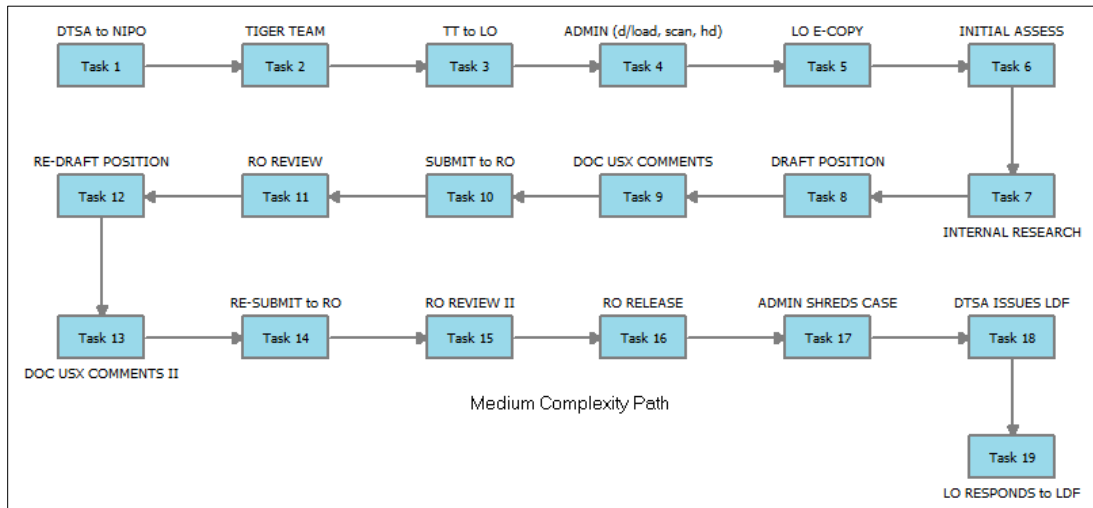
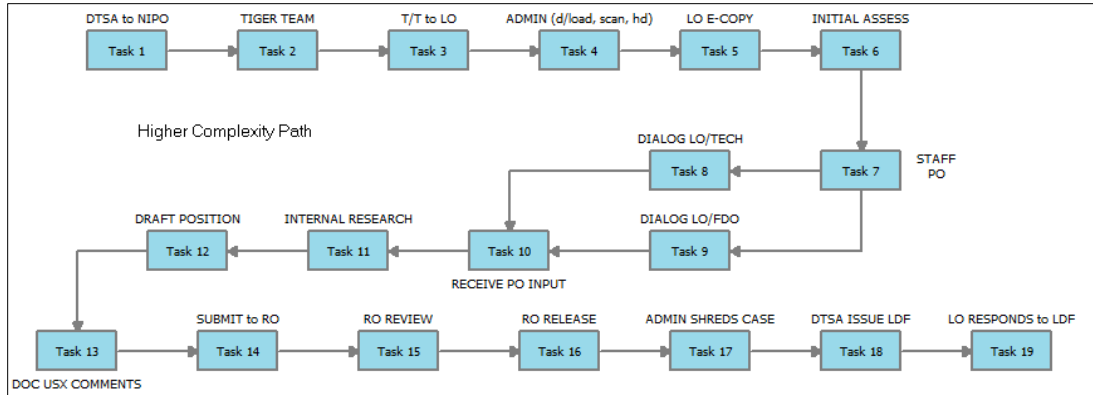


Figure 11: Higher Complexity Path to the Simplest Path



Step 2: Subject Matter Expert Data Gathering (Schedule and Cost)

Once the processes and their pathways are mapped, the Project Economics Analysis Tool (PEAT; see www.realoptionsvaluation.com for more details) software application automatically generates the model and required assumption dataset (see Figure 12). Subject matter experts (SMEs) were interviewed to solicit the relevant assumptions. For each of the pathways, the following variables were obtained:

- **Schedule.** The minimum, most likely, and maximum number of working days to complete each task are recorded. Tasks that take less than a day are prorated accordingly (e.g., a one-hour task is 0.125 days). The minimum amount of days indicates that a relatively simple request (e.g., existing policy and prior direct experience exists in handling said request) has come in, and the personnel handling that particular task has less workload than usual, indicating a best-case scenario of completing the task. The most likely scenario is the most common situation with average workload and average request complexity. The maximum number of working days per task corresponds to the situation where there is higher complexity in the request, additional issues surface during the execution of the request, and the workloads of the personnel handling the tasks are higher than usual, indicating a possible worst-case scenario in terms of the amount of time required to handle a specific task. Note that all of these tasks make up a single implementation pathway, and Figure 12 shows the tasks associated with the most complex path (as shown in Figure 10).

Note also that in the event that there is a reduced manning at NIPO, these minimum, most likely, and maximum schedule spreads may be shifted to include more time needed to complete each task due to the reduced human resources available, even with the same workload. Similarly, higher workload situations (e.g., a sudden spike in the amount of incoming requests) means that these spreads can be shifted accordingly, to reflect the longer time required to complete each task.

- **Cost and Cost Spreads.** Similarly, the minimum, most likely, and maximum human resource costs to complete each task are recorded. We utilized NH and NK government salary scales per year, prorated to 250 working days per year, to obtain the daily cost spreads. The relevant NH and NK levels assigned to various tasks are listed and their corresponding salary rates are used. These cost spreads are multiplied by the number of days to complete each task.



- Variable Daily Cost. These are the prorated average daily salary levels corresponding to the relevant NH and NK personnel and their respective salary levels. These values are multiplied by the possibility of an overrun for each specific task.
- Overrun Assumption. This is included as a buffer, typically set between 0% and 5%, which includes the possibility that a task's schedule and cost can go beyond the maximum amount specified. In fact, this variable can be used to account for any new employees with less experience in handling a specific task. In such a situation, the overrun assumption would be allowed to increase beyond the standard 0% to 5%.
- NH Level and Number. This column indicates the salary grade of the personnel responsible for each task (e.g., NH-3) as well as the number of individuals involved in the task (e.g., Going forward, two people will be involved in the Tiger Team review task.).

PATH: MOST COMPLEX		Cost (Fixed Cost)			Most complex case with LO staffing and RO rejects						
Task	Task Name	80%	100%	120%	Time Schedule (Days)			Variable Daily Cost	Overrun Assumption	NH Level	Number
		Minimum	Most Likely	Maximum	Minimum	Most Likely	Maximum				
Task 1	D TSA to NIPO	224.32	280.40	336.48	0.250	1.000	6.000	280.40	5.00%	NK-2	1
Task 2	TIGER TEAM	954.46	1193.07	1431.69	0.125	0.125	1.000	596.54	5.00%	NH-4	2
Task 3	TT to LO	313.97	392.46	470.95	2.000	2.000	5.000	392.46	5.00%	NH-3	1
Task 4	ADMIN (d/load, scan, hd)	224.32	280.40	336.48	0.125	0.250	0.500	280.40	5.00%	NK-2	1
Task 5	LO E-COPY	313.97	392.46	470.95	0.125	0.125	0.250	392.46	5.00%	NH-3	1
Task 6	INITIAL ASSESS	313.97	392.46	470.95	0.250	2.000	5.000	392.46	5.00%	NH-3	1
Task 7	STAFF PO	313.97	392.46	470.95	0.125	0.125	0.125	392.46	5.00%	NH-3	1
Task 8	DIALOG LO/TECH	313.97	392.46	470.95	5.000	10.000	25.000	392.46	5.00%	NH-3	1
Task 9	DIALOG LO/FDO	313.97	392.46	470.95	5.000	10.000	25.000	392.46	5.00%	NH-3	1
Task 10	RECEIVE PO INPUT	313.97	392.46	470.95	2.000	4.000	10.000	392.46	5.00%	NH-3	1
Task 11	INTERNAL RESEARCH	313.97	392.46	470.95	2.000	5.000	10.000	392.46	5.00%	NH-3	1
Task 12	DRAFT POSITION	313.97	392.46	470.95	2.500	5.000	7.500	392.46	5.00%	NH-3	1
Task 13	DOC USX COMMENTS	313.97	392.46	470.95	0.125	0.125	0.250	392.46	5.00%	NH-3	1
Task 14	SUBMIT to RO	313.97	392.46	470.95	0.125	0.125	0.125	392.46	5.00%	NH-3	1
Task 15	RO REVIEW	477.23	596.54	715.84	5.000	12.500	25.000	596.54	5.00%	NH-4	1
Task 16	RE-DRAFT POSITION	313.97	392.46	470.95	2.000	5.000	10.000	392.46	5.00%	NH-3	1
Task 17	DOC USX COMMENTS II	313.97	392.46	470.95	0.125	0.125	0.250	392.46	5.00%	NH-3	1
Task 18	RE-SUBMIT to RO	313.97	392.46	470.95	0.125	0.125	0.125	392.46	5.00%	NH-3	1
Task 19	RO REVIEW II	477.23	596.54	715.84	0.125	0.125	0.250	596.54	5.00%	NH-4	1
Task 20	RO RELEASE	477.23	596.54	715.84	0.125	0.125	1.000	596.54	5.00%	NH-4	1
Task 21	ADMIN SHREDS CASE	224.32	280.40	336.48	0.125	0.125	0.250	280.40	5.00%	NK-2	1
Task 22	D TSA ISSUE LDF	313.97	392.46	470.95	5.000	10.000	15.000	392.46	5.00%	NH-3	1
Task 23	LO RESPONDS to LDF	313.97	392.46	470.95	0.125	0.500	2.000	392.46	5.00%	NH-3	1
SUM:					32.500	68.500	149.625	DAYS			
SUM:					6.500	13.700	29.925	WEEKS			

Figure 12: Cost and Schedule Data by Task

Step 3: Sensitivity Analysis

Tornado analysis is a powerful analytical tool that captures the static impacts of each variable on the outcome of the model; that is, the tool automatically perturbs each variable in the model a preset amount, captures the fluctuation on the model's forecast or final result, and lists the resulting perturbations ranked from the most



significant to the least. This capability makes tornado analysis a key component to execute before running a Monte Carlo simulation. One of the very first steps in risk analysis is to capture and identify the most important impact drivers in the model. The next step is to identify which of these important impact drivers are uncertain. These uncertain impact drivers are the critical success drivers of a project on which the results of the model depend and are the ones that should be simulated. Tornado charts assist in identifying these critical success drivers quickly and easily.

Figure 13 shows the two tornado analyses for the most complex path, aimed at modeling schedule and cost uncertainties. For instance, in the first analysis, we see that Tasks 15, 22, 9, and 8 have the highest impact on the total time required to complete the most complex path. These tasks correspond to RO review, DTSA to issue the LDF, and Licensing Officer's information gathering conversations with technical services and FDO. The analysis can be replicated for costs and across all other implementation pathways. The common-denominator tasks can be identified, and ways can be determined to minimize their impact, reduce their variance, and implement options to increase the speed of these bottleneck tasks.



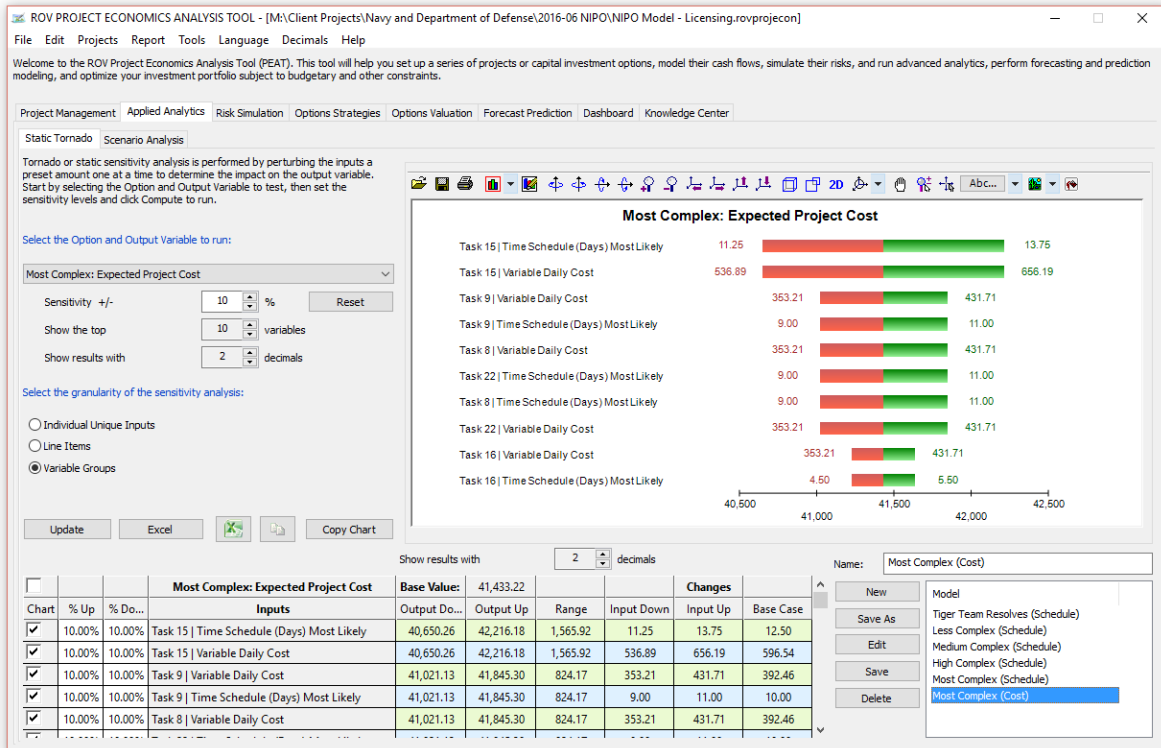
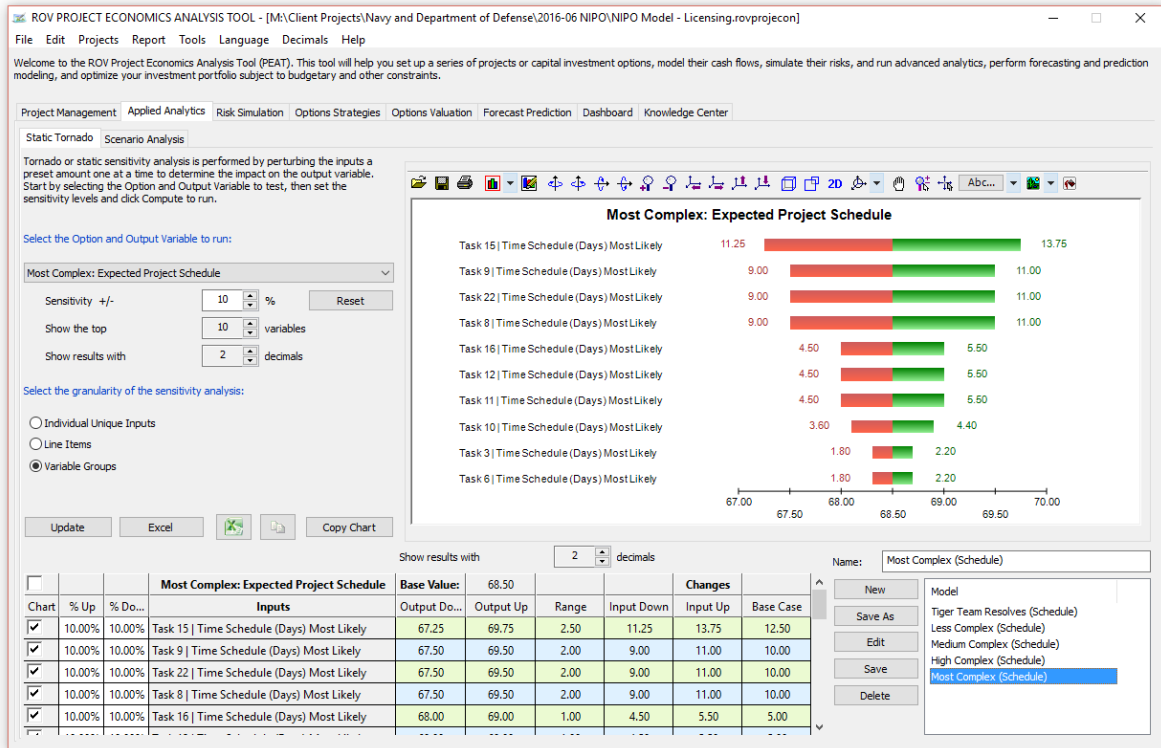


Figure 13: Most Complex Schedule and Cost Tornado Sensitivity Analyses



A related element is sensitivity analysis. While tornado analysis applies static perturbations before a simulation run, sensitivity analysis applies dynamic perturbations created after the simulation run. Tornado and spider charts are the results of static perturbations, meaning that each precedent or assumption variable is perturbed a preset amount one at a time, and the fluctuations in the results are tabulated. In contrast, sensitivity charts are the results of dynamic perturbations in the sense that multiple assumptions are perturbed simultaneously, and their interactions in the model and correlations among variables are captured in the fluctuations of the results. Tornado charts therefore identify which variables drive the results the most and, hence, are suitable for simulation, whereas sensitivity charts identify the impact on the results when multiple interacting variables are simulated together in the model. This effect is clearly illustrated in Figure 14. Notice that the rankings of critical success drivers are similar to those shown in the tornado charts (as shown in Figure 13).

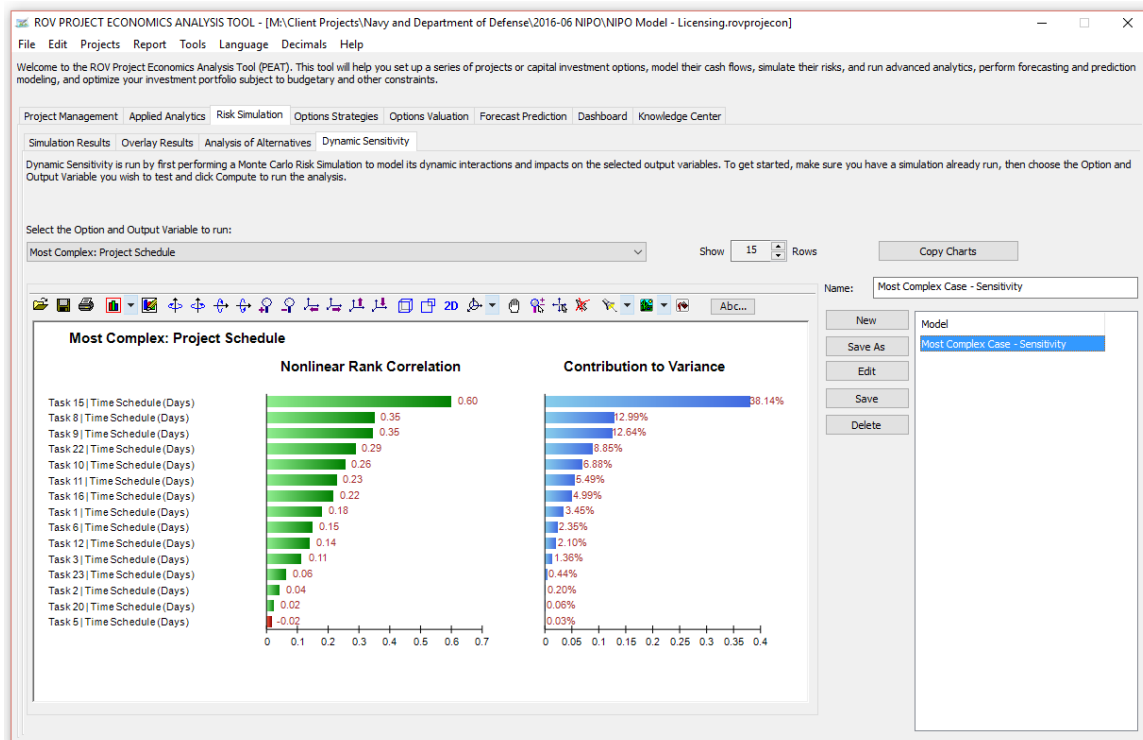


Figure 14: Most Complex Schedule Simulated Dynamic Sensitivity Analysis



Step 4: Monte Carlo Risk Simulation

Monte Carlo simulation creates artificial futures by generating thousands and even hundreds of thousands of sample paths of outcomes and analyzes their prevalent characteristics. In practice, Monte Carlo simulation methods are used for risk analysis, risk quantification, sensitivity analysis, and prediction. An alternative to simulation is the use of highly complex stochastic closed-form mathematical models. For analysts in a company, taking graduate-level advanced math and statistics courses is just not logical or practical. An analyst should use all available tools to obtain the same answer in the easiest and most practical way possible. And in all cases, when modeled correctly, Monte Carlo simulation provides similar answers to the more mathematically elegant methods.

Today, fast computers have made possible many complex computations that were seemingly intractable in past years. For scientists, engineers, statisticians, managers, business analysts, and others, computers have made it possible to create models that simulate reality and aid in making predictions, one of which is used in simulating real systems by accounting for randomness and future uncertainties through investigating hundreds and even thousands of different scenarios. The results are then compiled and used to make decisions. This is what Monte Carlo simulation is all about.

Monte Carlo simulation in its simplest form is a random number generator that is useful for forecasting, estimation, and risk analysis. A simulation calculates numerous scenarios of a model by repeatedly picking values from a user-predefined probability distribution for the uncertain variables and using those values for the model. As all those scenarios produce associated results in a model, each scenario can have a forecast. Forecasts are events (usually with formulas or functions) that users define as important outputs of the model.

Think of the Monte Carlo simulation approach as picking golf balls out of a large basket repeatedly with replacement. The size and shape of the basket depend on the distributional Input Assumption (e.g., a normal distribution with a mean of 100 and a standard deviation of 10, versus a uniform distribution or a triangular



distribution) where some baskets are deeper or more symmetrical than others, allowing certain balls to be pulled out more frequently than others. The number of balls pulled repeatedly depends on the number of trials simulated. For a large model with multiple related assumptions, imagine the large model as a very large basket, wherein many baby baskets reside. Each baby basket has its own set of colored golf balls that are bouncing around. Sometimes these baby baskets are linked with each other (if there is a correlation between the variables), forcing the golf balls to bounce in tandem, whereas in other uncorrelated cases, the balls are bouncing independently of one another. The balls that are picked each time from these interactions within the model (the large basket) are tabulated and recorded, providing a Forecast Output result of the simulation.

Figures 15–19 show the results from a Monte Carlo simulation run on the process model. The Monte Carlo simulated schedule risk outcomes for the most complex path in the licensing product line are shown in Figure 15. From the statistics grid, the fastest completion time is anticipated to be 47 days and can take as much as 102 days in a worst-case scenario, with a 90% confidence interval between 61.4 and 84.4 days (we obtain the 90% confidence interval by taking the Two-Tails value of 5% and 95%, which means that there is a 5% probability that the request will be completed in less than 61.4 days and 5% probability that it will take longer than 84.4 days, or a total of 90% probability between these two values). This means that 90% of the time, given that a licensing request that falls into the category of most complex arrives amidst any combination of human resource workload levels, it would take NIPO between 61.4 and 84.4 work days to complete, with an average of 72.7 days (this is indicated as the mean value in the results data grid).

Figure 16 shows the cost distribution of a licensing request that is considered the most complex, where we see that the cost to NIPO, and, hence, the government, is anywhere between \$41,566 and \$54,863 to complete. This cost distribution corresponds to the human resource load that took 61.4 to 84.4 days. It assumes that all NH and NK personnel are fully loaded and focus on this single request. The values can simply be divided by the average workload of the personnel involved to arrive at a more realistic set of figures for one licensing request. For example, for the



specified time period, the relevant staff members were working on four most complex licensing projects and three exception requests. Where we assume that the workload of the most complex licensing projects is half of the exception requests, we can take the cost distribution and divide by 10 to arrive at the expected cost of a licensing request (i.e., [4 most complex × index of 1] + [3 exception requests × index of 2] = 10 index units).

The schedule and cost results for the situations just described can now be compared with new organizational structures (e.g., where some of the tasks are modified and the entire process may change, or the process remains the same but the number of days to complete a specific task may be more, accounting for the reduced manning resources). These differences can then be compared, and relevant decisions can be made. Also, third industry vendors working on time-critical requests may be charged the relevant cost-based service fee to expedite their requests, thereby saving the government additional expenses. These service fees can be set to correspond to the previously discussed analysis.

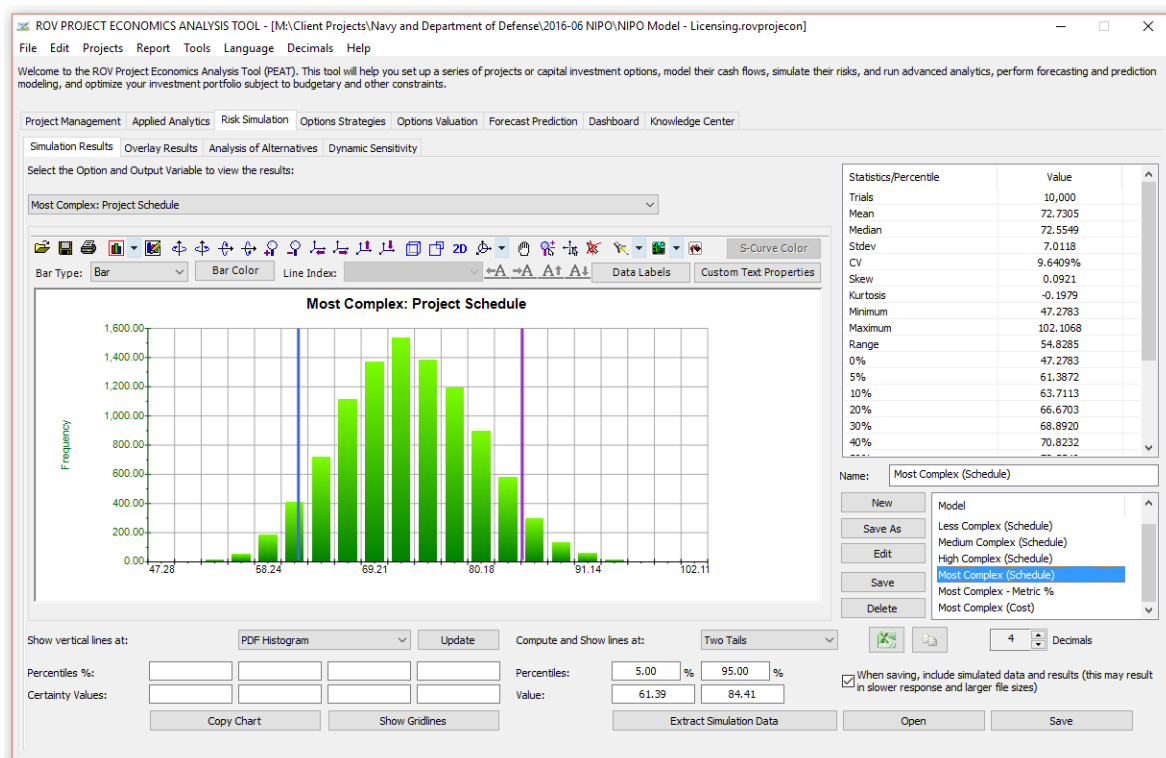


Figure 15: Most Complex Path's Simulated Probability Distribution on Schedule

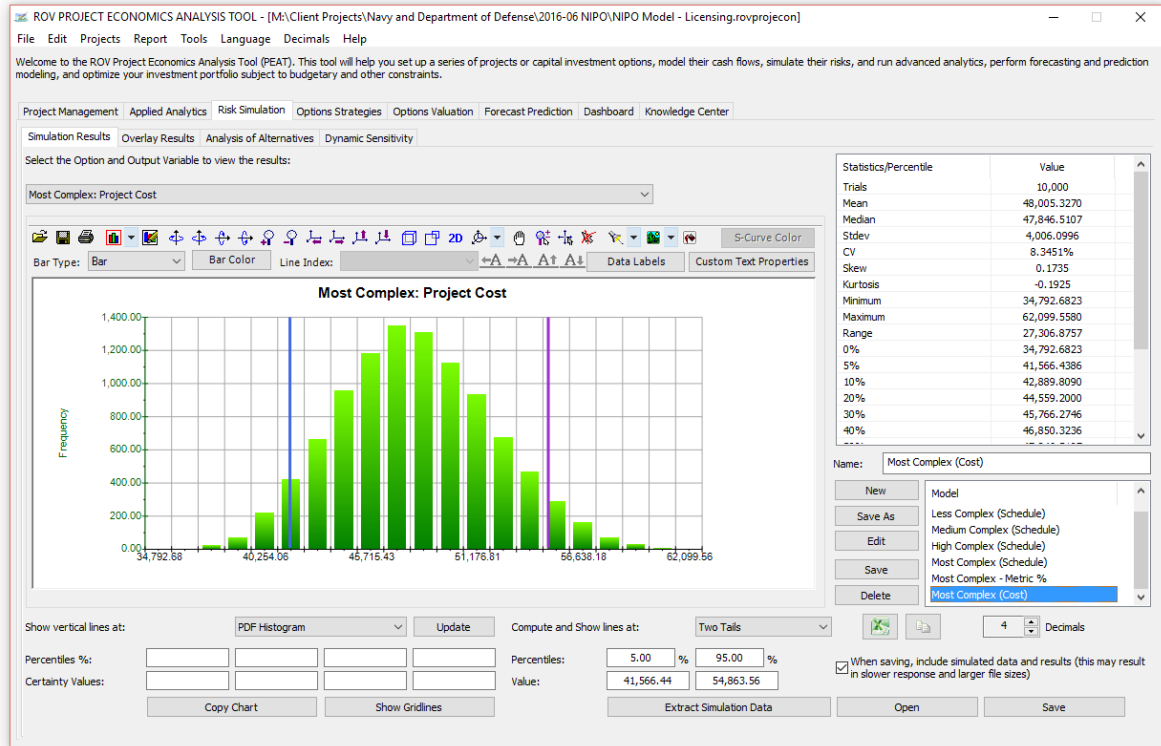


Figure 16: Most Complex Path's Simulated Probability Distribution on Cost

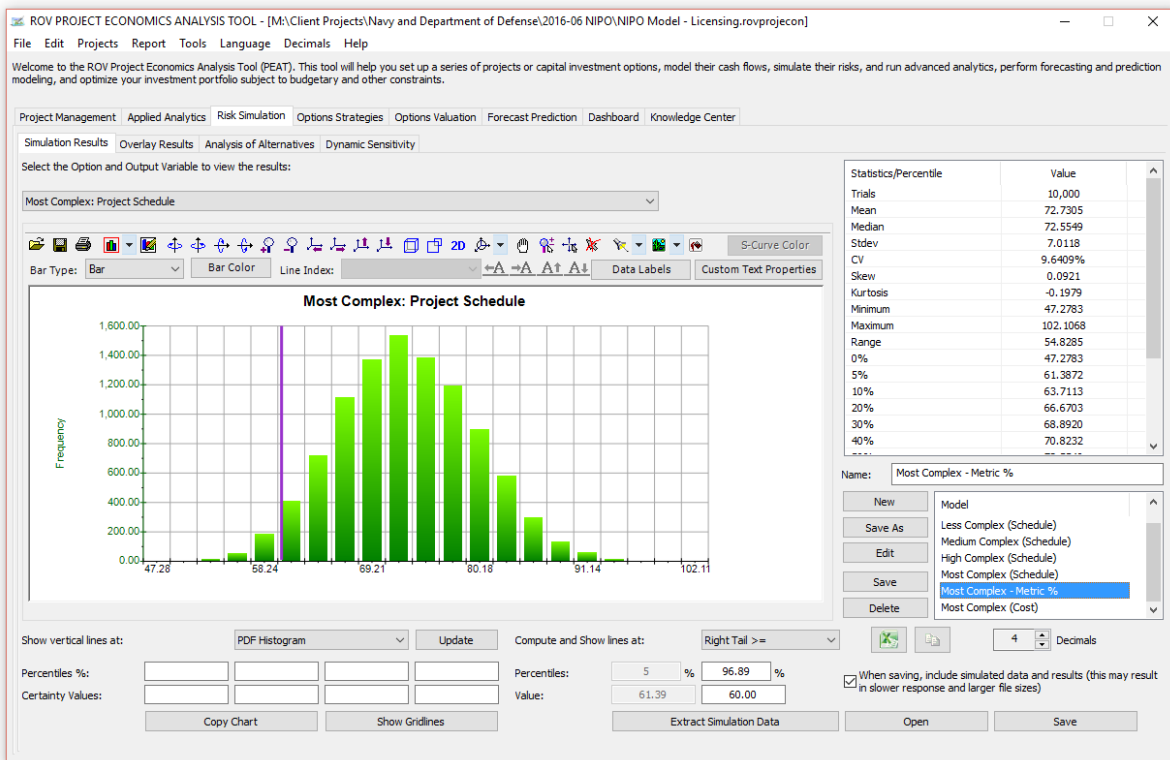


Figure 17: Most Complex Path's Simulated Metric Attainment



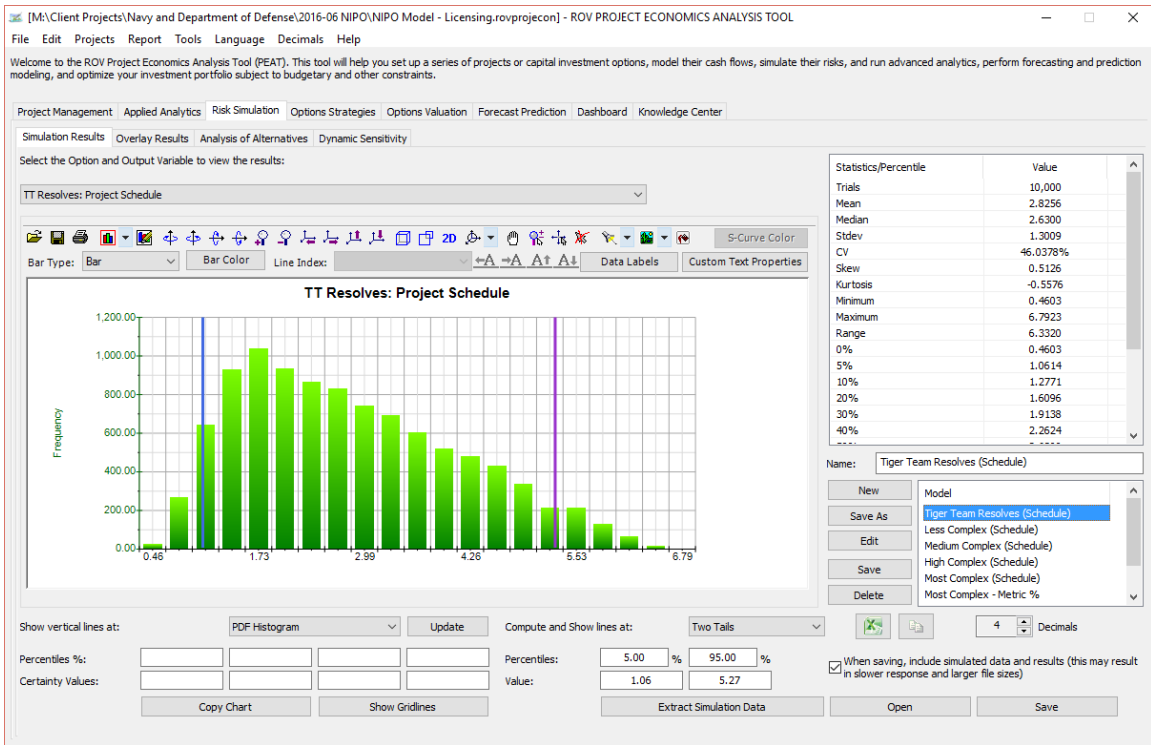


Figure 18: Simplest Path's Simulated Probability Distribution on Schedule

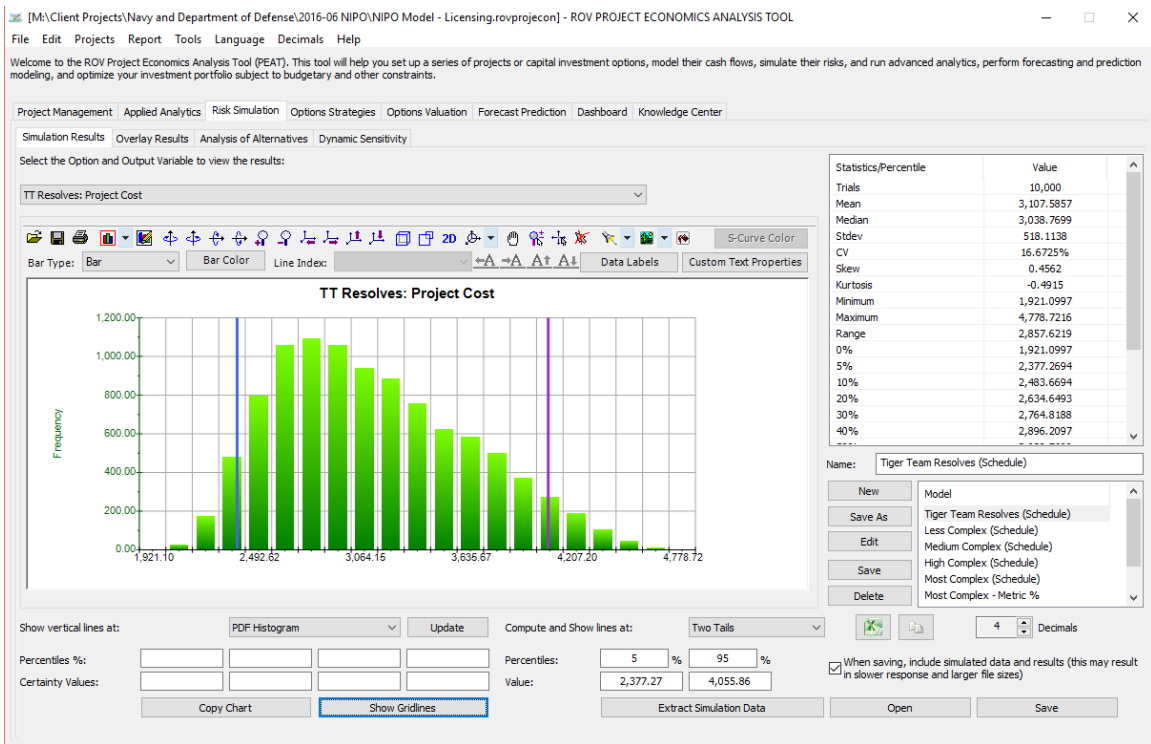


Figure 19: Simplest Path's Simulated Probability Distribution on Cost



Step 5: Results Analysis

Multiple simulated probability distributions can be overlaid one on another, as illustrated in Figure 20's overlay charts. The charts show how the schedules of the five independent paths of the licensing product line are distributed. These charts are also shown as a table of simulated statistical results in Figure 21 for a side-by-side comparison.

Finally, Figure 22 shows another example of usage of the simulated schedule results. For instance, suppose all the requests at NIPO are tracked in terms of the amount of time each takes to complete. Further suppose that a specific medium complexity request is completed in 45 working days. Using the simulated results of medium complexity (Figure 22), the right-tail ≥ 45 day results show a value of 87.7%. This indicates that completing a medium complexity project in 45 days means that this project is 87.7% better and faster than all other comparable ones. In other words, the team working on this request is working in top form at a high metric attainment. Such analyses can be performed on all product lines with various complexity levels under all types of conditions (reduced manning, updated organization structure, etc.).



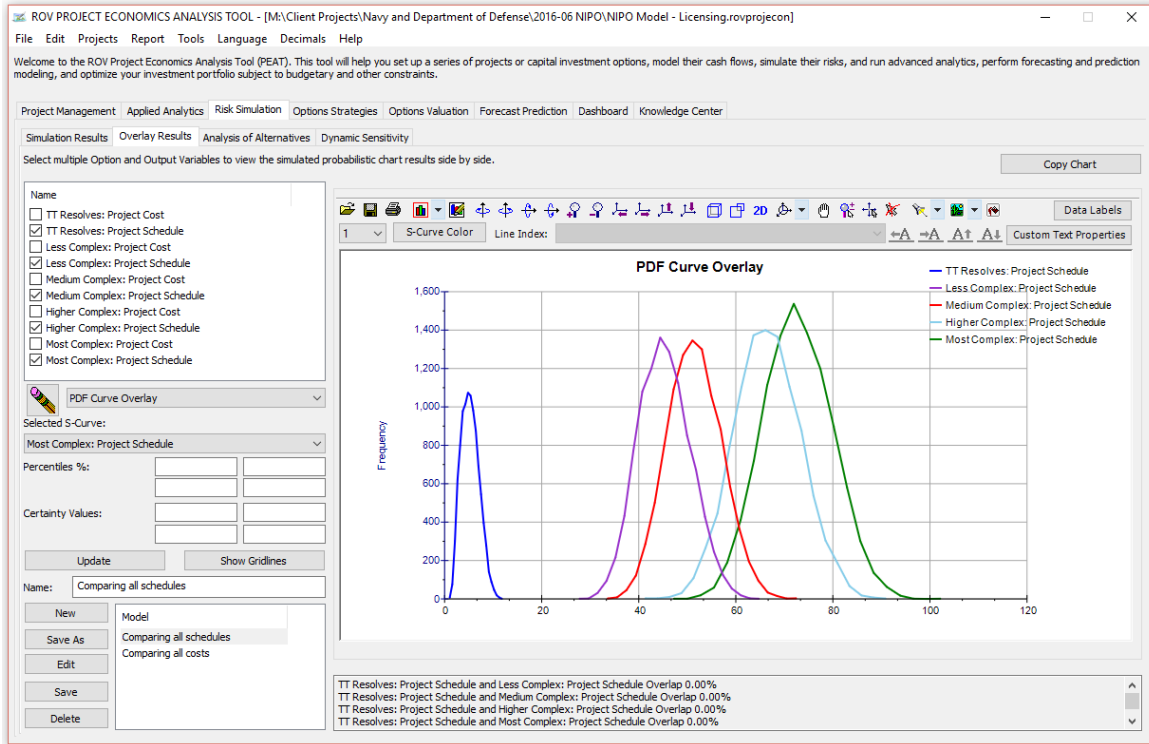


Figure 20: Overlay of All Simulated Probability Distributions on Schedule

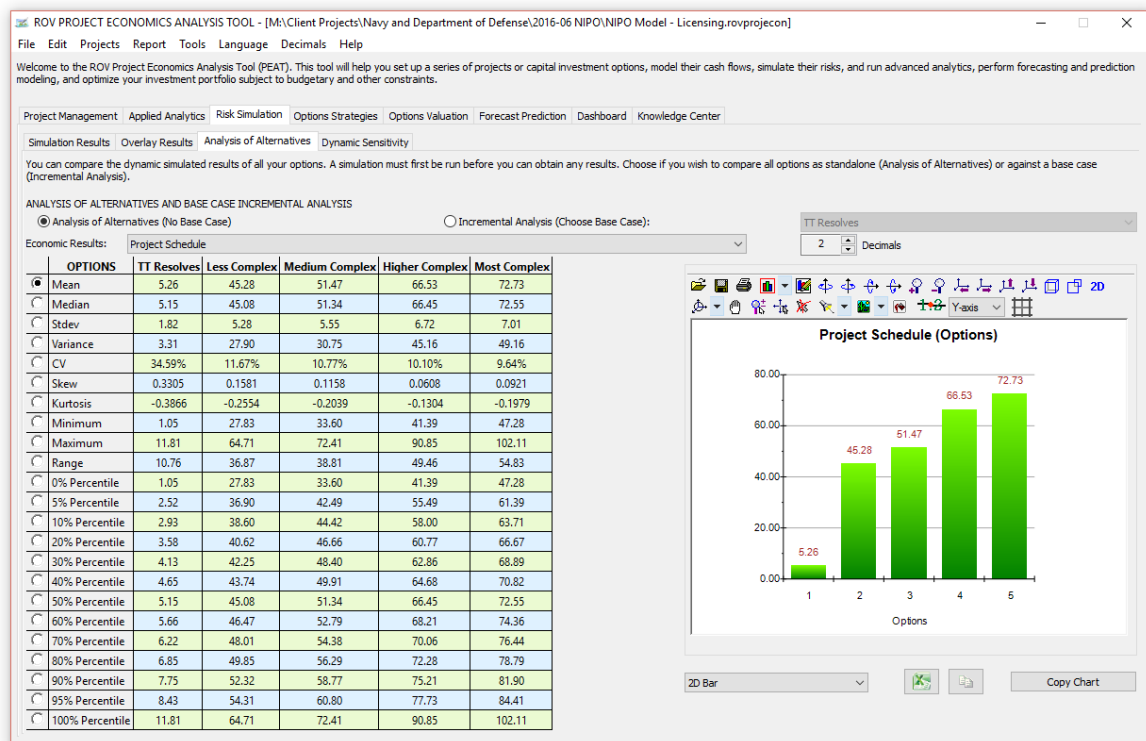


Figure 21: Simulated Side-by-Side Comparisons of Probability Distributions on Schedule



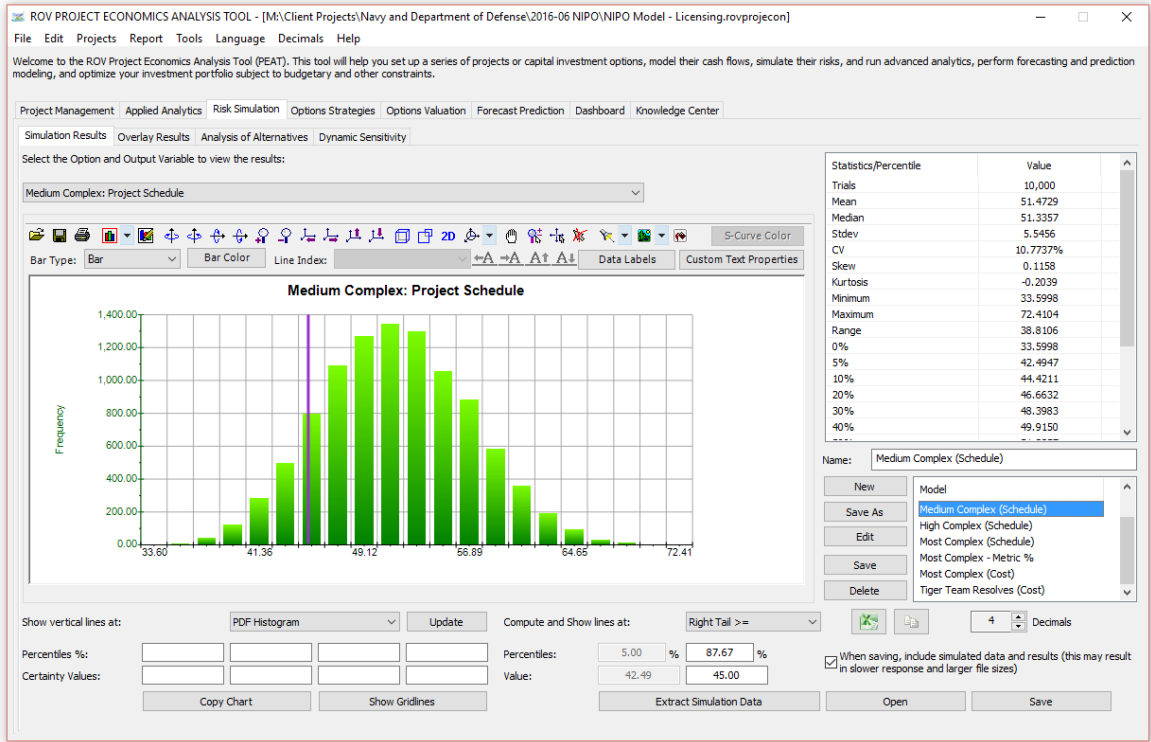


Figure 22: Another Metric Attainment Example for Medium Complexity Projects



Detailed Model Report of Schedule-Cost Risk for ENDP, ITAR, TPTP, and TTSARB Processes

The following are the detailed reports generated by the PEAT software application for the Exceptions to National Disclosure Policy (ENDP) and International Traffic In-Arms Regulations (ITAR) areas in NIPO.

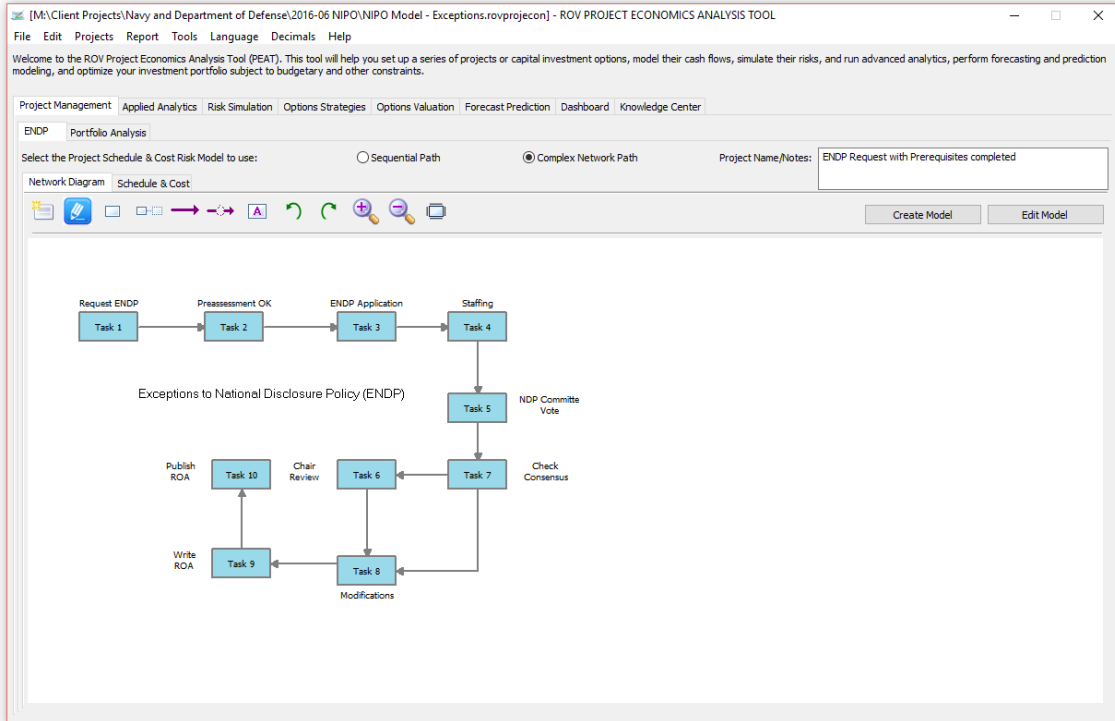
Exceptions to National Disclosure Policy

ENDP requests (Task 1) typically come as one-off requests from the U.S. Navy Programs Office (see Figure 23). An initial assessment is performed (Task 2). If the initial preassessment indicates all required documentation is in place (e.g., endorsement from the commander and approval by the relevant U.S. embassy), the ENDP application process officially starts (Task 3). The required NIPO personnel are staffed, and a preliminary writeup is generated, reviewed by a supervisor (Task 4), and then sent for review to the National Disclosure Policy (NDP) committee for a vote (Task 5). The NDP committee chair reviews the report, checks for consensus among committee members, and provides required modifications (Tasks 5–8). Once NIPO receives the required feedback, the record of action (ROA) is generated (Task 9) and published (Task 10).

For the purposes of the analysis, we assume the required prework to be in place. In other words, the required field commander's endorsement and embassy approvals are in order, and existing policy covering the required military hardware or software also exists or requires only minor modifications. In situations where such prework is not in place (e.g., policies are missing, new policies are required, or combinations of multiple policies are required in more complex cases), we can model said prework tasks separately to determine the length of time and associated costs to get the prework portion of the process completed prior to the ENDP request process mentioned previously.

Figures 23, 24, and 25 illustrate the results of the ENDP process modeling. The same interpretation that was used in the Recommended Methodology section of this paper applies equally when reviewing the results in this section.





Simulation Parameters:

- Include Schedule-Based Cost Analysis:
- Include Budget Overrun & Buffers:
- Include Probabilities of Success of Each Task and Model Their Impacts:
- Perform Risk Simulation:
- Simulation Trials: 10,000
- Apply Seed Value:
- Run: 123
- Triangular:

Task	Task Name	Cost (Fixed Cost)			Computed Cost	Time Schedule (Days)			Variable Daily Cost	Overrun Assumption
		Minimum	Most Likely	Maximum		Minimum	Most Likely	Maximum		
Task 1	Request ENDP	313.97	392.46	470.95	618	0.125	0.5	1	392.46	5.00%
Task 2	Preassessment OK	313.97	392.46	470.95	1,236	1	2	3	392.46	5.00%
Task 3	ENDP Application	313.97	392.46	470.95	1,442	1	2.5	5	392.46	5.00%
Task 4	Staffing	313.97	392.46	470.95	1,648	2	3	4	392.46	5.00%
Task 5	NDP Committe Vote	313.97	392.46	470.95	2,472	5	5	10	392.46	5.00%
Task 6	Chair Review	313.97	392.46	470.95	4,533	5	10	20	392.46	5.00%
Task 7	Check Consensus	313.97	392.46	470.95	4,533	5	10	20	392.46	5.00%
Task 8	Modifications	313.97	392.46	470.95	1,648	2	3	5	392.46	5.00%
Task 9	Write ROA	313.97	392.46	470.95	2,472	2	5	10	392.46	5.00%
Task 10	Publish ROA	313.97	392.46	470.95	618	0.125	0.5	1	392.46	5.00%
Project Total Cost		3,140	3,925	4,709	21,222					
Expected Total Duration						23	31.50	79		

Figure 23: ENDP Process and SME Assumptions



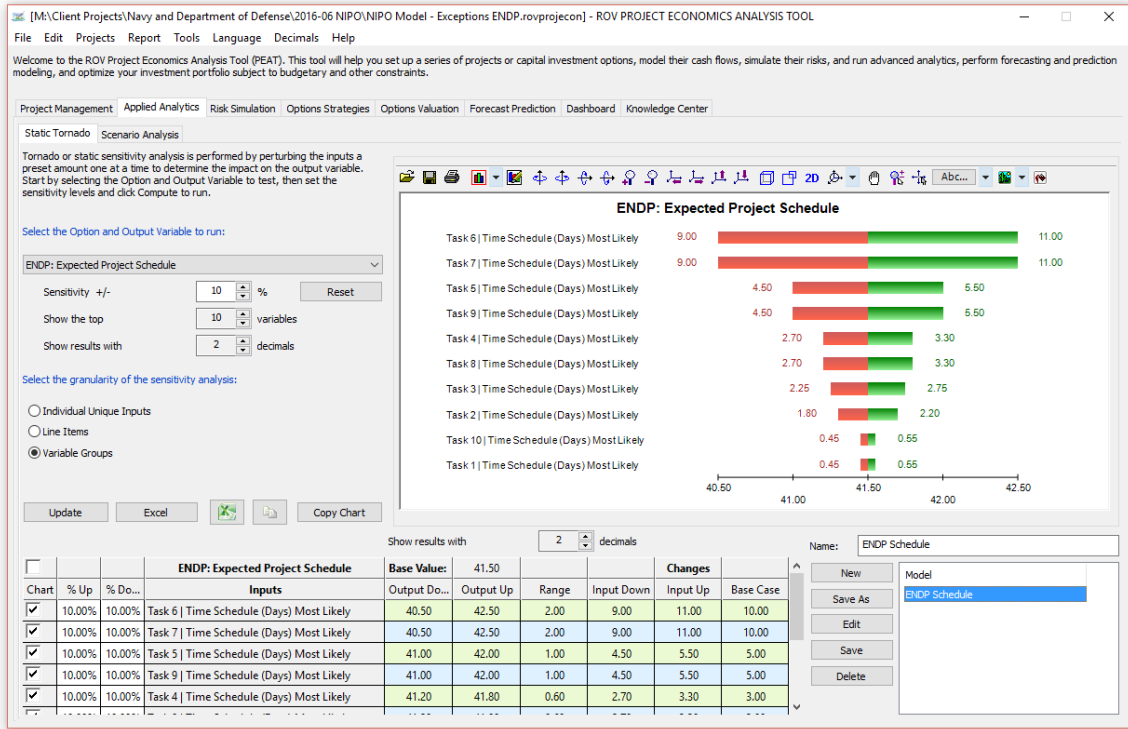


Figure 24: ENDP Schedule-Cost Input Assumptions and Sensitivities

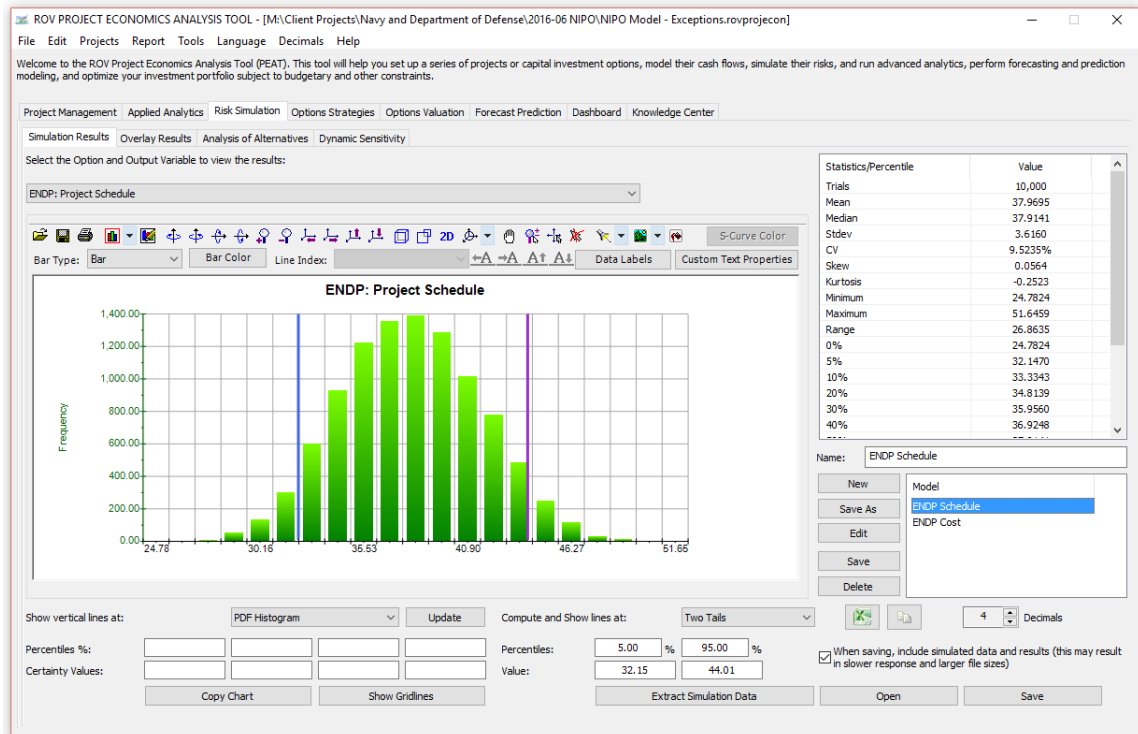


Figure 25: ENDP Distribution of Simulated Schedule

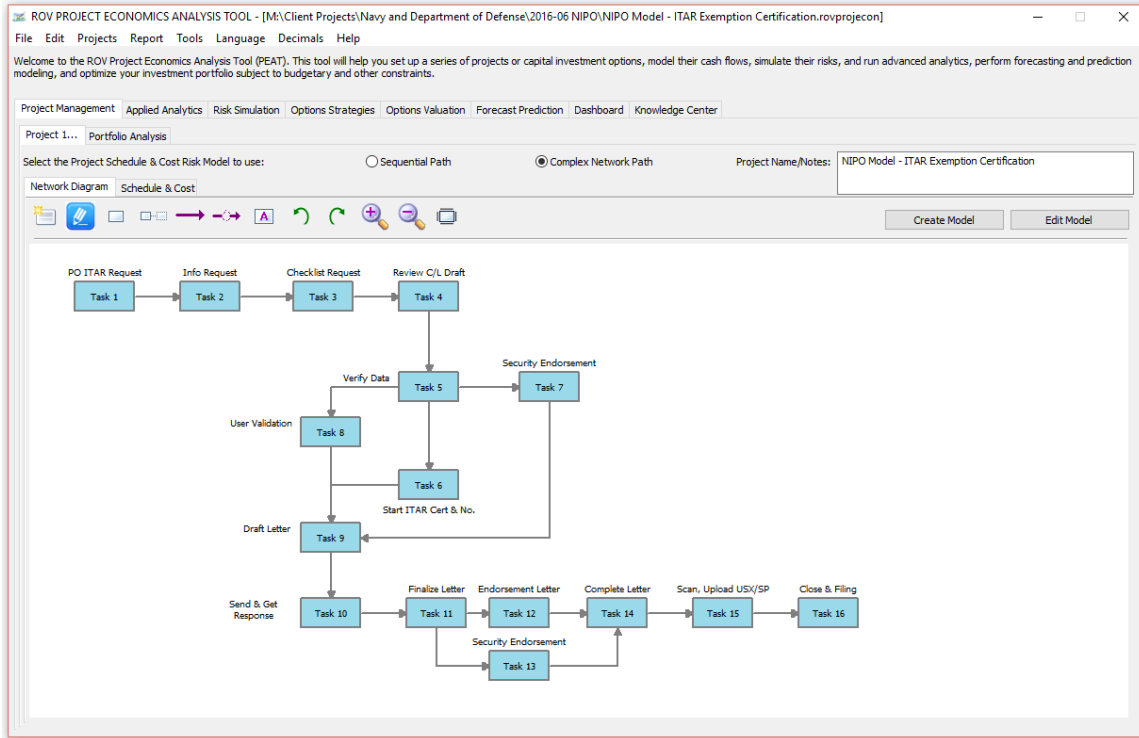


International Traffic In-Arms Regulations

ITAR requests are made by the U.S. Navy prior to an upcoming event at which foreign governments or foreign military contractors are anticipated to attend (see Figure 26). Given that such events usually occur within several weeks, there may be insufficient time to obtain a complete certification for all the products and services that will be discussed. As such, the Navy's Programs Office (PO) may request an ITAR certification, which usually starts with an e-mail request (Task 1). NIPO may request additional or missing information (Task 2) and compare it against a checklist of required items (Task 3). An initial cover letter is drafted (Task 4) and reviewed while the updated information is being reviewed (Task 5). In parallel, a new ITAR certificate and identification number are generated (Task 6) while a request for security endorsement (Task 7) is being obtained from the foreign disclosure officer, and a user validation (Task 8) is performed (this is required if foreign companies will be attending the event). An initial endorsement cover letter is then drafted (Task 9) and sent for review and response (Task 10). Appropriate modifications are made and the cover letter is finalized (Task 11). Meanwhile, an official endorsement letter from the foreign disclosure office (Task 12) and security endorsement (Task 13) are obtained and the letter is completed (Task 14). Any required final modifications are made to the final documentation, which is scanned, uploaded, and updated in USX/Sharepoint (Task 15), and the project is filed and closed (Task 16).

Figures 26, 27, and 28 illustrate the results of the ENDP process modeling. The same interpretation that was used in the Recommended Methodology section of this paper applies equally when reviewing the results in this section.





ROV PROJECT ECONOMICS ANALYSIS TOOL - [M:\Client Projects\Navy and Department of Defense\2016-06 NIPO\NIPO Model - ITAR Exemption Certification.rovprojecan]

File Edit Projects Report Tools Language Decimals Help

Welcome to the ROV Project Economics Analysis Tool (PEAT). This tool will help you set up a series of projects or capital investment options, model their cash flows, simulate their risks, and run advanced analytics, perform forecasting and prediction modeling, and optimize your investment portfolio subject to budgetary and other constraints.

Project Management Applied Analytics Risk Simulation Options Strategies Options Valuation Forecast Prediction Dashboard Knowledge Center

Project 1... Portfolio Analysis

Select the Project Schedule & Cost Risk Model to use: Sequential Path Complex Network Path Project Name/Notes: NIPO Model - ITAR Exemption Certification

Network Diagram Schedule & Cost

Include Schedule-Based Cost Analysis Include Probabilities of Success of Each Task and Model Their Impacts

Include Budget Overrun & Buffers Perform Risk Simulation

Show: 15 Tasks with: Daily Simulation Trials: 10,000 Apply Seed Value: 123 Triangular

Task	Task Name	Cost (Fixed Cost)			Computed Cost	Time Schedule (Days)			Variable Daily Cost	Overrun Assumption
		Minimum	Most Likely	Maximum		Minimum	Most Likely	Maximum		
Task 1	PO ITAR Request	477.23	596.54	715.84	783	0.125	0.250	0.500	596.54	5.00%
Task 2	Info Request	477.23	596.54	715.84	2,505	2.000	3.000	4.000	596.54	5.00%
Task 3	Checklist Request	477.23	596.54	715.84	3,758	3.000	5.000	7.000	596.54	5.00%
Task 4	Review C/L Draft	477.23	596.54	715.84	2,192	1.000	2.500	5.000	596.54	5.00%
Task 5	Verify Data	477.23	596.54	715.84	2,192	1.000	2.500	5.000	596.54	5.00%
Task 6	Start ITAR Cert & No.	313.97	392.46	470.95	515	0.125	0.250	0.500	392.46	5.00%
Task 7	Security Endorsement	477.23	596.54	715.84	3,758	2.500	5.000	7.500	596.54	5.00%
Task 8	User Validation	477.23	596.54	715.84	4,385	5.000	6.000	7.000	596.54	5.00%
Task 9	Draft Letter	477.23	596.54	715.84	783	0.125	0.250	0.500	596.54	5.00%
Task 10	Send & Get Response	477.23	596.54	715.84	10,022	10.000	15.000	20.000	596.54	5.00%
Task 11	Finalize Letter	477.23	596.54	715.84	783	0.125	0.250	0.500	596.54	5.00%
Task 12	Endorsement Letter	477.23	596.54	715.84	3,758	2.500	5.000	7.500	596.54	5.00%
Task 13	Security Endorsement	477.23	596.54	715.84	3,758	2.500	5.000	7.500	596.54	5.00%
Task 14	Complete Letter	477.23	596.54	715.84	783	0.125	0.250	0.500	596.54	5.00%
Task 15	Scan, Upload USX/SP	313.97	392.46	470.95	515	0.125	0.250	0.500	392.46	5.00%
Task 16	Close & Filing	313.97	392.46	470.95	515	0.125	0.250	0.500	392.46	5.00%
Project Total Cost		7,146	8,932	10,719	41,006					
Expected Total Duration						30	40.50	74		

Figure 26: ITAR Process and SME Assumptions



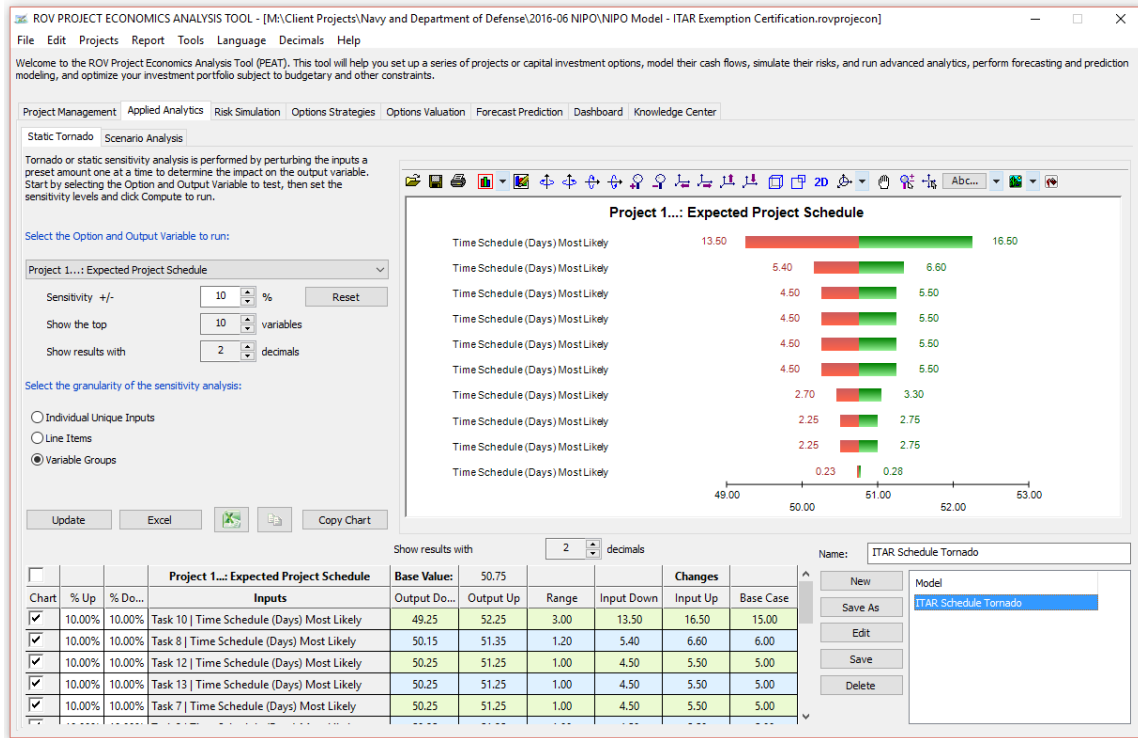


Figure 27: ITAR Schedule-Cost Input Assumptions and Sensitivities

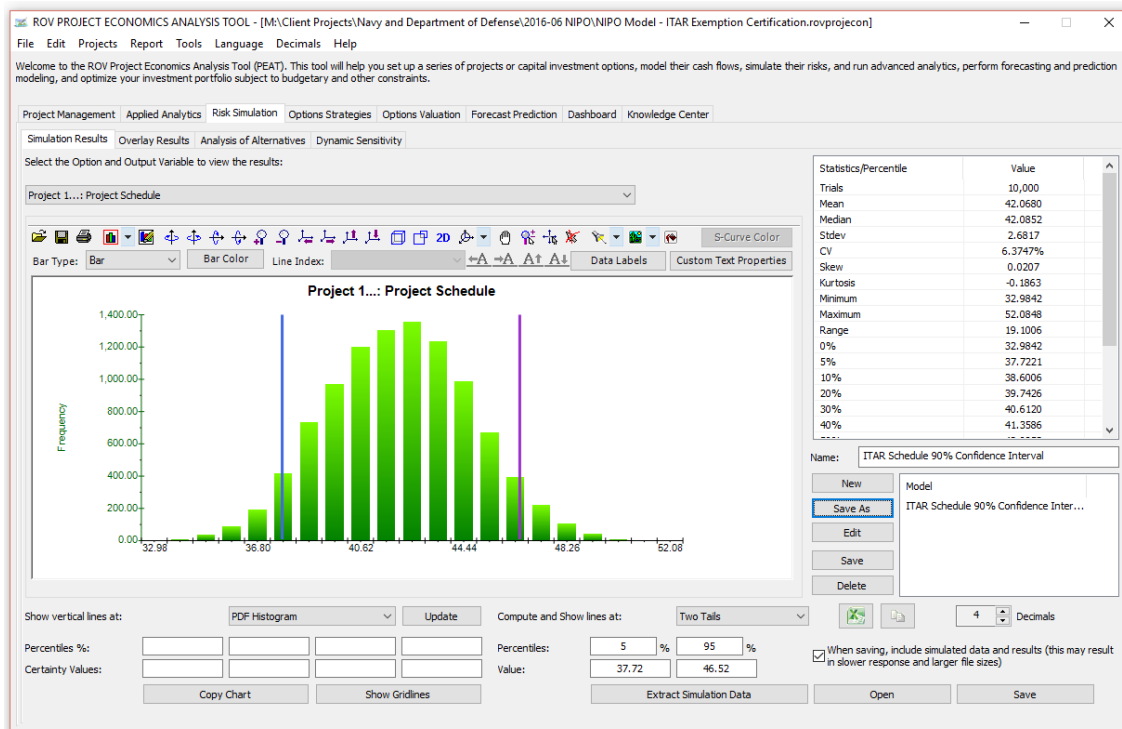


Figure 28: ITAR Distribution of Simulated Schedule



Third-Party Transfer Process

In Figure 29, the Third-Party Transfer Process (TPTP) is shown. In Task 1, the U.S. Department of State sends a request e-mail, including attachments, for each Third-Party Transfer case. The request is filed and entered into SharePoint, and an automated e-mail is sent to the deputies in 01D (Task 2).

In Task 3, the administrative work, data archiving, and staffing are performed. For instance, the SharePoint case data is set up, hard copies are created and printed, Outlook folders are created, stakeholder staffing requirements are determined, the WMT system is activated and the relevant data are entered, and stakeholders are sent a notification e-mail.

In Task 4, stakeholders evaluate the request and submit their responses. In Task 5, the stakeholders' responses are evaluated for consensus. If there is consensus, then the decision cover sheet is drafted (Task 6) and placed in the hard copy folder.

In Task 7, the hard copy is sent to the 01D Sea/Land Deputy for review and approval. Once the request is approved by the Sea/Land Deputy, an official response is sent to the Department of State (Task 8).

The final step, Task 9, is where the case is closed out in SharePoint and the WMT system and a hard copy is filed.

In the event that there is no consensus from the stakeholders' responses (Task 5), the process takes a slight detour, as seen in Figure 30. A new set of Tasks 6, 7, and 8 are required to analyze and address specific issues raised and identified with the appropriate offices, and to verify if said concerns were adequately addressed. If so, the appropriate responses are filed, and hard copies are printed and filed. The process then continues with Tasks 9–12 as usual (see Tasks 6–9 in Figure 29).

In the extreme event when Task 7's review of the issues indicate that problems still exist and there is no true consensus, the issues will have to be re-



analyzed (Task 8 in Figure 31). Only if the issues are all verified to be resolved will the next step be allowed to continue (Task 9) as usual (Tasks 10–14).

As the three process paths are nested within one another, Figure 32 shows the input assumptions in the model for the longest pathway, and Figures 33, 34, and 35 show the simulation results of the TPTP process. All results interpretation proceeds the same way as the previously laid-out processes.

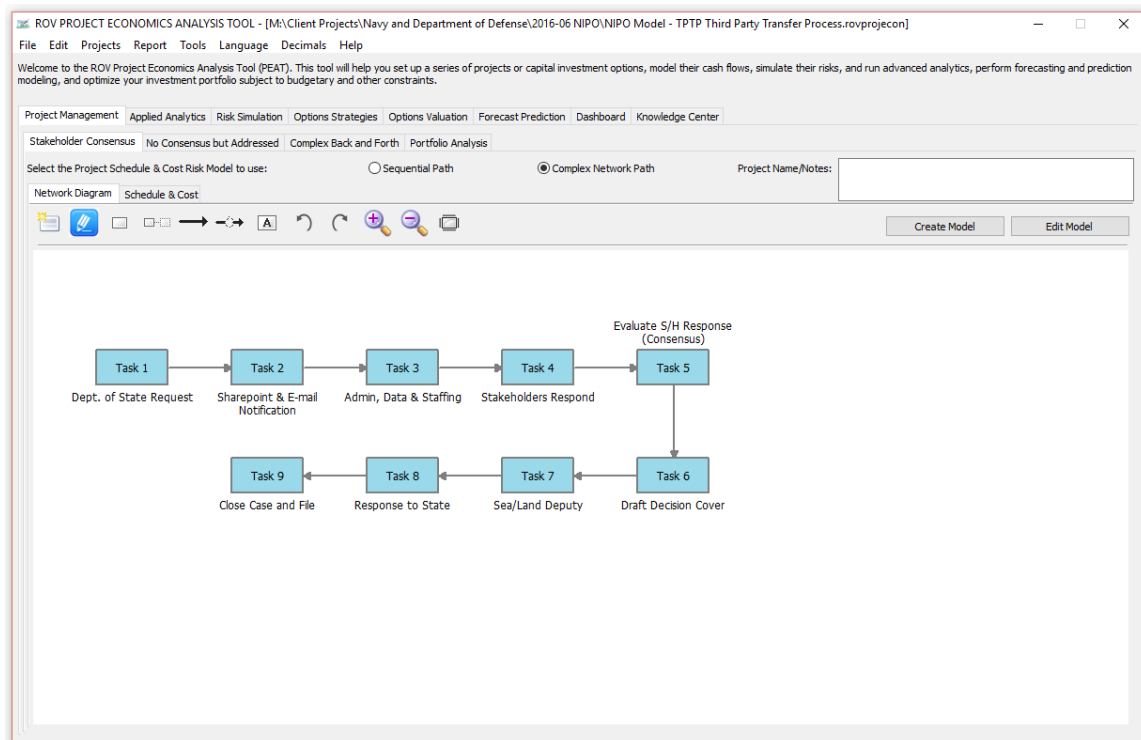


Figure 29: TPTP With Stakeholder Consensus

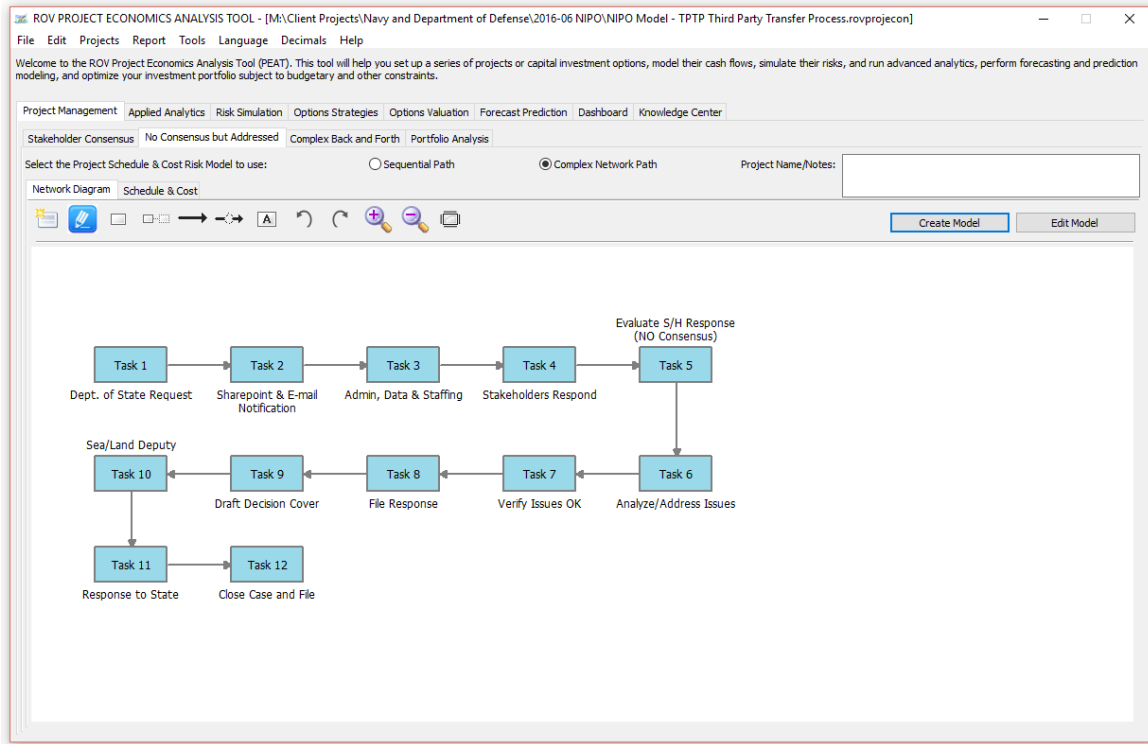


Figure 30: TPTP Without Stakeholder Consensus

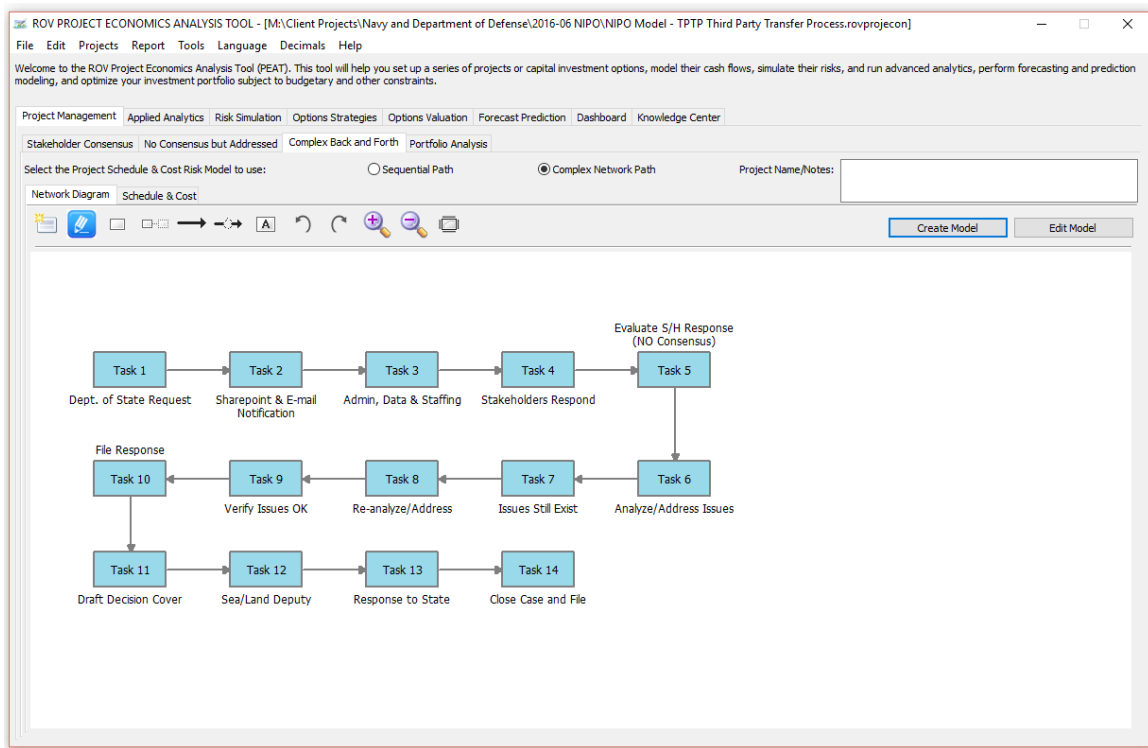


Figure 31: TPTP With Complex Back and Forth

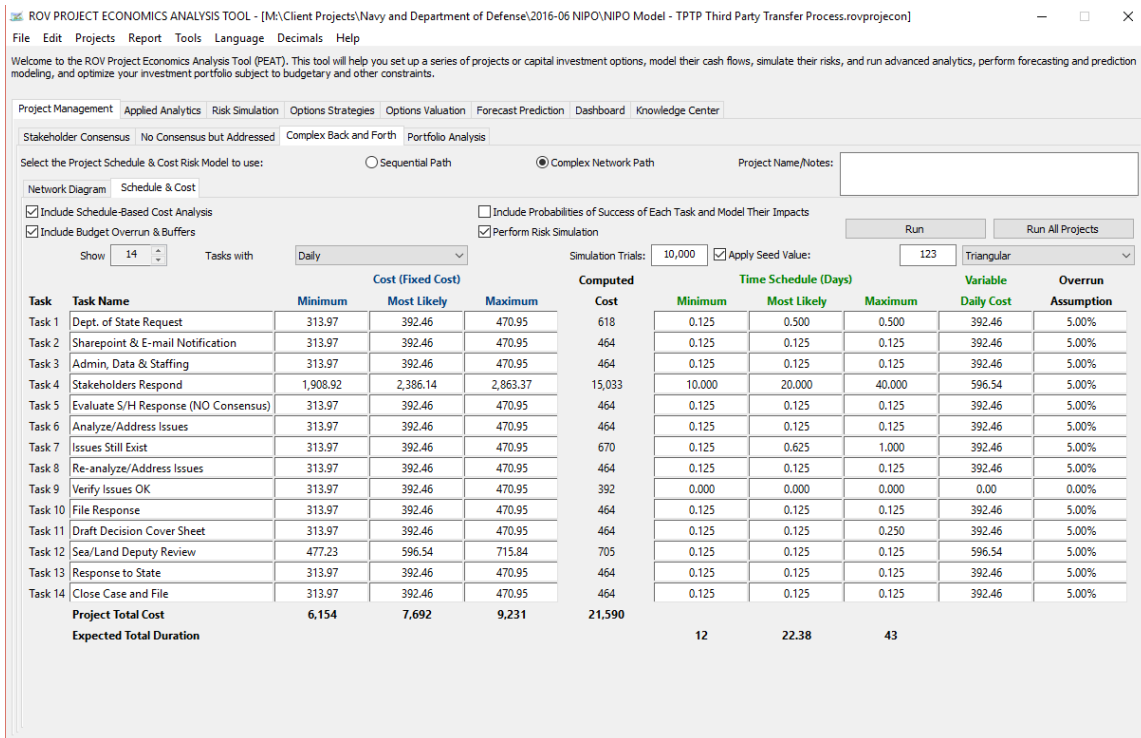


Figure 32: Input Assumptions for Complex Back and Forth



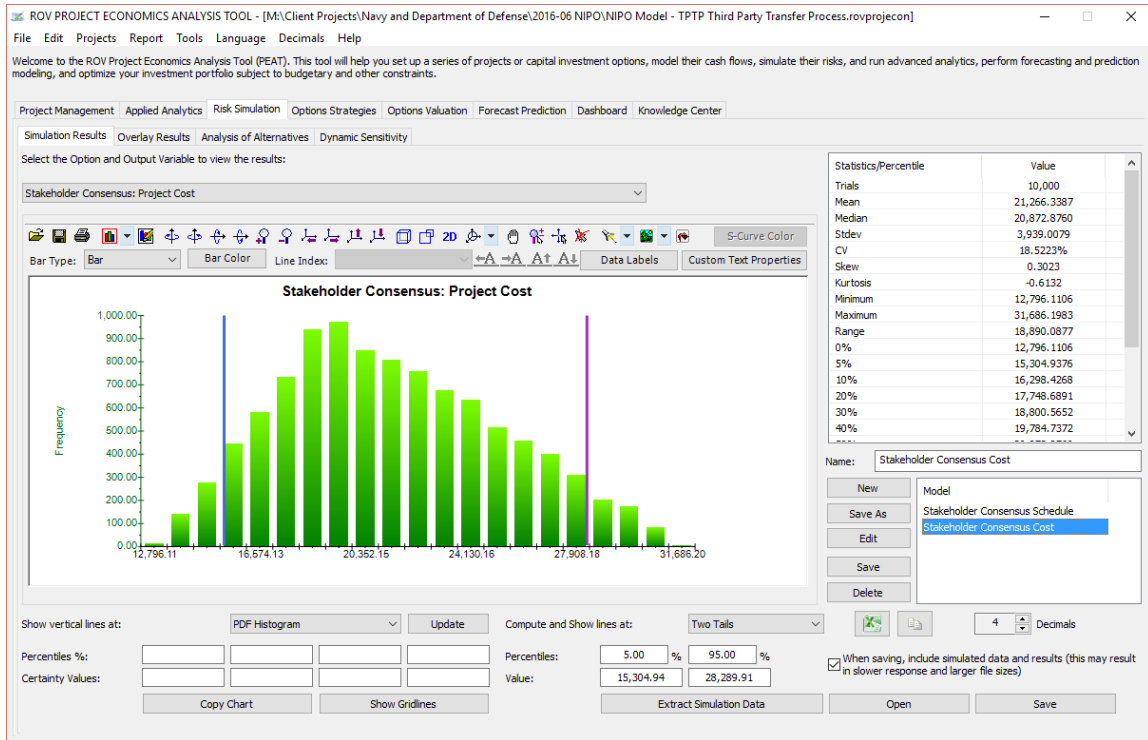
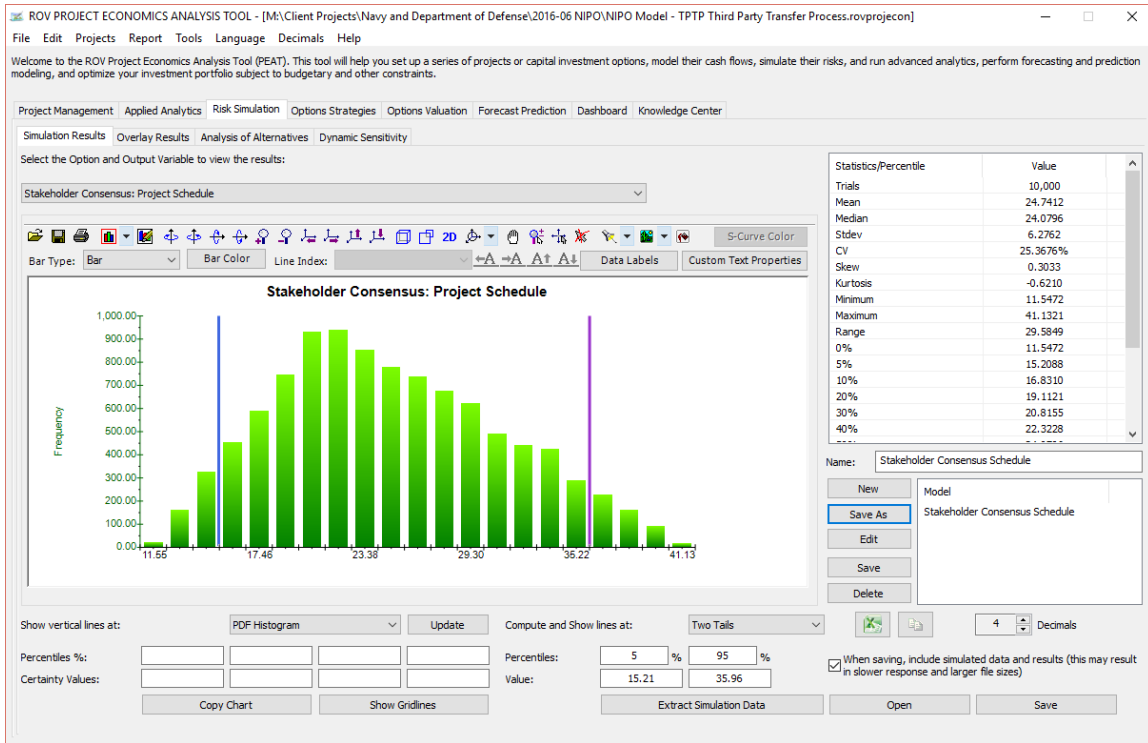


Figure 33: Simulation Schedule and Cost Results for Stakeholder Consensus



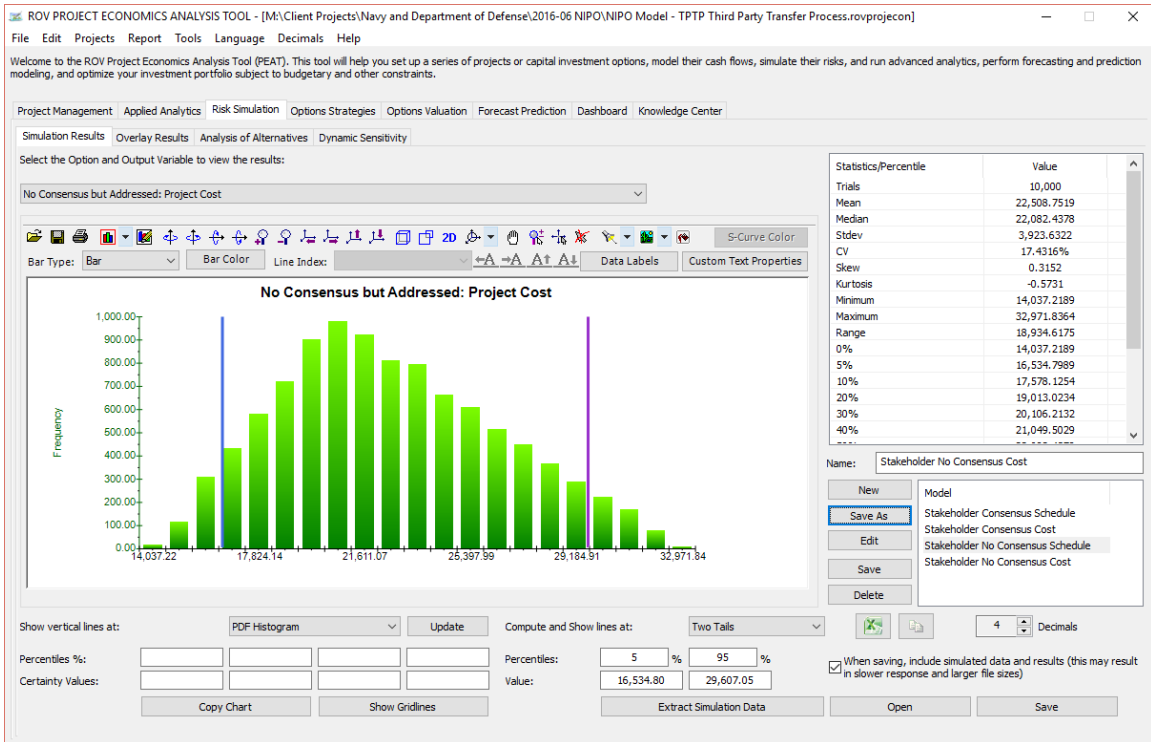
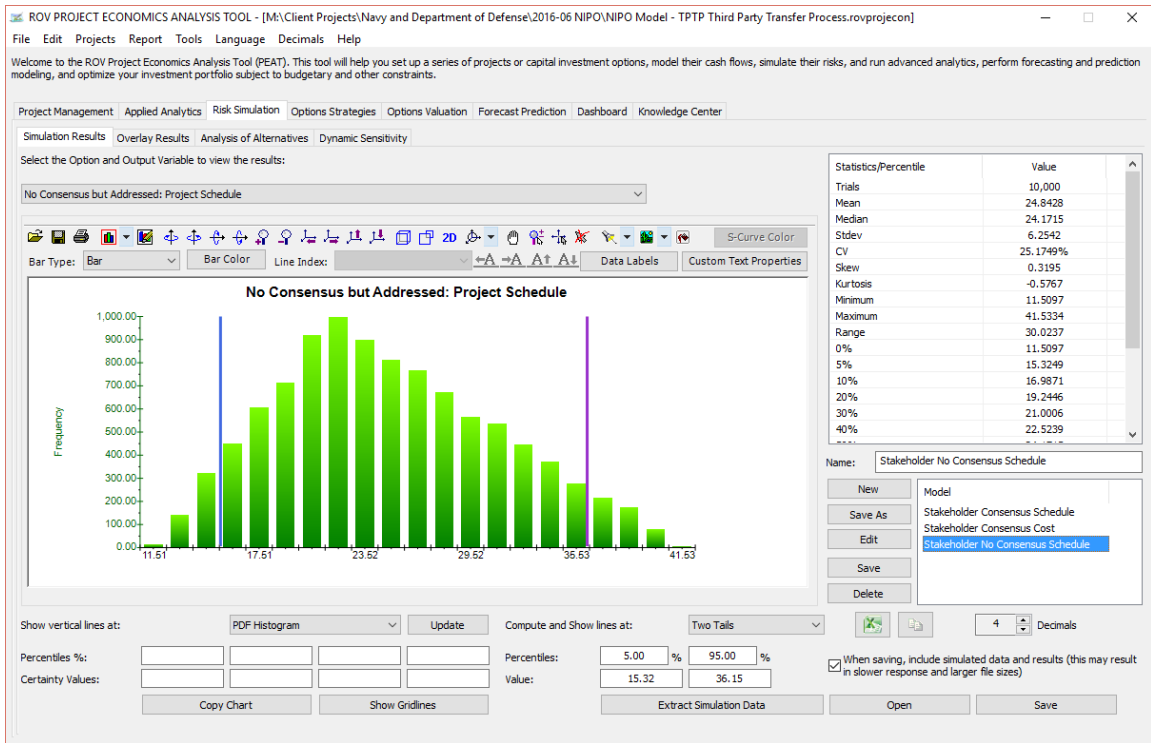


Figure 34: Simulation Schedule and Cost Results Without Stakeholder Consensus



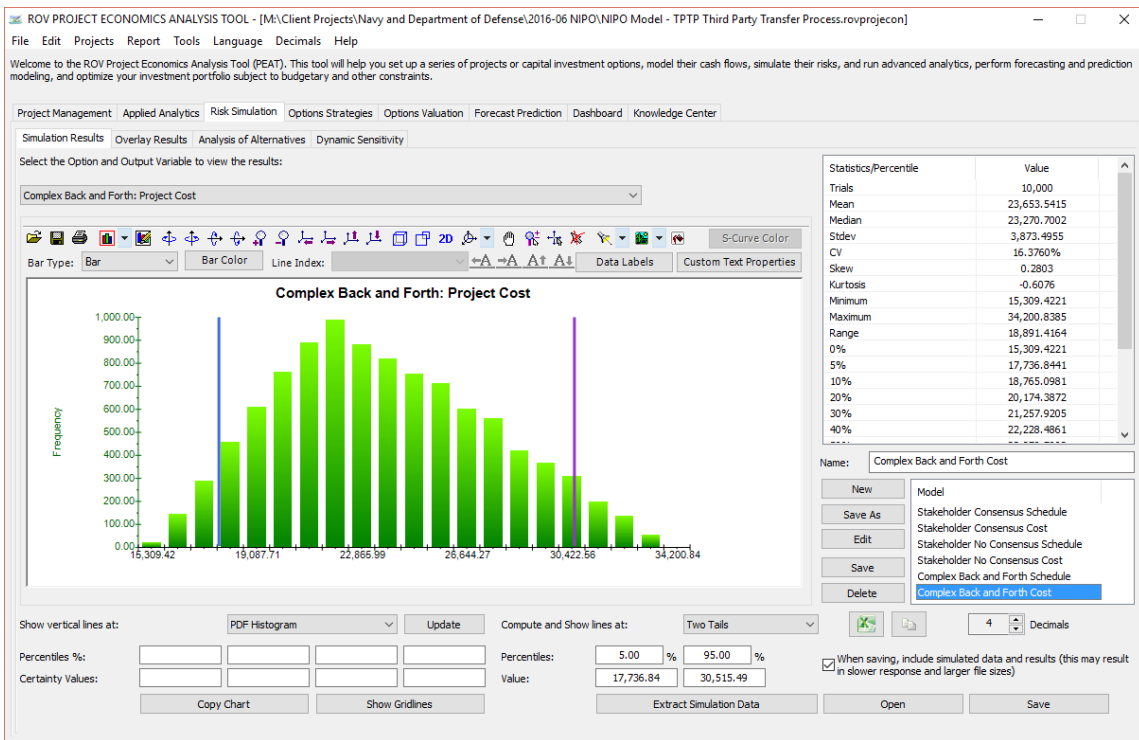
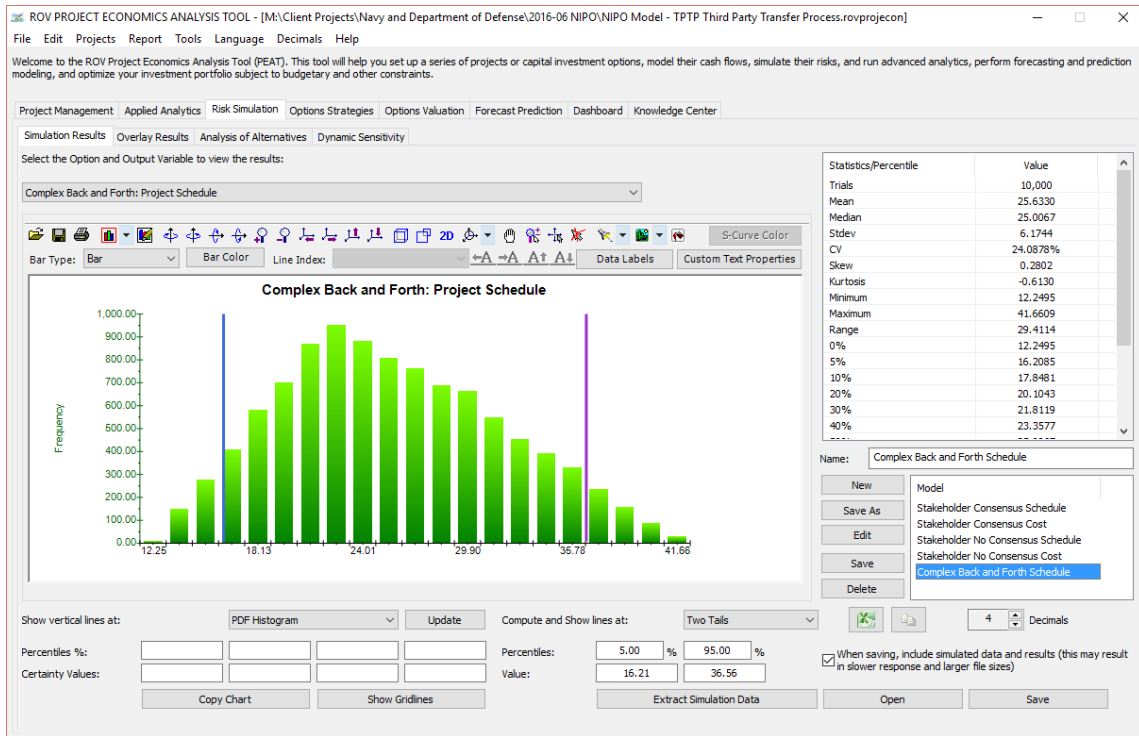


Figure 35: Simulation Schedule and Cost Results for Complex Back and Forth



TTSARB Full, TTSARB CBC, and TTSARB FDD

Figures 36, 37, and 38 show the process paths of the TTSARB product line (FDD, CBC, and Full TTSARB processes). Figures 39–42 show the TTSARB results, and their interpretations are identical to previous sections. See the Conclusion section for a summary of the results in simple-to-interpret tables.

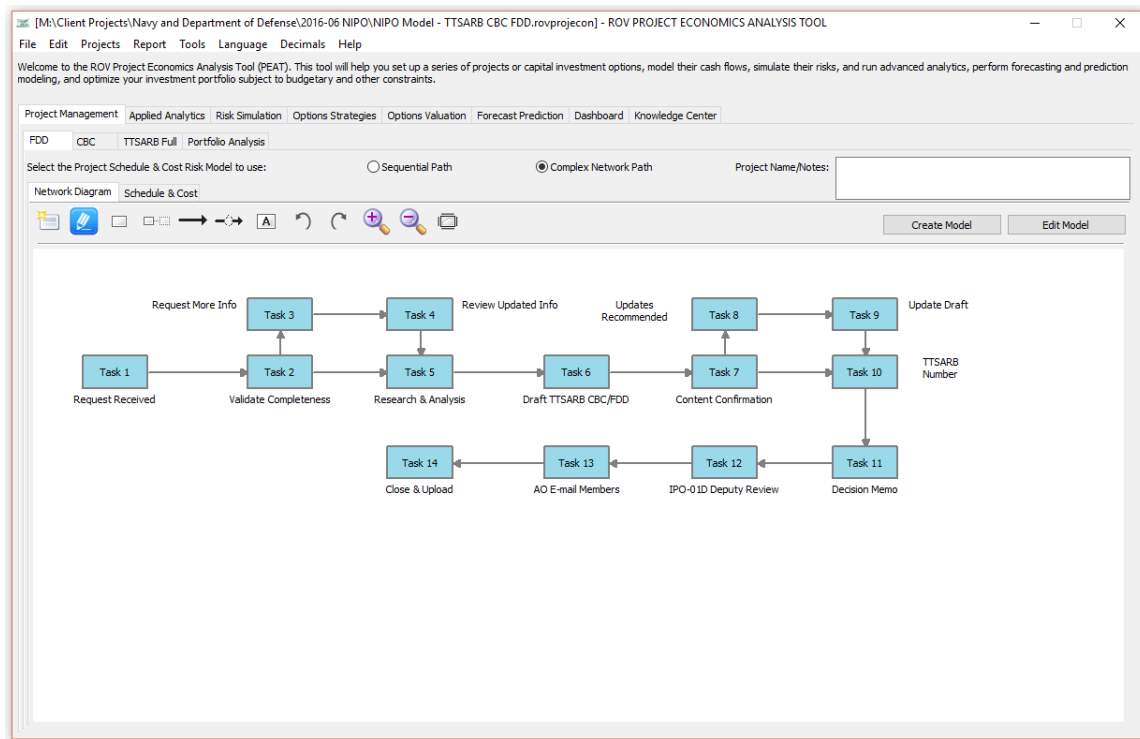


Figure 36: TTSARB FDD Process Path

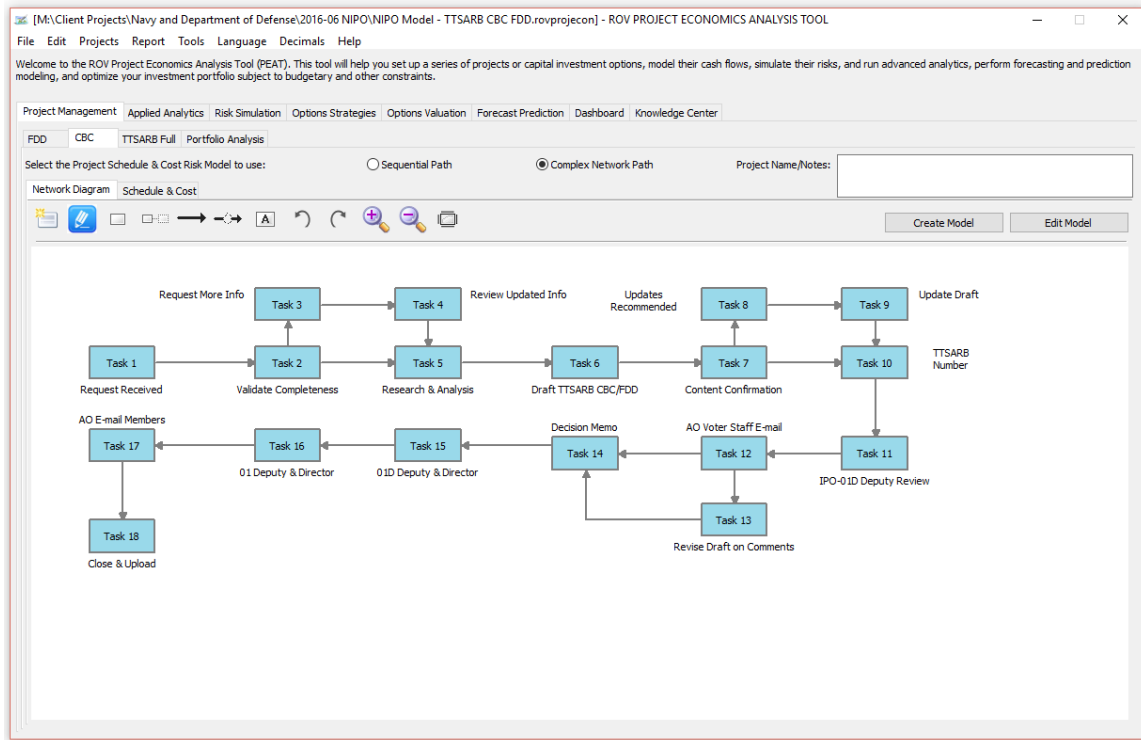


Figure 37: TTSARB CBC Process Path

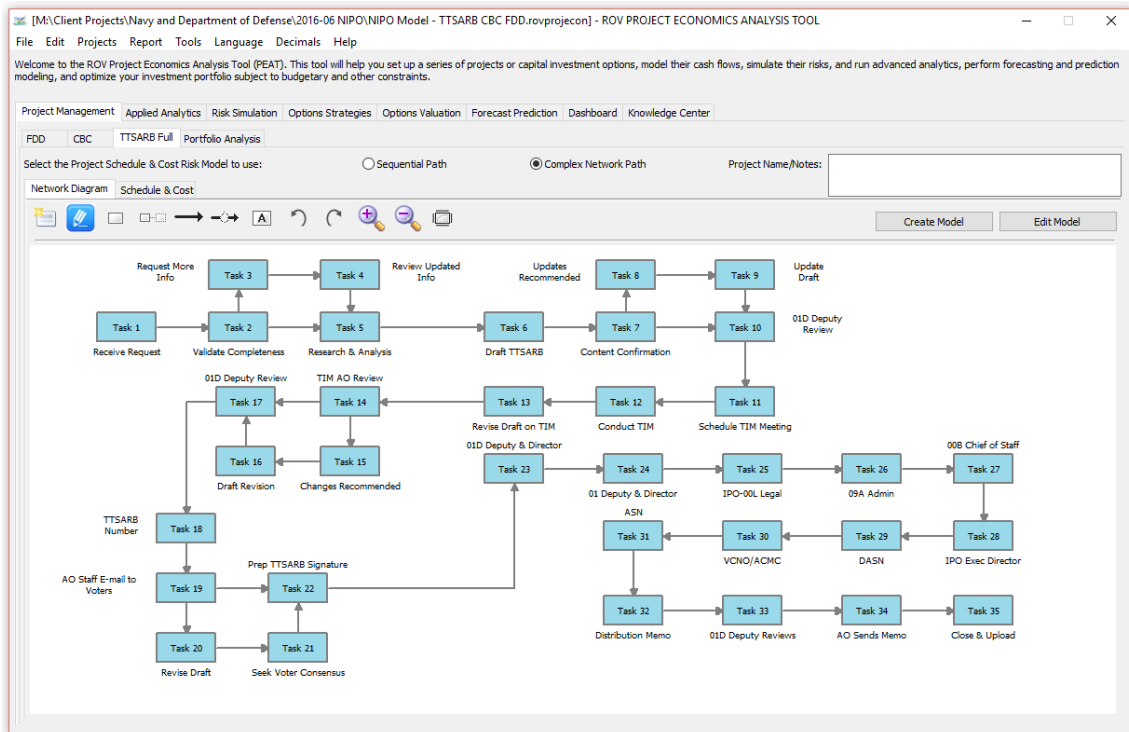


Figure 38: TTSARB Full Process Path



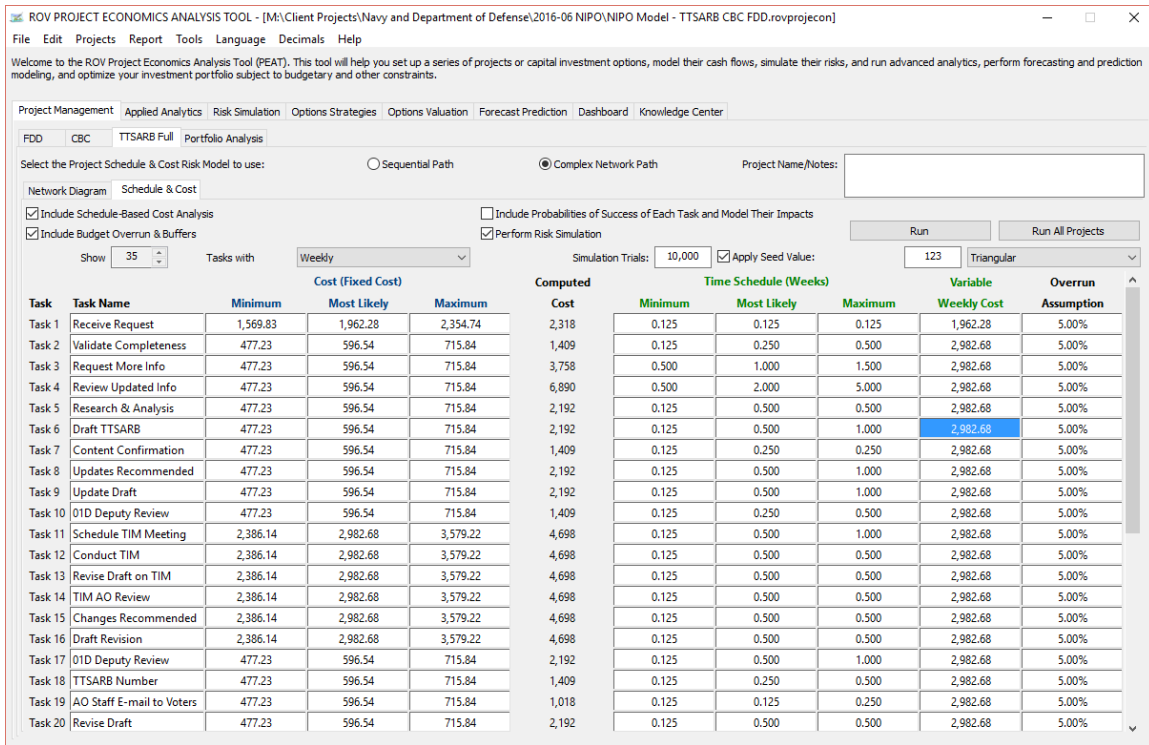


Figure 39: TTSARB Input Assumptions for Full Path

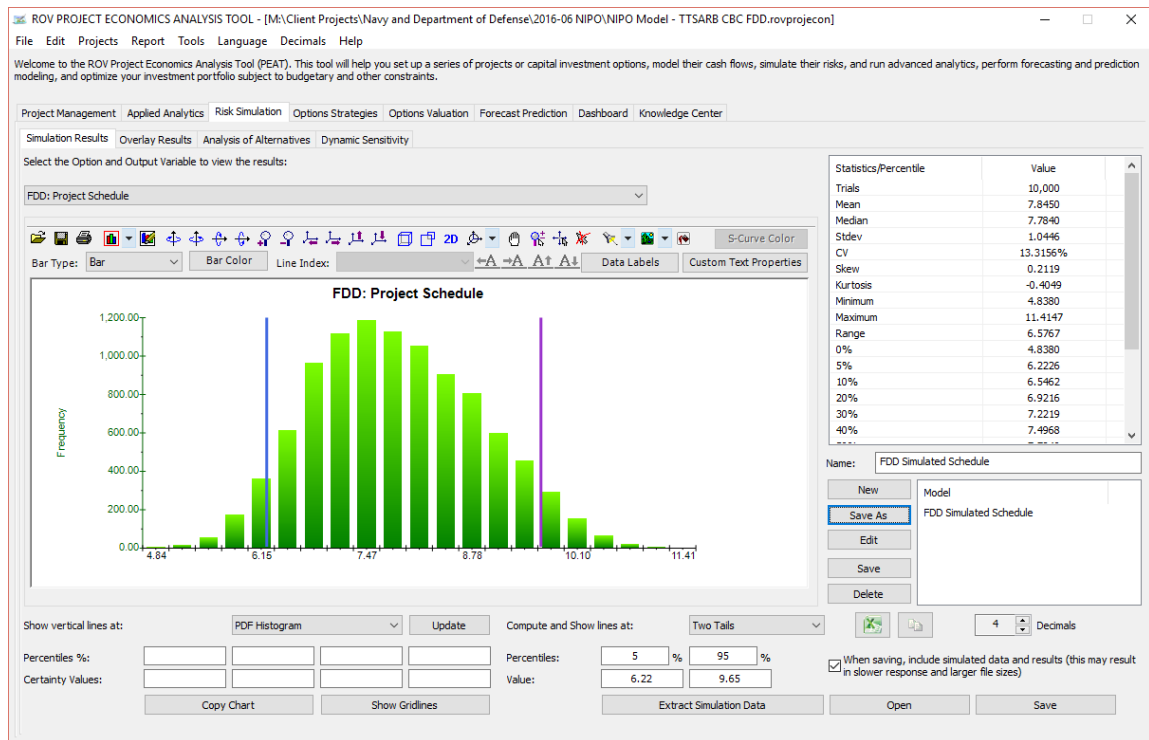


Figure 40: Simulation Schedule Results for TTSARB FDD



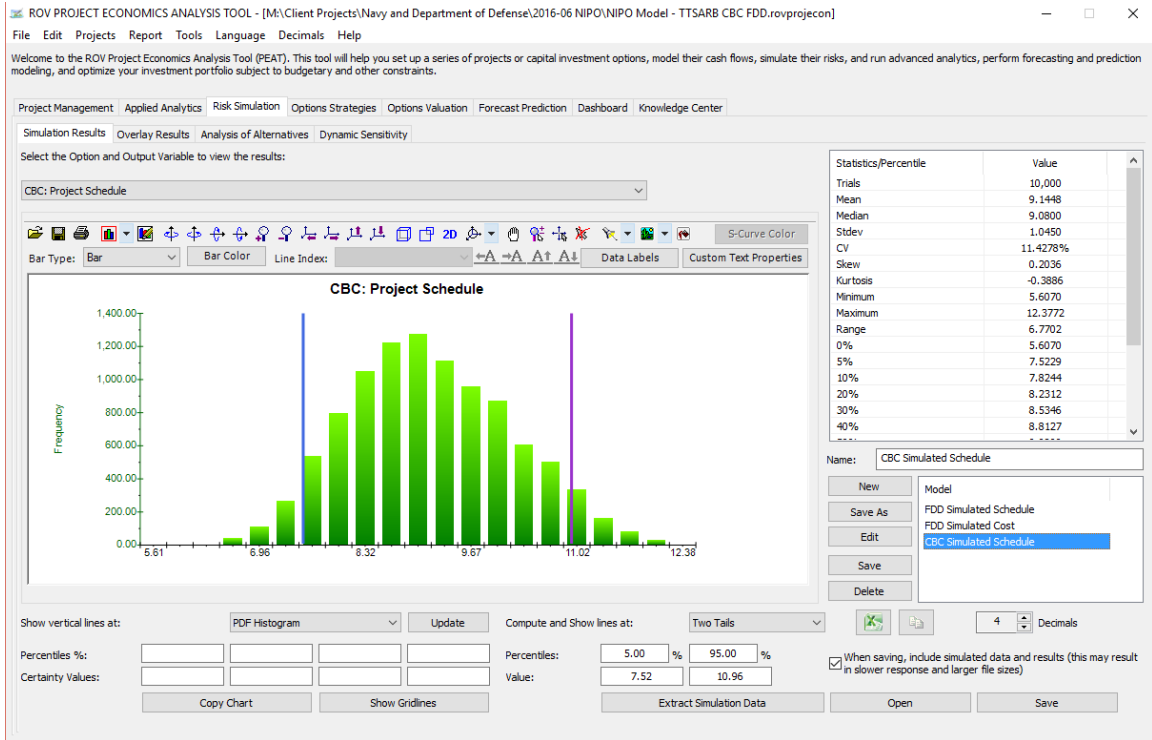


Figure 41: Simulation Schedule Results for TTSARB CBC

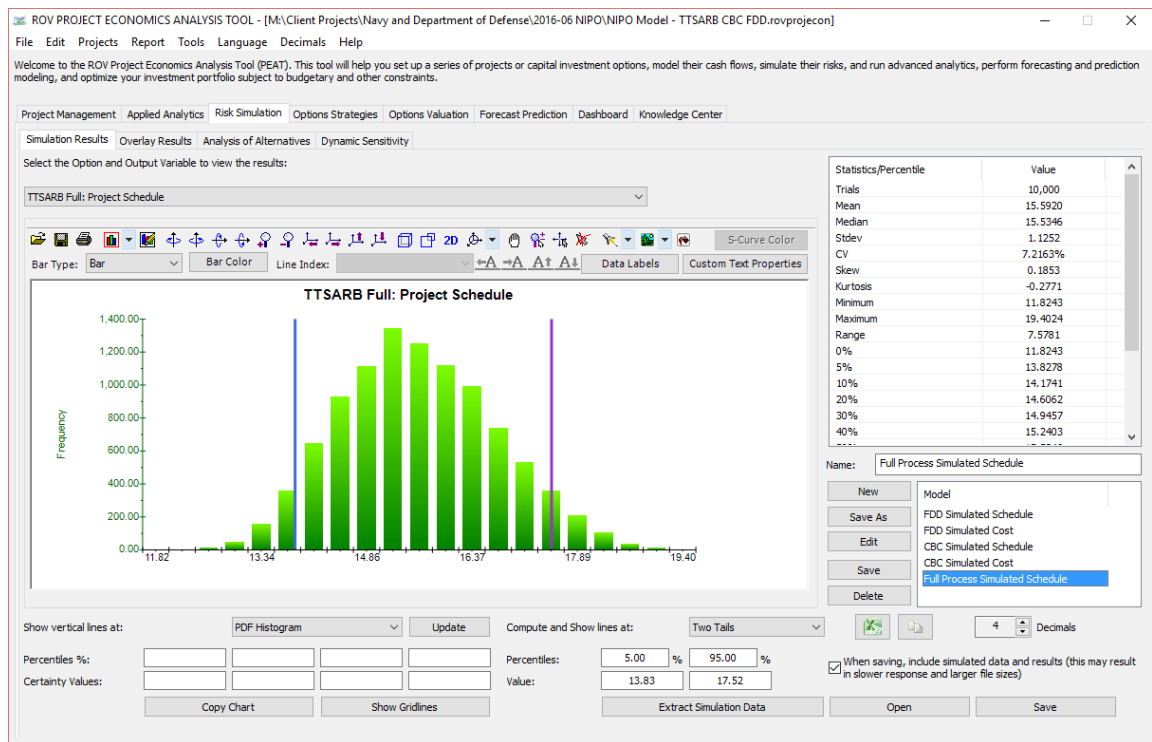


Figure 42: Simulation Schedule Results for TTSARB Full Process Path



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Conclusions and Recommendations

Figure 43 provides a summary of the simulation results for all of the product lines under analysis. The first three columns are the average, 5th, and 95th percentiles of the number of days or weeks it takes to complete a specific product line based on current manning levels (TTSARB product lines are measured in weeks versus working days for the other product lines.). The last three columns are the average, 5th, and 95th percentiles based on an anticipated reduction in manning. For this first phase of the analysis, we assumed that the reduction in manning is from 44 to 36 full-time equivalence, is organization-wide (i.e., without any preference in terms of less or more experienced individuals, pay grades, or departments), and equally applies to all product lines. In addition, we assumed that the same organizational structure that currently exists holds true with the reduced manning levels, while the incoming request signals remain the same as previous years.

Exceptions to National Disclosure Policy (ENDP)						
Simulated Schedule (Current) in Days			Simulated Schedule (Reduced Manning) in Days			
Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	
ENDP Standard Process	37.9	32.1	44.0	46.4	39.3	53.8
ITAR Exemption Certification (ITAR)						
Simulated Schedule (Current) in Days			Simulated Schedule (Reduced Manning) in Days			
Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	
ITAR Standard Process	42.0	37.7	46.5	51.4	46.1	56.9
NIPO Licensing						
Simulated Schedule (Current) in Days			Simulated Schedule (Reduced Manning) in Days			
Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	
Tiger Team Resolves	1.0	0.6	1.5	1.6	1.0	2.4
Less Complex Projects	45.3	36.9	54.3	55.3	45.1	66.3
Medium Complex Projects	51.5	42.5	60.8	62.9	51.9	74.2
More Complex Projects	66.5	55.5	77.7	81.3	67.8	94.9
Most Complex Projects	72.7	61.4	84.4	88.9	75.0	103.2
Third Party Transfers (TPTP)						
Simulated Schedule (Current) in Days			Simulated Schedule (Reduced Manning) in Days			
Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	
With Stakeholder Consensus	24.7	15.2	35.9	30.2	18.6	43.9
Without Stakeholder Consensus	24.8	15.3	36.2	30.4	18.7	44.2
Complex Back and Forth	25.6	16.2	36.5	31.3	19.8	44.7
Technology Transfer Security Assistance Review Board (TTSARB)						
Simulated Schedule (Current) in Weeks			Simulated Schedule (Reduced Manning) in Weeks			
Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile	
FDD Foreign Disclosure Determination	7.8	6.2	9.6	9.6	7.6	11.8
CBC Case by Case Evaluation	9.1	7.5	10.9	11.2	9.2	13.4
Full TTSARB Implementation	15.6	13.8	17.5	19.1	16.9	21.4

Figure 43: Summary Results With Current vs. Decreased Manning Levels



We see in Figure 43 that there is certainly an impact on the time-to-completion schedules for all product lines. For instance, the ENDP standard requests on average now take 37.9 days to complete, with a 90% confidence interval (i.e., there is a 90% probability that a request will be completed within this time period, accounting for the uncertainties in complexity as well as number of arriving requests) of 32.1 and 44.0 days.

In the reduced manning environment, the average goes from 37.9 days to 46.4 days, constituting an increase of 8.5 days on average. This change is a 22.4% increase in the number of days required and can be seen in Figure 44, which provides the marginal impacts of both schedule and cost.

This increased schedule results in an increase in the cost to complete a specific request, where we define cost solely as the gross FTE salary levels for the individuals involved in each of the tasks in the product lines. For the purposes of this first phase of research, where the bulk of the work was focused on developing the methodology, developing the software module, mapping the processes and tasks, soliciting the input assumptions from subject matter experts, running the simulations, and performing trial runs of the analytics, certain gross assumptions are required. One of these assumptions is that we do not yet incorporate the number of projects and types of requests an individual is dealing with on average per day or the number and types of incoming signal requests. These assumptions can be tested and modeled in the next phase of the work, if desired, to obtain better estimates of actual dollar amounts, assuming such dollar costs are of interest to the sponsors. This current first-phase work is used as a proof of concept such that any such intricacies and complexities can be flushed out, modeled, and accounted for in the next phase of the work. Additional issues that can be considered are also listed in the following section on recommended next steps.

As we had to use such gross approximations and assumptions, the total costs for each product line assume that individuals involved are only working on a single project or request at a time. This clearly is not reality, which we can address in the next phase of the research. However, such a gross level cost is still valuable



information in that we can compare across multiple product lines and determine which product line(s) are most expensive to execute (i.e., cross-sectional analysis). In addition, instead of looking at actual dollar levels, we can review the percentage difference or increases in cost (i.e., relative analysis). In other words, instead of stating that processing a specific product request signal costs a certain amount, we can conclude that, given the same state of nature (similar levels of request signals a month with similar levels of complexities, handled using the same processes), with a manning reduction, the schedule will increase X days and costs will, as a consequence, increase by Y%. These cost increments are shown in Figure 44 in the fourth column (e.g., there is a simulated increase of 19.5% in costs to complete an ENDP process under a reduced manning environment compared to current existing manning structures).



Exceptions to National Disclosure Policy (ENDP) - Marginal Effects						
	Simulated Schedule Results (Days)			Simulated Schedule Results (\$)		
	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
ENDP Standard Process <i>% Increase</i>	8.5 22.4%	7.2	9.8	\$4,652 19.5%	\$3,913	\$5,419
ITAR Exemption Certification (ITAR) - Marginal Effects						
	Simulated Schedule Results (Days)			Simulated Schedule Results (\$)		
	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
ITAR Standard Process <i>% Increase</i>	9.4 22.4%	8.4	10.4	\$7,776 18.7%	\$7,066	\$8,503
NIPO Licensing - Marginal Effects						
	Simulated Schedule Results (Days)			Simulated Schedule Results (\$)		
	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
Tiger Team Resolves <i>% Increase</i>	0.6 14.6%	0.3	0.9	\$352 14.6%	\$215	\$498
Less Complex Projects <i>% Increase</i>	10.0 18.3%	8.2	12.0	\$5,244 18.3%	\$4,212	\$6,366
Medium Complex Projects <i>% Increase</i>	11.4 18.0%	9.4	13.4	\$5,940 18.0%	\$4,870	\$7,078
More Complex Projects <i>% Increase</i>	14.8 19.1%	12.3	17.2	\$8,296 19.1%	\$6,917	\$9,740
Most Complex Projects <i>% Increase</i>	16.2 22.3%	13.6	18.8	\$9,018 18.8%	\$7,581	\$10,761
Third Party Transfers (TPTP) - Marginal Effects						
	Simulated Schedule Results (Days)			Simulated Schedule Results (\$)		
	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
With Stakeholder Consensus <i>% Increase</i>	5.5 17.6%	3.4	8.0	\$3,389 17.6%	\$2,063	\$4,968
Without Stakeholder Consensus <i>% Increase</i>	5.6 16.5%	3.4	8.0	\$3,392 16.5%	\$2,063	\$4,990
Complex Back and Forth <i>% Increase</i>	5.7 22.3%	3.6	8.2	\$3,468 16.0%	\$2,149	\$5,003
Technology Transfer Security Assistance Review Board (TTSARB) - Marginal Effects						
	Simulated Schedule Results (Weeks)			Simulated Schedule Results (\$)		
	Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
FDD Foreign Disclosure Determination <i>% Increase</i>	1.8 12.4%	1.4	2.2	\$8,136 12.4%	\$6,807	\$9,496
CBC Case by Case Evaluation <i>% Increase</i>	2.1 12.0%	1.7	2.5	\$9,876 12.0%	\$8,503	\$11,365
Full TTSARB Implementation <i>% Increase</i>	3.5 22.4%	3.1	3.9	\$59,662 52.3%	\$57,741	\$61,655

Figure 44: Marginal Impacts of Reduced Manning—Higher Cost and Longer Schedules

Recommended Next Steps

It is recommended that NIPO personnel be trained in the use of the PEAT software such that all updated analyses and modifications can be done in-house. Modeling is complete for the various processes, but input assumptions are still based on subject matter experts (SMEs). We therefore recommend collecting actual data going forward in order to better “calibrate” the inputs based on real-life conditions. We can provide inputs and suggestions on how to generate a database and methods to capture said required data.



In addition, we recommend thinking outside the box in terms of various things, such as

- Identifying the exact levels of FTEs that will be reduced and the costs saved, and comparing them to the higher costs of completing each of the product requests given that the schedule to complete the same number of requests will be extended. This essentially provides a justification and modeling of the return on investment (ROI) on the FTE reduction, or perhaps the lack thereof.
- Using the simulated probability distributions to determine “how well” the organization is performing (e.g., running at 92% efficiency, etc.). This creates level of performance metrics for the organization.
- Using control charts (based on simulated results) to determine if any processes are in-control or out-of-control over time.
- Determining if charging additional “costs” to complete a product line can be “externalized” or charged to third-party government contractors to accelerate any requests.
- Applying historical data to calibrate the input assumptions of the models and results in this report.
- Performing “touch-time” analysis to determine how much actual time a project is “touched” during the production process of a product line, providing a much more accurate determination of actual costs of each product line.
- Factoring in the number of projects/requests each product line receives a year and simulating these as additional inputs to better calibrate the model.
- Identifying critical success factors to start collecting schedule data for better estimates.
- Making modifications to the ROV PEAT module to further facilitate data entry such as salary and wage levels, without the need for any preliminary work in Excel to compute said salary levels.
- Considering changes in the organizational structure, with a possible reshuffling of responsibilities as well as changes in the mapped processes.
- Reusing the same methodologies across other groups within NIPO to create a portfolio of resources that can be optimized (i.e., how to shuffle the focus of a limited number of FTEs within the organization to maximize “military value” or benefit to the entire organization).



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Appendix A. Example Applications of Schedule-Cost Risk

All organizations depend heavily on project planning tools to forecast when various projects will complete. Completing projects within specified times and budgets is critical to facilitate smooth business operations. In our high-technology environment, many things can impact schedule. Technical capabilities can often fall short of expectations. Requirements are insufficient in many cases and need further definition. Tests can bring surprising results—good or bad. A whole host of other reasons can lead to schedule slips. On rare occasions, we may run into good fortune, and the schedule can be accelerated. Project schedules are inherently uncertain and change is normal. Therefore, we should expect changes and find the best way to deal with them. So why do projects almost always take longer than anticipated? The following discussion presents a description on shortcomings in the traditional methods of schedule estimation and how the Risk Simulator software can be applied to address these shortcomings.

Traditional Schedule Management

Traditional schedule management typically starts with a list of tasks. Next, these tasks are put in order and linked from the predecessor to successor for each task. They are typically displayed in either a Gantt chart form or a network. For our discussion, we concentrate on the network. The duration for each task within the network is then developed. The estimated duration for each task is given a single-point estimate, even though we know from experience that this estimate should be a range of values. The first shortcoming, then, is using a single-point estimate. In addition, many people who provide duration estimates try to put their best foot forward and give an optimistic or best-case estimate. If we assume that the probability of achieving this best-case estimate for one task is 20%, then the likelihood of achieving the best case for two tasks is merely 4% (20% of 20%), and three tasks yields only 0.8%. Within a real project with many more tasks, there is thus only an infinitesimal chance of making the best-case schedule.



Once the task duration estimates have been developed, the network is constructed, and the various paths through the network are traced. The task durations are summed along each of these paths, and the one that takes the longest is identified as the *critical path*. Figure A1.1 illustrates an example network and critical path. The sum of task durations along the critical path is the *project completion date*. In Figure A1.1, there are four paths through the network from beginning to end. The shortest/quickest path is Tasks 1-2-3-10-11 with a total duration of 22 days. The next shortest path is Tasks 1-7-8-9-10-11 at 34 days, and then path 1-4-5-6-10-11 at 36 days. Finally, the path of Tasks 1-4-8-9-10-11 takes the longest at 37 days and is the critical path for this network.

So let us assume that this network of tasks is our part of a larger effort and some other effort upstream of ours has overrun by a day. Our boss has asked us to shorten our schedule by one or two days to get the overall effort back on track. Traditional schedule management has one target: shorten the longest duration item in the critical path. Another approach is to shorten every task on the entire critical path. Because the first technique is more focused, more prone to success, and creates fewer conflicts on our team, let us assume that we will use that one. Hence, we will want to reduce Task 8 from 10 days to 9 days to shorten our schedule and we will satisfy our boss or our customer. Let us leave the traditional methodology at this stage feeling satisfied with our efforts.

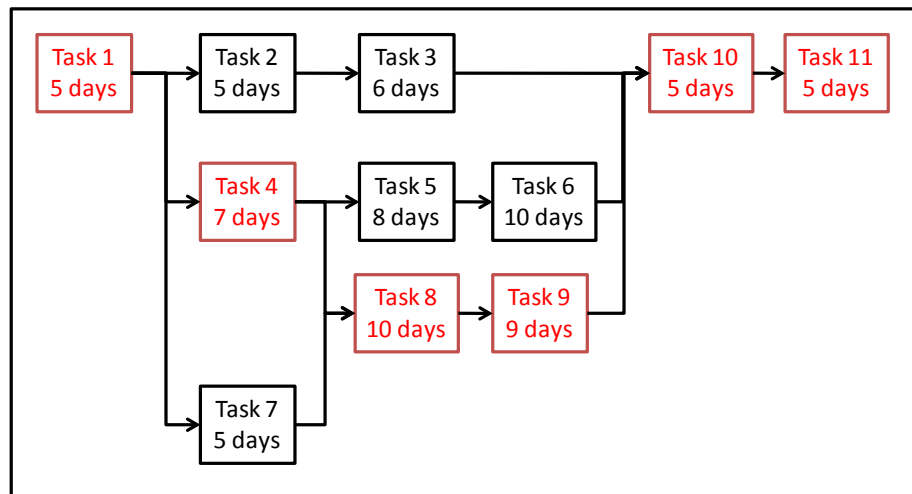


Figure A1.1: Schedule Network

Probabilistic Schedule Management

If we agree that task durations can vary, then that uncertainty should be taken into account in schedule models. A schedule model can be developed by creating a probability distribution for each task, representing the likelihood of completing the particular task at a specific duration. Monte Carlo simulation techniques can then be applied to forecast the entire range of possible project durations.

A simple triangular distribution is a reasonable probability distribution to use to describe the uncertainty for a task's duration. It is a natural fit because if we ask someone to give a range of duration values for a specific task, he or she usually supplies two of the elements: the minimum duration and the maximum duration. We need only ask or determine the most likely duration to complete the triangular distribution. The parameters are simple, intuitively easy to understand, and readily accepted by customers and bosses alike. Other more complex distributions, such as the beta or the Weibull, could be used, but little, if anything, is gained because the determination of the estimated parameters for these distributions is prone to error and the method of determination is not easily explainable to the customer or boss.

To get the best estimates, we should use multiple sources to get the estimates of the minimum, most likely, and maximum values for the task durations. We can talk to the contractor, the project manager, and the people doing the hands-on work and then compile a list of duration estimates. Historical data can also be used, but with caution, because many efforts may be similar to past projects but usually contain several unique elements or combinations. We can use Figure A1.2 as a guide. Minimum values should reflect optimal utilization of resources. Maximum values should take into account substantial problems, but it is not necessary to account for the absolute worst case where everything goes wrong and the problems compound each other. Note that the most likely value will be the value experienced most often, but it is typically less than the median or mean in most cases.



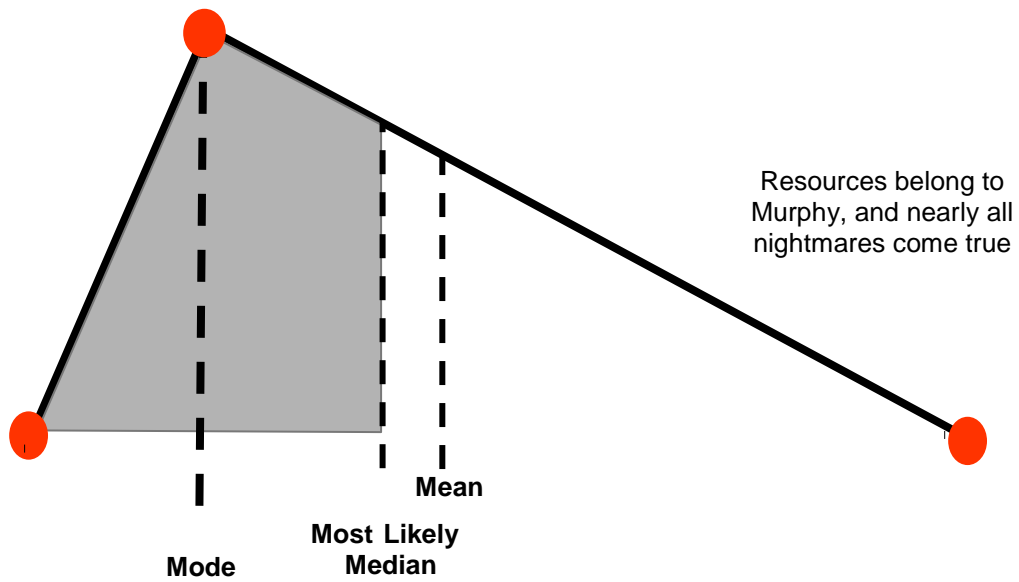


Figure A1.2: Triangular Distribution

For our example problem, shown in Figure A1.1, the minimum, most likely, and maximum values given in Table A1.1 will be used. We can use Risk Simulator’s input assumptions to create triangular distributions based on these minimum, most likely, and maximum parameters. The column of dynamic duration values shown in the table was created by taking one random sample from each of the associated triangular distributions.

Table A1.1: Range of Task Durations

Task #	Task Name	Dynamic Duration	Minimum	Most Likely	Maximum	Point Estimate
1	Stakeholder Analysis	5.78	4.5	5	6	5
2	Objectives Hierarchy	4.79	4.5	5	6	5
3	Decision Metrics Development	6.16	5.5	6	7	6
4	Functional Analysis	7.78	6	7	9	7
5	Primary Module Rqmts	9.22	7	8	10	8
6	Primary Module Development	10.12	9	10	13	10
7	Secondary Module Functional Analysis	5.42	4.5	5	6	5
8	Secondary Requirements Allocation	10.05	9	10	12	10
9	Secondary Module Development	9.40	8	9	10	9
10	Trade Studies	3.33	2.5	3	4	3
11	Final Development Specification	3.76	2.5	3	4	3

After the triangular distributions are created, the next step is to use the schedule network to determine the paths. For the example problem shown in Figure A1.1, there are four paths through the network from beginning to end. These paths are shown in Table A1.2 with their associated durations. (Note: When setting up the spreadsheet for the various paths, it is absolutely essential to use the input assumptions for the task durations and then reference these task duration cells when calculating the duration for each path. This method ensures that the duration of individual tasks is the same regardless of which path is used.) The overall schedule total duration is the maximum of the four paths. In Risk Simulator, we would designate that cell as an *Output Forecast*. In probabilistic schedule analysis, we are not concerned with the critical path/near-critical path situations because the analysis automatically accounts for all path durations through the calculations.

Table A1.2: Paths and Durations for Example Problem

Path1	Duration1	Path2	Duration2	Path3	Duration3	Path4	Duration4
1	5.78	1	5.78	1	5.78	1	5.78
2	4.79	4	7.78	4	7.78	7	5.42
3	6.16	5	9.22	8	10.05	8	10.05
10	3.33	6	10.12	9	9.40	9	9.40
11	3.76	10	3.33	10	3.33	10	3.33
		11	3.76	11	3.76	11	3.76
Total1	23.81	Total2	39.99	Total3	40.10	Total4	37.73

Overall Schedule Total >>>>>> 40.0968125 =MAX(Total1,Total2,Total3,Total4)

We can now use Risk Simulator and run a Monte Carlo simulation to produce a forecast for the schedule duration. Figure A1.3 shows the results for the example problem. Let us return to the numbers given by the traditional method. The original estimate stated the project would be complete in 37 days. If we use the left-tail function on the forecast chart, we can determine the likelihood of completing the task in 37 days based on the Monte Carlo simulation. In this case, there is a mere 8.27% chance of completion within the 37 days. This result illustrates the second shortcoming in the traditional method: Not only is the single-point estimate incorrect, but it also puts us in a high-risk overrun situation before the work even has started!



As shown in Figure A1.3, the median value is 38.5 days. Some industry standards recommend using the 80% certainty value for most cases, which equates to 39.5 days in the example problem.

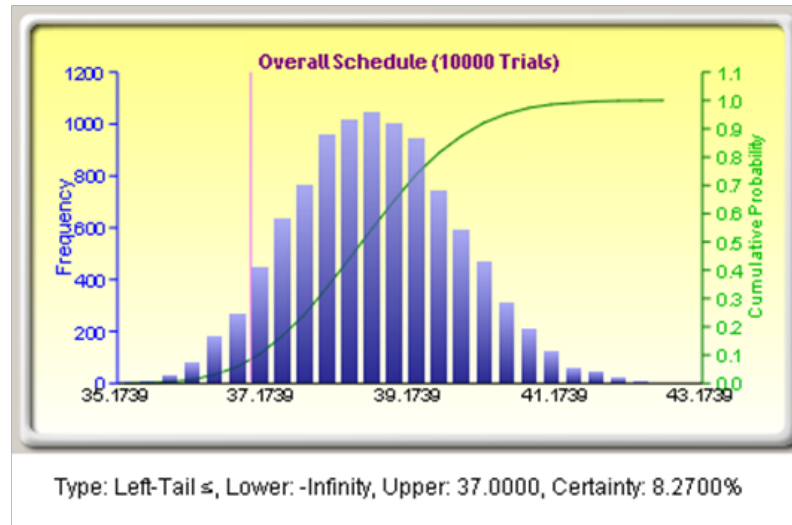


Figure A1.3: Results of Monte Carlo Analysis

Now let us revisit the boss's request to reduce the overall schedule by one day. Where do we put the effort to reduce the overall duration? If we are using probabilistic schedule management, we do not use the critical path, so where do we start? Using Risk Simulator's Tornado and Sensitivity Analysis tools, we can identify the most effective targets for reduction efforts. The tornado chart (see Figure A1.4) identifies the variables (tasks) most influential on the overall schedule. This chart provides the best targets to reduce the mean/median values. We cannot address the mean/median without addressing the variation, however. The Sensitivity Analysis tool shows what variables (tasks) contribute the most to the variation in the overall schedule output (see Figure A1.5). In this case, we can see that the variation in Task 4 is the major contributor to the variation in the overall schedule. Another interesting observation is that the variation in Task 6, a task *not* on the critical path, is also contributing nearly 9% of the overall variation.

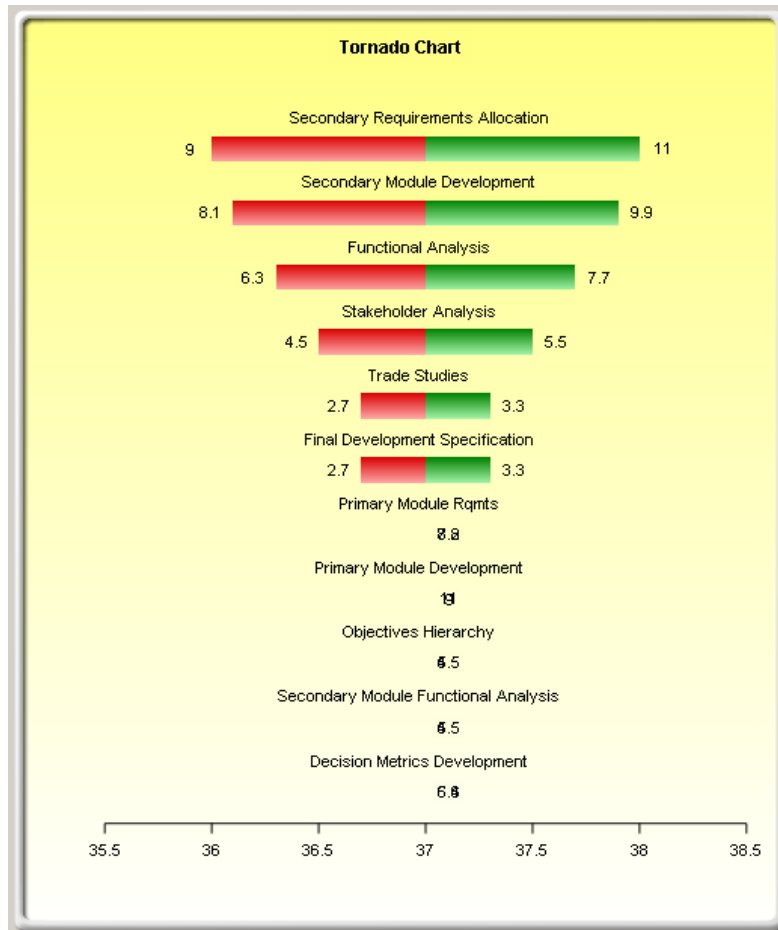


Figure A1.4: Tornado Chart

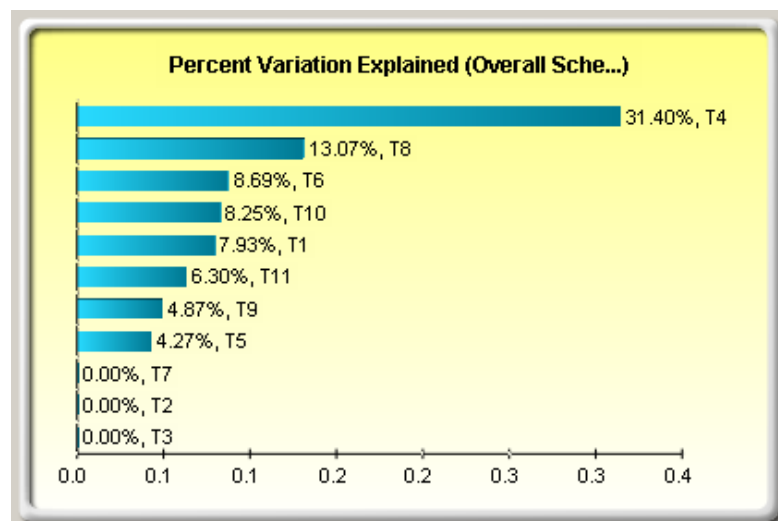


Figure A1.5: Sensitivity Analysis Chart

In this example, reducing the schedule duration for Task 4, Task 8, and Task 9 would pay the most dividends as far as reducing the overall schedule length. Determining the underlying reasons for the substantial variation in Tasks 4, 6, and 8 would likely give better insight into these processes. For example, the variation in Task 4 may be caused by the lack of available personnel. Management actions could be taken to dedicate personnel to the effort and reduce the variation substantially, which would reduce the overall variation and enhance the predictability of the schedule. Digging into the reasons for variation will lead to targets where management actions will be most effective, much more so than simply telling the troops to reduce their task completion time.

Using the network schedule model, we can also experiment to see how different reduction strategies may pay off. For example, taking one day out of Tasks 4, 8, and 9 under the traditional method would lead us to believe that a three-day reduction has taken place, but if we reduce the Most Likely value for Tasks 4, 8, and 9 by one day and run the Monte Carlo risk simulation, we find that the median value is still 37.84, or only a 0.7-day reduction. This small reduction proves that the variation must be addressed. If we reduce the variation by 50%, keeping the original minimum and the most likely values, but reducing the maximum value for each distribution, then we reduce the median from 38.5 to 37.84—about the same as reducing the Most Likely values. Taking both actions (reducing the Most Likely and Maximum values) reduces the median to 36.83, giving us a 55% chance of completing within 37 days. This analysis proves that reducing the most likely value *and* the overall variation is the most effective action.

To get to 36 days, we need to continue to work down the list of tasks shown in the sensitivity and tornado charts addressing each task. If we give Task 1 the same treatment, reducing its most likely and maximum values, then completion within 36 days can be accomplished with 51% certainty, and 79.25% certainty of completing within 37 days. The maximum value for the overall schedule is reduced from more than 42 days to less than 40 days. Substantial management efforts would be needed, however, to reach 36 days at the 80% certainty level.



Rules for Schedule Risk Management

When managing the production schedule, use the best-case numbers. If we use the most likely values or, worse yet, the maximum values, production personnel will not strive to hit the best-case numbers, thus implementing a self-fulfilling prophecy of delayed completion. When budgeting, we should create the budget for the median outcome but recognize that there is uncertainty in the real world as well as risk. When advertising the schedule to the customer, provide the values that equate to the 75% to 80% certainty level. In most cases, customers prefer predictability (on-time completion) over potential speedy completion that includes significant risk. Lastly, acknowledge that the “worst case” can conceivably occur and create contingency plans to protect your organization in case it does occur. If the “worst case”/maximum value is unacceptable, then make the appropriate changes in the process to reduce the maximum value of the outcome to an acceptable level.

How to Apply This Method to Larger Networks

Some could argue that this methodology is only good for small networks because it appears that you have to trace all of the paths from beginning to end. We can, however, break up the schedule network to make the problem easier for larger cases. In our example problem, all of the paths came together at Task 10. We can call Task 10 a Merge Event. We can break up a large network into smaller pieces utilizing the merge points to define the boundaries. To further illustrate this technique, we use the schedule network shown in Figure A1.6.



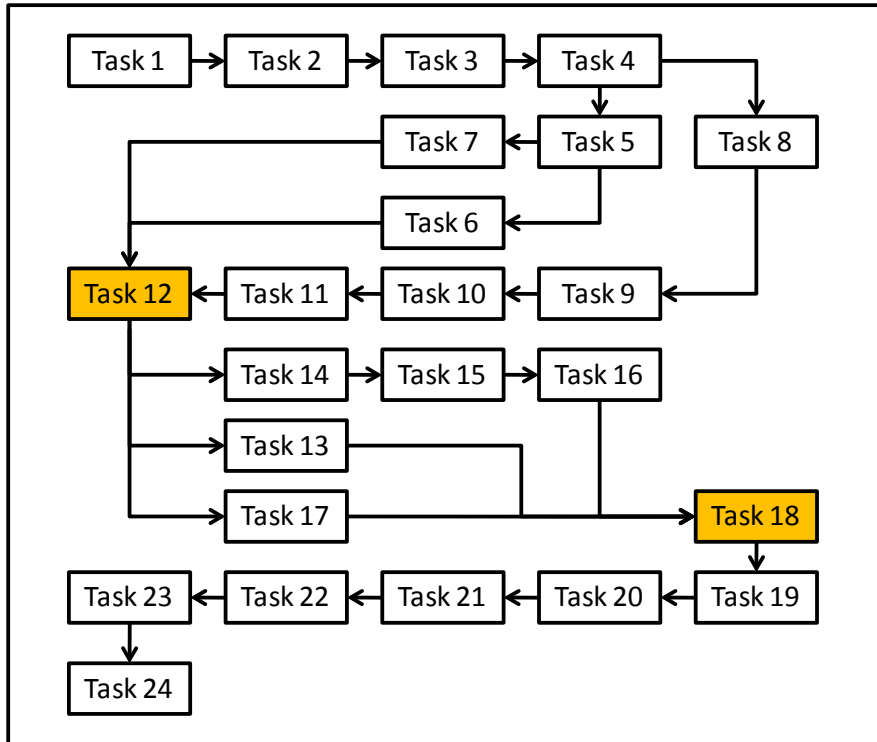


Figure A1.6: Example Schedule Network With Multiple Merge Points

In Figure A1.6, there are two merge points—Task 12 and Task 18. After we have created *Input Assumptions* for each task, we can set up our calculations. For this example, we should create the sum of the durations for Tasks 1-2-3-4 as our first subtotal since these tasks are in series. The second subtotal would be equal to the maximum duration among Tasks 5-6, Task 5-7, and Tasks 8-9-10-11. We would then add the duration of Task 12 as the third subtotal. The fourth subtotal would be the maximum duration among Task 13, Tasks 14-15-16, and Task 17. Lastly we sum the durations of Tasks 18 through 24 as the fifth subtotal. We can then sum all of the five subtotals to determine the overall schedule duration. The spreadsheet cell that sums all five subtotals is set as the *Output Forecast* for our entire schedule network. The calculations are demonstrated in the spreadsheet shown in Figure A1.7.

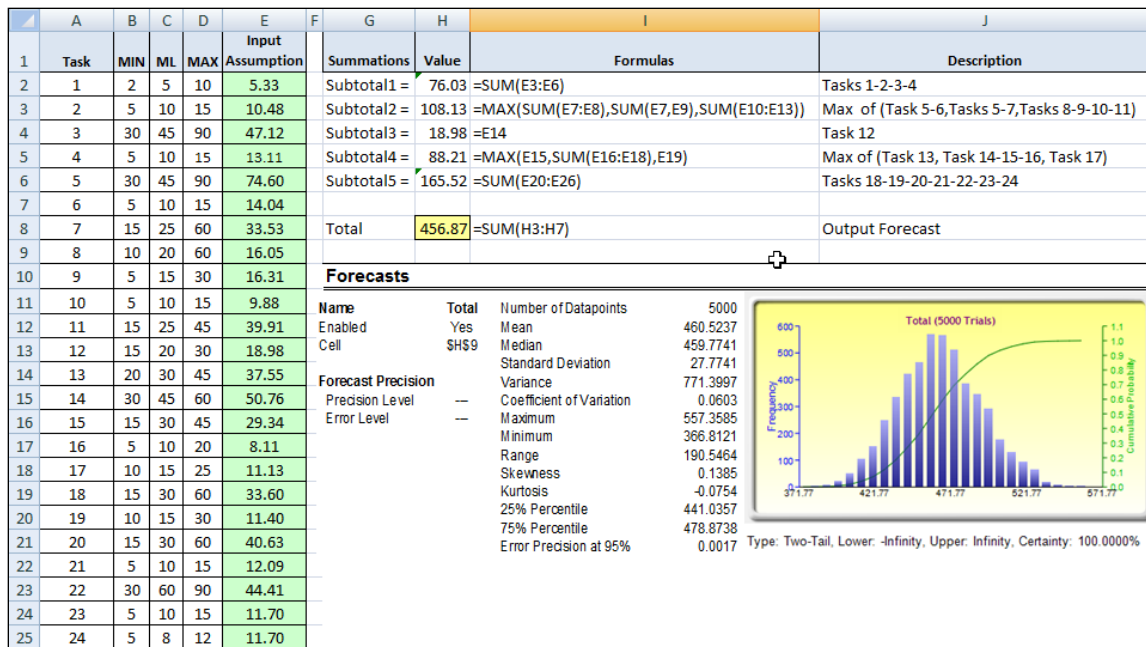


Figure A1.7: Example Schedule Spreadsheet With Multiple Merge Points

Risk Simulator can also be used to take into account correlations between tasks. After we create the *Input Assumptions*, we can go back and use the *Tools / Edit Correlations* to account for correlations among tasks. For example, if previous experience or data indicates that as Task 8 takes longer, the duration for Task 9 will also increase, then there is likely a correlation between those two tasks. If we have paired data, then we can use Risk Simulator’s *Distribution Fitting (Multi-Variable)* tool to determine the correlation values between the two items. This tool also works with more than two items. If we have data from several previous cases, we can use this tool to determine the correlation matrix for all of the tasks. To build the most accurate forecast, we should account for correlations whenever we know they exist.

Conclusion

With traditional schedule management, there is only one answer for the scheduled completion date. Each task gets one duration estimate, and that estimate is accurate only if everything goes according to plan, which is not a likely occurrence. With probabilistic schedule management, thousands of trials are run exploring the range of possible outcomes for schedule duration. Each task in the network receives a time estimate distribution, accurately reflecting each task’s

uncertainty. Correlations can be entered to more accurately model real-world behavior. Critical paths and near-critical paths are automatically taken into account, and the output forecast distribution will accurately reflect the entire range of possible outcomes. Using tornado and sensitivity analyses, we can maximize the effectiveness of our management actions to control schedule variations and reduce the overall schedule at high certainty levels.



Appendix B. Understanding Probability Distributions

Before getting started with Monte Carlo risk simulation, one first needs to understand the concept of probability distributions. To begin to understand probability, consider this example: Suppose an analyst wants to look at the distribution of nonexempt wages within one department of a large company. First, you gather raw data—in this case, the wages of each nonexempt employee in the department. Second, you organize the data into a meaningful format and plot the data as a frequency distribution on a chart. To create a frequency distribution, you divide the wages into group intervals and list these intervals on the chart's horizontal axis. Then you list the number or frequency of employees in each interval on the chart's vertical axis. Now you can easily see the distribution of nonexempt wages within the department.

A glance at the chart illustrated in Figure A2.1 reveals that the employees earn from \$7.00 to \$9.00 per hour. You can chart this data as a probability distribution. A probability distribution shows the number of employees in each interval as a fraction of the total number of employees. To create a probability distribution, you divide the number of employees in each interval by the total number of employees and list the results on the chart's vertical axis.

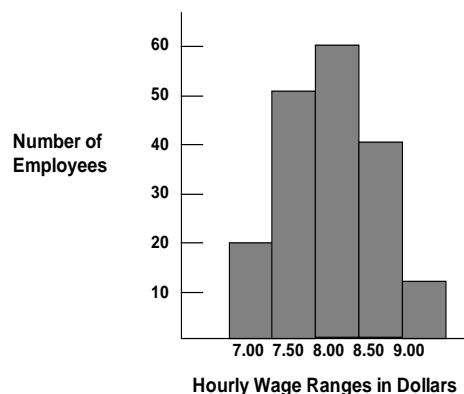


Figure A2.1: Frequency Histogram I



The chart in Figure A2.2 shows the number of employees in each wage group as a fraction of all employees; you can estimate the likelihood or probability that an employee drawn at random from the whole group earns a wage within a given interval. For example, assuming the same conditions exist at the time the sample was taken, the probability is 0.20 (a one in five chance) that an employee drawn at random from the whole group earns \$8.50 an hour.

Probability distributions are either discrete or continuous. *Discrete probability distributions* describe distinct values, usually integers, with no intermediate values and are shown as a series of vertical bars. A discrete distribution, for example, might describe the number of heads in four flips of a coin as 0, 1, 2, 3, or 4. *Continuous probability distributions* are actually mathematical abstractions because they assume the existence of every possible intermediate value between two numbers; that is, a continuous distribution assumes there is an infinite number of values between any two points in the distribution. However, in many situations, you can effectively use a continuous distribution to approximate a discrete distribution even though the continuous model does not necessarily describe the situation exactly.

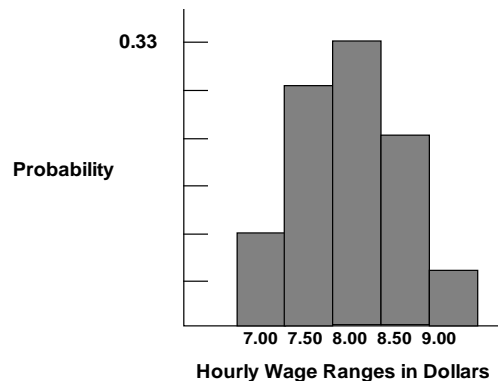


Figure A2.2: Frequency Histogram II

Selecting a Probability Distribution

Plotting data is one method for selecting a probability distribution. The following steps provide another process for selecting probability distributions that best describe the uncertain variables in your spreadsheets.

To select the correct probability distribution, use the following steps:

- Look at the variable in question. List everything you know about the conditions surrounding this variable. You might be able to gather valuable information about the uncertain variable from historical data. If historical data are not available, use your own judgment, based on experience, listing everything you know about the uncertain variable.
- Review the descriptions of the probability distributions.
- Select the distribution that characterizes this variable. A distribution characterizes a variable when the conditions of the distribution match those of the variable.

Alternatively, if you have historical, comparable, contemporaneous, or forecast data, you can use Risk Simulator's distributional fitting modules to find the best statistical fit for your existing data. This fitting process will apply some advanced statistical techniques to find the best distribution and its relevant parameters that describe the data.

Probability Density Functions, Cumulative Distribution Functions, and Probability Mass Functions

In mathematics and Monte Carlo simulation, a probability density function (PDF) represents a *continuous* probability distribution in terms of integrals. If a probability distribution has a density of $f(x)$, then intuitively the infinitesimal interval of $[x, x + dx]$ has a probability of $f(x) dx$. The PDF therefore can be seen as a smoothed version of a probability histogram; that is, by providing an empirically large sample of a continuous random variable repeatedly, the histogram using very narrow ranges will resemble the random variable's PDF. The probability of the interval between $[a,$



$b]$ is given by $\int_a^b f(x)dx$, which means that the total integral of the function f must be 1.0. It is a common mistake to think of $f(a)$ as the probability of a . In fact, $f(a)$ can sometimes be larger than 1—consider a uniform distribution between 0.0 and 0.5. The random variable x within this distribution will have $f(x)$ greater than 1. The probability, in reality, is the function $f(x)dx$ discussed previously, where dx is an infinitesimal amount.

The cumulative distribution function (CDF) is denoted as $F(x) = P(X \leq x)$, indicating the probability of X taking on a less than or equal value to x . Every CDF is monotonically increasing, is continuous from the right, and at the limits has the following properties: $\lim_{x \rightarrow -\infty} F(x) = 0$ and $\lim_{x \rightarrow +\infty} F(x) = 1$. Further, the CDF is related to the PDF by $F(b) - F(a) = P(a \leq X \leq b) = \int_a^b f(x)dx$, where the PDF function f is the derivative of the CDF function F .

In probability theory, a probability mass function, or PMF, gives the probability that a *discrete* random variable is exactly equal to some value. The PMF differs from the PDF in that the values of the latter, defined only for continuous random variables, are not probabilities; rather, its integral over a set of possible values of the random variable is a probability. A random variable is discrete if its probability distribution is discrete and can be characterized by a PMF. Therefore, X is a discrete random variable if $\sum_u P(X = u) = 1$ as u runs through all possible values of the random variable X .

Normal Distribution

The normal distribution is the most important distribution in probability theory because it describes many natural phenomena, such as people's IQs or heights. Decision-makers can use the normal distribution to describe uncertain variables such as the inflation rate or the future price of gasoline.



The three conditions underlying the normal distribution are

- Some value of the uncertain variable is the most likely (the mean of the distribution).
- The uncertain variable could as likely be above the mean as it could be below the mean (symmetrical about the mean).
- The uncertain variable is more likely in the vicinity of the mean than further away.

The mathematical constructs for the normal distribution are as follows:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \text{ for all values of } x \text{ and } \mu; \text{ while } \sigma > 0$$

Mean = μ

Standard Deviation = σ

Skewness = 0 (this applies to all inputs of mean and standard deviation)

Excess Kurtosis = 0 (this applies to all inputs of mean and standard deviation)

Mean (μ) and standard deviation (σ) are the distributional parameters.

Input requirements: standard deviation > 0 and can be any positive value whereas mean can be any value

Project Evaluation and Review Technique Distribution

The PERT distribution is widely used in project and program management to define the worst-case, nominal-case, and best-case scenarios of project completion time. It is related to the beta and triangular distributions. PERT distribution can be used to identify risks in project and cost models based on the likelihood of meeting targets and goals across any number of project components using minimum, most likely, and maximum values, but it is designed to generate a distribution that more closely resembles realistic probability distributions. The PERT distribution can provide a close fit to the normal or lognormal distributions. Like the triangular distribution, the PERT distribution emphasizes the *most likely* value over the minimum and maximum estimates. However, unlike the triangular distribution, the



PERT distribution constructs a smooth curve that places progressively more emphasis on values around (near) the most likely value, in favor of values around the edges. In practice, this means that we *trust* the estimate for the most likely value, and we believe that even if it is not exactly accurate (as estimates seldom are), we have an expectation that the resulting value will be close to that estimate. Assuming that many real-world phenomena are normally distributed, the appeal of the PERT distribution is that it produces a curve similar to the normal curve in shape, without knowing the precise parameters of the related normal curve. Minimum, most likely, and maximum are the distributional parameters.

The mathematical constructs for the PERT distribution are as follows:

$$f(x) = \frac{(x - \text{Min})^{A1-1} (\text{Max} - x)^{A2-1}}{B(A1, A2)(\text{Max} - \text{Min})^{A1+A2-1}}$$

$$\text{where } A1 = 6 \left[\frac{\text{Min} + 4(\text{Likely}) + \text{Max}}{6} - \text{Min} \right] \text{ and } A2 = 6 \left[\text{Max} - \frac{\text{Min} + 4(\text{Likely}) + \text{Max}}{6} \right]$$

and B is the Beta function

$$\text{Mean} = \frac{\text{Min} + 4\text{Mode} + \text{Max}}{6}$$

$$\text{Standard Deviation} = \sqrt{\frac{(\mu - \text{Min})(\text{Max} - \mu)}{7}}$$

$$\text{Skew} = \sqrt{\frac{7}{(\mu - \text{Min})(\text{Max} - \mu)}} \left(\frac{\text{Min} + \text{Max} - 2\mu}{4} \right)$$

Excess Kurtosis is a complex function and cannot be readily computed

Input requirements: $\text{Min} \leq \text{Most Likely} \leq \text{Max}$ and can be positive, negative, or zero



Triangular Distribution

The triangular distribution describes a situation where you know the minimum, maximum, and most likely values to occur. For example, you could describe the number of cars sold per week when past sales show the minimum, maximum, and usual number of cars sold.

The three conditions underlying the triangular distribution are

- The minimum number of items is fixed.
- The maximum number of items is fixed.
- The most likely number of items falls between the minimum and maximum values, forming a triangular-shaped distribution, which shows that values near the minimum and maximum are less likely to occur than those near the most likely value.

The mathematical constructs for the triangular distribution are as follows:

$$f(x) = \begin{cases} \frac{2(x - \text{Min})}{(\text{Max} - \text{Min})(\text{Likely} - \text{Min})} & \text{for } \text{Min} < x < \text{Likely} \\ \frac{2(\text{Max} - x)}{(\text{Max} - \text{Min})(\text{Max} - \text{Likely})} & \text{for } \text{Likely} < x < \text{Max} \end{cases}$$

$$\text{Mean} = \frac{1}{3}(\text{Min} + \text{Likely} + \text{Max})$$

$$\text{Standard Deviation} = \sqrt{\frac{1}{18}(\text{Min}^2 + \text{Likely}^2 + \text{Max}^2 - \text{MinMax} - \text{MinLikely} - \text{MaxLikely})}$$

$$\text{Skewness} = \frac{\sqrt{2}(\text{Min} + \text{Max} - 2\text{Likely})(2\text{Min} - \text{Max} - \text{Likely})(\text{Min} - 2\text{Max} + \text{Likely})}{5(\text{Min}^2 + \text{Max}^2 + \text{Likely}^2 - \text{MinMax} - \text{MinLikely} - \text{MaxLikely})^{3/2}}$$

Excess Kurtosis = -0.6 (this applies to all inputs of Min, Max, and Likely)

Minimum (Min), most likely (Likely) and maximum (Max) are the parameters.

Input requirements: $\text{Min} \leq \text{Most Likely} \leq \text{Max}$ and can take any value;
however, $\text{Min} < \text{Max}$ and can take any value



Uniform Distribution

With uniform distribution, all values fall between the minimum and maximum and occur with equal likelihood.

The three conditions underlying the uniform distribution are

- The minimum value is fixed.
- The maximum value is fixed.
- All values between the minimum and maximum occur with equal likelihood.

The mathematical constructs for the uniform distribution are as follows:

$$f(x) = \frac{1}{Max - Min} \text{ for all values such that } Min < Max$$

$$Mean = \frac{Min + Max}{2}$$

$$Standard\ Deviation = \sqrt{\frac{(Max - Min)^2}{12}}$$

Skewness = 0 (this applies to all inputs of Min and Max)

Excess Kurtosis = -1.2 (this applies to all inputs of Min and Max)

Maximum value (*Max*) and minimum value (*Min*) are the distributional parameters.

Input requirements: $Min < Max$ and can take any value



Appendix C. Peat Quick Getting Started Guide

This appendix provides a quick getting started guide to using ROV PEAT's project management module that was used to run the analytical models as described in this report. This guide uses the default example model for practice. To follow along, start the ROV PEAT software (double-click on the desktop icon), select the *Project Management—Dynamic Cost and Schedule Risk* module, and click *Load Example*. We begin by illustrating a simple linear path project in the *Simple Linear Path 1* tab (see Figure A3.1). Note that users can click on the *Projects* menu to add projects and delete, rearrange, and rename existing projects. The example loaded has five sample predefined projects (each project is shown as a tab). In this simple linear path project, there are 11 sample tasks, and each task is linked to its subsequent tasks linearly (i.e., Task 2 can only start after Task 1 is done, and so forth). For each project, a user has a set of controls and inputs:

- *Sequential Path versus Complex Network Path*. The first example illustrated uses the simple linear or sequential path, which means there is a simple linear progression of tasks. In the next example, we will explore the complex network path where tasks can be executed linearly, simultaneously, and recombined at any point in time.
- *Fixed Costs*. The fixed costs and their ranges suitable for risk simulation (minimum, most likely, maximum) are required inputs. These fixed costs are costs that will be incurred regardless of there being an overrun in schedule (the project can be completed early or late but the fixed costs will be the same regardless).
- *Time Schedule*. This refers to a period-specific time schedule (minimum, most likely, maximum) in days, weeks, or months. Users will first select the periodicity (e.g., days, weeks, months, or unitless) from the droplist and enter the projected time schedule per task. This schedule will be used in conjunction with the variable cost elements (see next bullet item), and will only be available if *Include Schedule-Based Cost Analysis* is checked.
- *Variable Cost*. This is the variable cost that is incurred based on the time schedule for each task. This variable cost is per period and will be multiplied by the number of periods to obtain the total variable cost for each task. The sum of all fixed costs and variable costs for all tasks will, of course, be the total cost for the project (denoted as *Project Total Cost*).



- *Overrun Assumption.* This is a percent budget buffer or cushion to include in each task. This column is only available and used if the *Include Budget Overruns and Buffers* checkbox is selected.
- *Probability of Success.* This allows users to enter the probability of each task being successful. If a task fails, then all subsequent tasks will be canceled and the costs will not be incurred, as the project stops and is abandoned. This column is available and will be used in the risk simulation only if the *Include Probabilities of Success* checkbox is selected.
- *Run.* The Run button will perform the relevant computations based on the settings and inputs, and also run risk simulations if the *Perform Risk Simulation* checkbox is selected (and if the requisite simulation settings such as distribution type, number of trials, and seed value settings are entered appropriately). This will run the current project's model. If multiple projects need to be run, you can first proceed to the *Portfolio Analysis* tab and click on the *Run All Projects* button instead.

To see which of these input assumptions drive total cost and schedule the most, a tornado analysis can be executed (see Figure A3.2). The model can then be risk simulated, and the results will show probability distributions of cost and schedule (see Figure A3.3). For instance, the sample results show that for Project 1, there is a 95% probability that the project can be completed at a cost of \$398,594. The expected median or most likely value was originally \$377,408 (see Figure A3.1). With simulation, it shows that to be 95% sure that there are sufficient funds to complete the project, an additional buffer of \$21,186 is warranted.



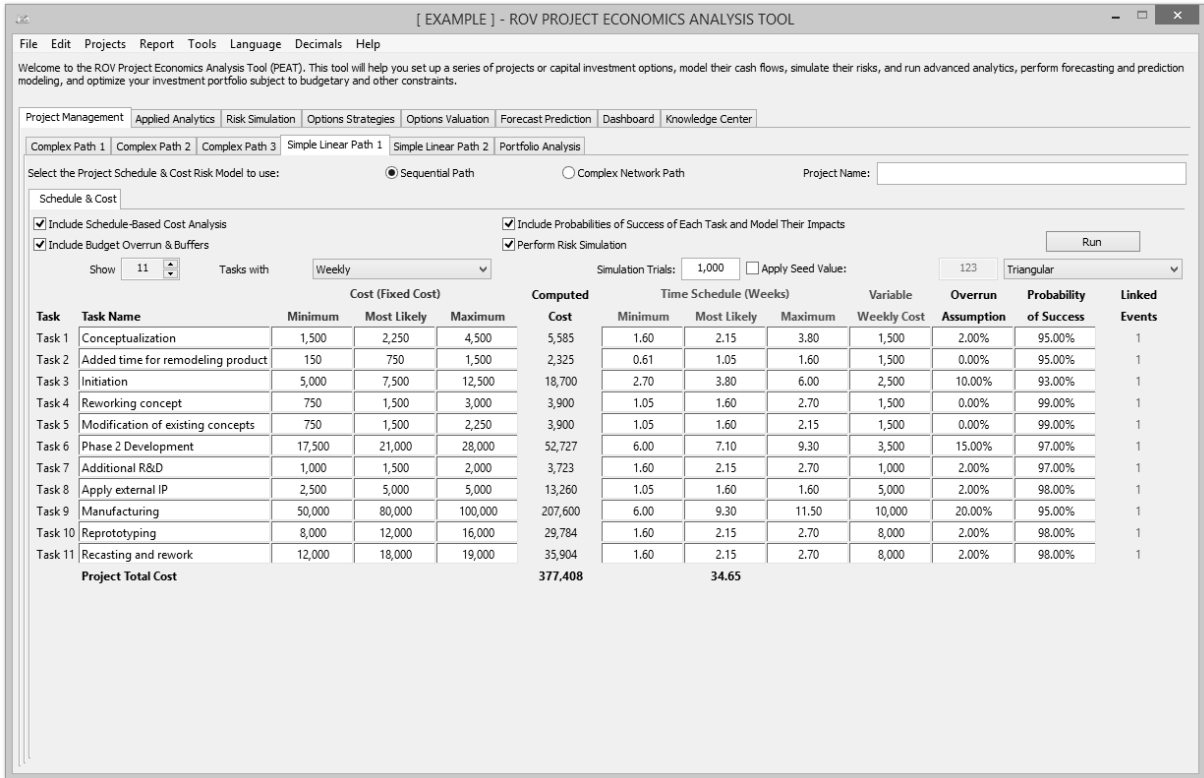


Figure A3.1: Simple Linear Path Project Management With Cost and Schedule Risk

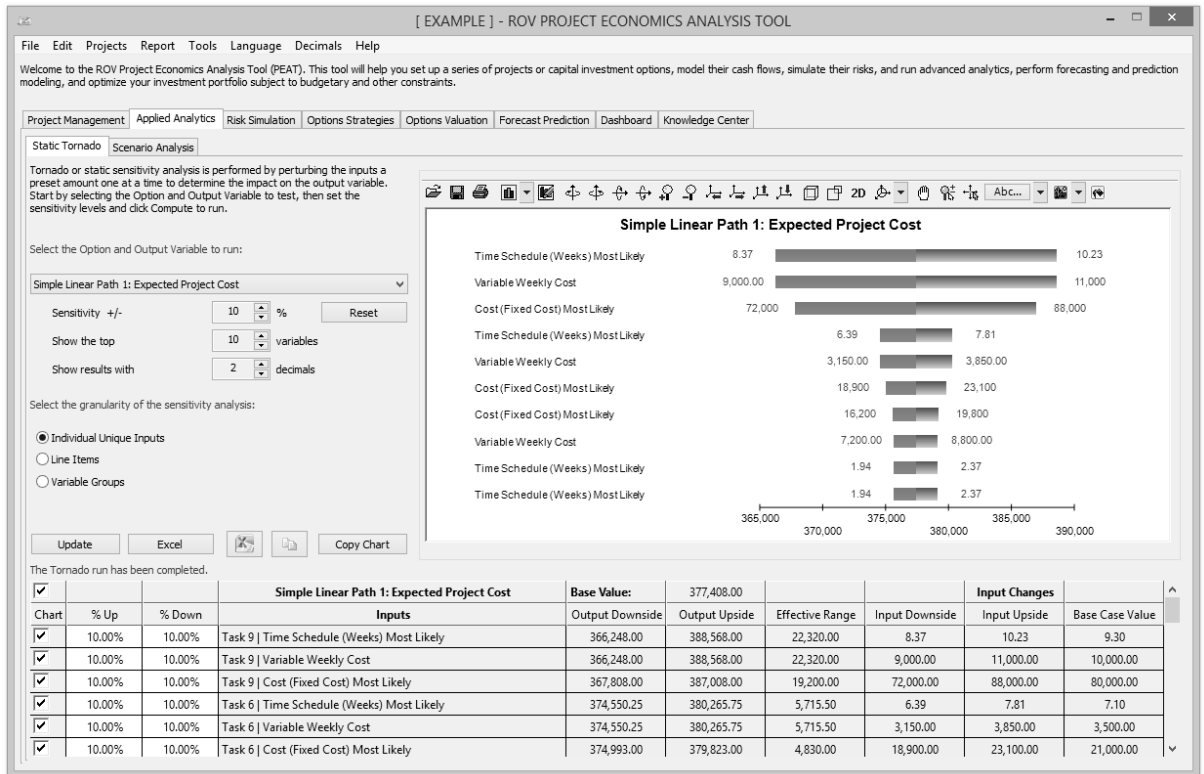


Figure A3.2: Simple Linear Path Tornado Analysis



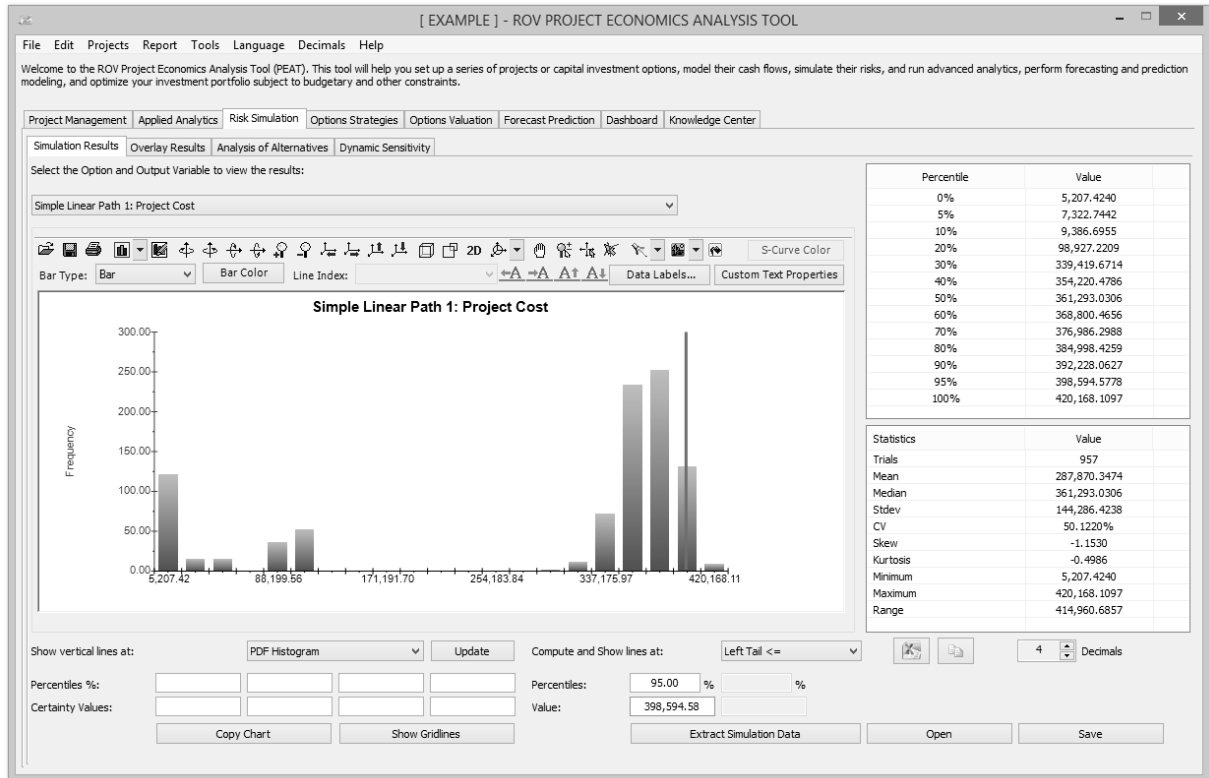


Figure A3.3: Monte Carlo Risk Simulated Results for Risky Cost and Schedule Values

In complex projects where there are nonlinear bifurcating and recombining paths (see Figure A3.4), the cost and schedule risk is more difficult to model and compute. For instance, in the *Complex Path 1* tab, we can see that after Task 1, future tasks can be run in parallel (Tasks 2, 3, and 4). Then, Tasks 3 and 4 recombine into Task 8. Such complex path models can be created by the user simply by adding tasks and combining them in the visual map as shown. The software will automatically create the analytical financial model when *Create Model* is clicked. That is, you will be taken to the *Schedule & Cost* tab and the same setup as shown previously is now available for data entry for this complex model (see Figure A3.5). The complex mathematical connections will automatically be created behind the scenes to run the calculations so that the user will only need to perform very simple tasks of drawing the complex network path connections. The following are some tips on getting started:



- Start by adding a new project from the *Projects* menu. Then, click on the *Complex Network Path* radio selection to access the *Network Diagram* tab.
- Use the icons to assist in drawing your network path. Hover your mouse over the icons to see their descriptions. You can start by clicking on the third icon to *Create a Task*, and then click anywhere in the drawing canvas to insert said task.
- With an existing task clicked on and selected, click on the fourth icon to *Add a Subtask*. This will automatically create the adjoining next task and next task number. You then need to move this newly inserted task to its new position. Continue with this process as required to create your network diagram. You can create multiple subtasks off a single existing task if simultaneous implementations occur.
- You can also recombine different tasks by clicking on one task, then holding down the Ctrl key and clicking on the second task you wish to join. Then click on the fifth icon to *Link Tasks* to join them. Similarly, you can click on the sixth icon to *Delete Link* between any two tasks.
- When the network diagram is complete, click on *Create Model* to generate the computational algorithms where you can then enter the requisite data in the *Schedule & Cost* tab as described previously.

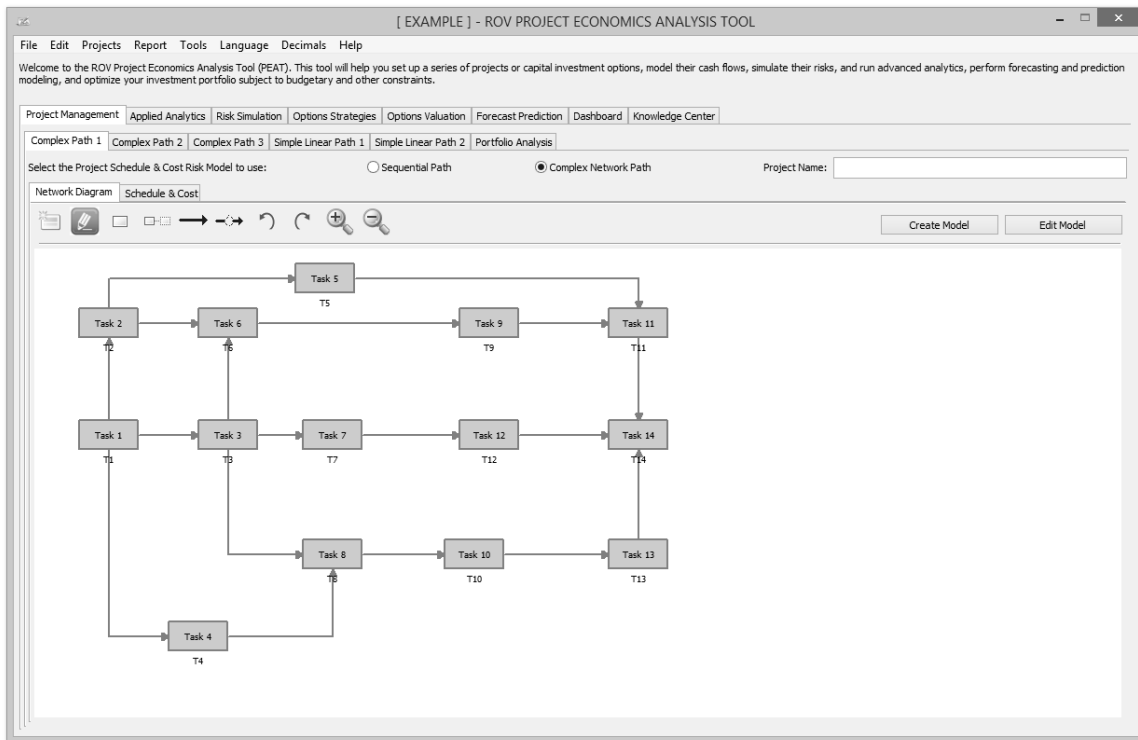


Figure A3.4: Complex Path Project Management

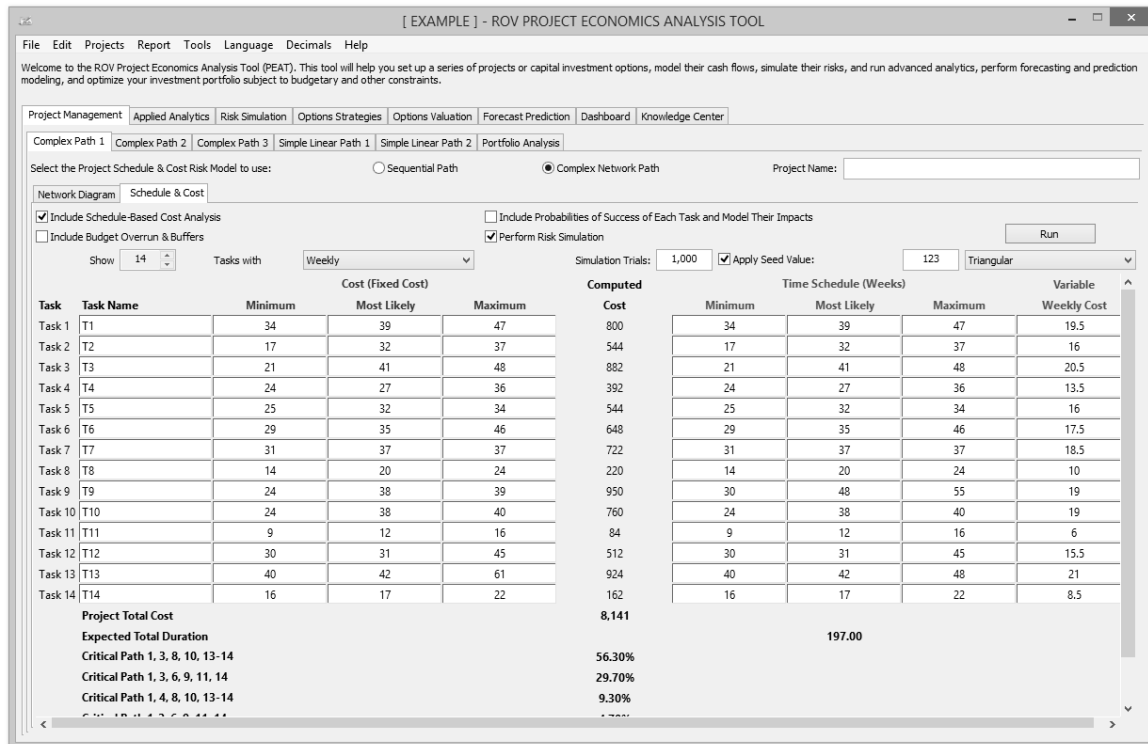


Figure A3.5: Complex Project Simulated Cost and Duration Model With Critical Path

After running the model, the complex path map shows the highlighted critical path (see Figure A3.6) of the project, that is, the path that has the highest potential for bottlenecks and delays in completing the project on time. The exact path specifications and probabilities of being on the critical path are seen in Figure A3.5 (e.g., there is a 56.30% probability that the critical path will be along Tasks 1, 3, 8, 10, 13, 14).

If there are multiple projects or potential project path implementations, the portfolio view (see Figure A3.7) compares all projects and implementation paths for the user to make a better and more informed risk-based decision. The simulated distributions can also be overlaid (see Figure A3.8) for comparison.

Figure A3.7 allows users to see at a glance all projects that were modeled. Each project modeled can actually be different projects or the same project modeled under different assumptions and implementation options (i.e., different ways of executing the project), to see which project or implementation option path makes more sense in terms of cost and schedule risks. The *Analysis of Alternatives* radio



selected allows users to see each project as stand-alone (as compared to *Incremental Analysis*, where one of the projects is selected as the base case and all other projects' results show their differences from the base case) in terms of cost and schedule: single-point estimate values, simulated averages, the probabilities each of the projects will have a cost or schedule overrun, and the 90th percentile value of cost and schedule. Of course, more detailed analysis can be obtained from the *Risk Simulation | Simulation Results* tab, where users can view all the simulation statistics and select any confidence and percentile values to show. The *Portfolio Analysis* tab also charts the simulated cost and schedule values using bubble and bar charts for a visual representation of the key results.

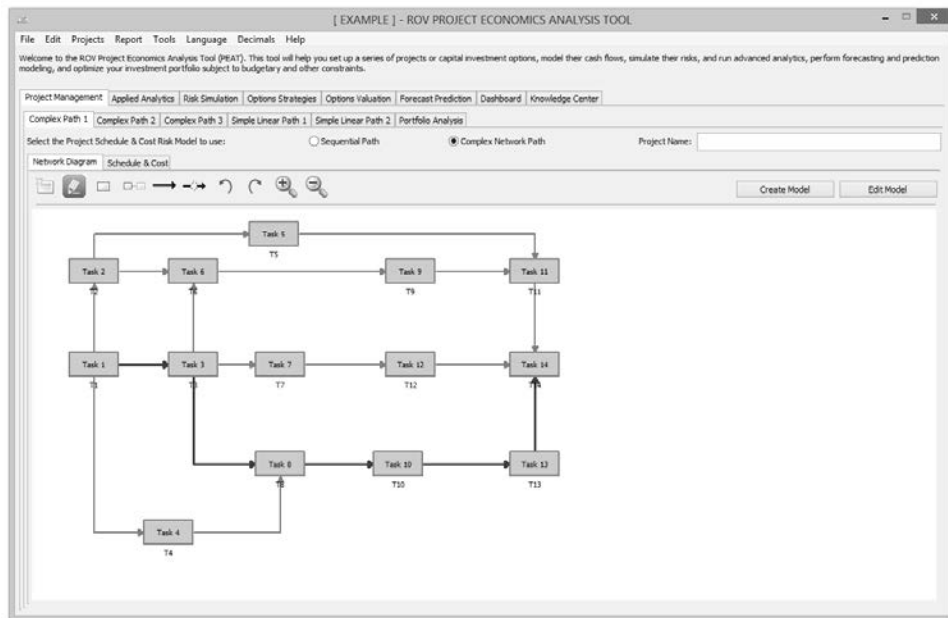


Figure A3.6: Complex Project Critical Path

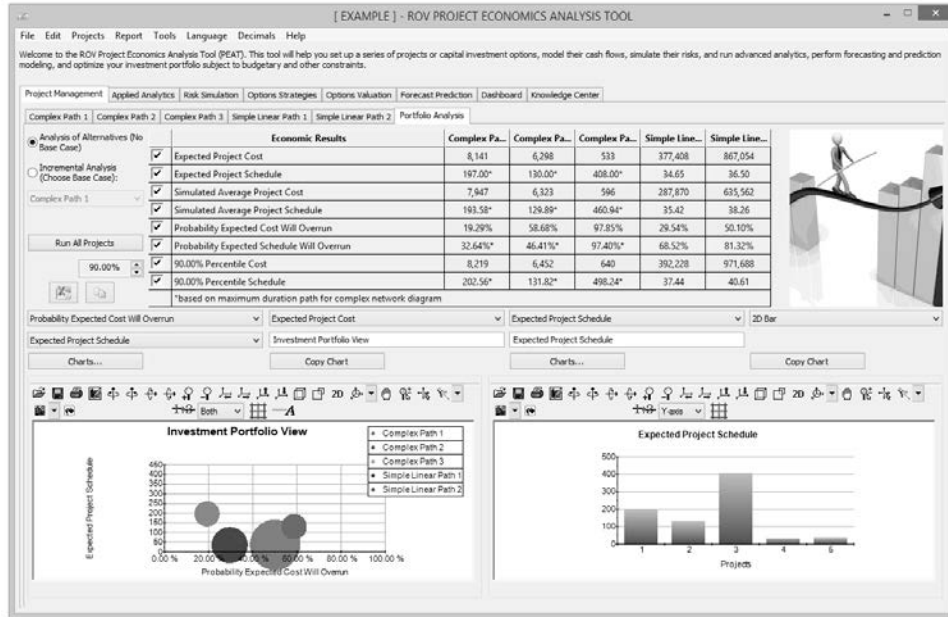


Figure A3.7: Portfolio View of Multiple Projects at Once

The *Overlay* chart in Figure A3.8 shows multiple projects' simulated costs or schedules overlaid on one another to see their relative spreads, location, and skew of the results. We clearly see that the project whose distribution lies to the right has a much higher cost to complete than the left, with the project on the right also having a slightly higher level of uncertainty in terms of cost spreads.

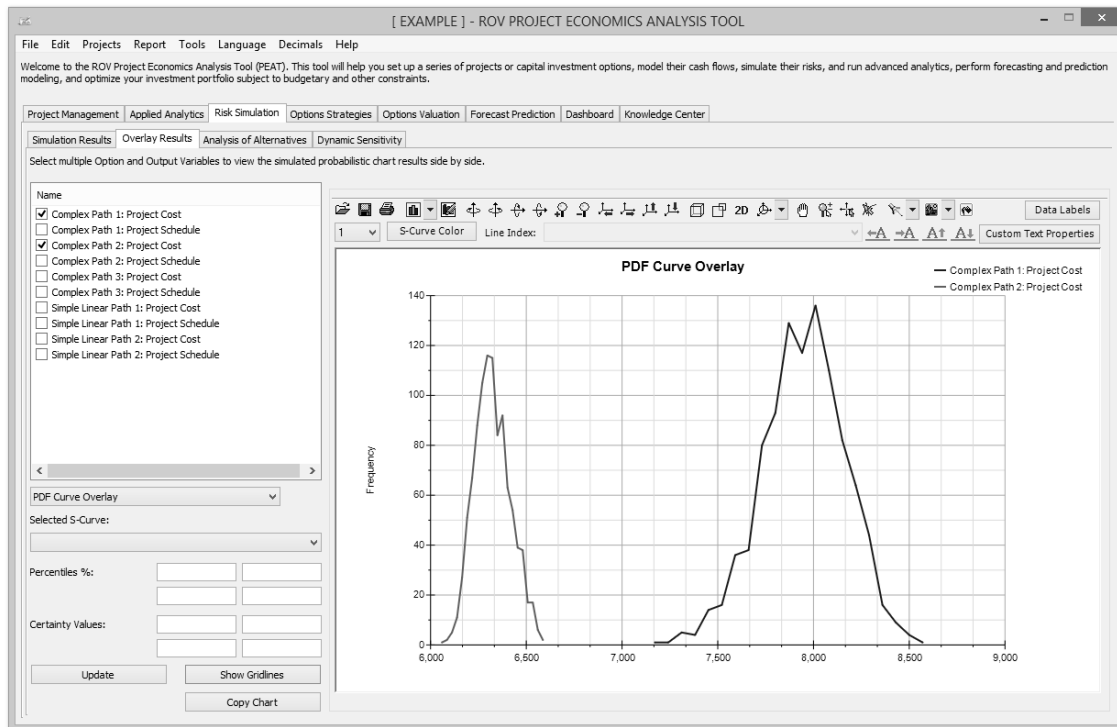


Figure A3.8: Overlay Charts of Multiple Projects' Cost or Schedule

Key Operational Areas for NIPO Product Lines in ROV PEAT's Schedule and Cost Module

This section highlights some noteworthy items for the new user to consider performing as well as some key tips for making the modeling process simpler. It is not meant as a full-fledged user's manual, but, instead, focuses on NIPO applications and provides tips for the most commonly used items in modeling NIPO product lines.

- Figure A3.9 shows the main modeling screen.
 - Area A shows the most common activities, such as
 - *File* menu for saving, opening, and creating new models.
 - *Projects* menu for adding new project tabs and renaming, rearranging, or moving project tabs.
 - Area B shows the location of the project tabs (the example here shows five projects with their own unique names).
 - Area C shows the *Portfolio Analysis* tab, which will only be populated if all the models are first run (see Figure A3.10's item N later).

- Area D shows the linear versus complex network path options, where in most cases, NIPO product lines will require the *Complex Network Path* option. If the *Sequential (Linear) Path* is selected, you will not be able to draw the network diagram. The *Network Diagram* tab (area E) and drawing canvas (area G) are only available if the *Complex Network Path* is selected.
- Area F shows the icons used to start drawing the complex network path. Click *Create Model* (area H) when you are done drawing the network path. This *Create Model* button, when clicked, will run an internal algorithm and connect all the paths and generate an input worksheet (area E) called *Schedule & Cost*, where you will be able to enter all the required input assumptions (see Figure A3.10). The *Edit Model* is required if you need to make changes to an existing network diagram, but remember when you are done with editing the diagram to click on *Create Model* once again to refresh the input worksheet (see Figure A3.10).
- Here are a few key tips when you are in this main tab (see Figure A3.9):
 - Consider drawing some of the processes on paper prior to actually committing them to the software.
 - Consider adding new project tabs as you progress with drawing the network diagram. You can use the *Projects | Duplicate Projects* menu to make a copy of the existing project and continue to *Edit Model* and make changes as required in the new tab. This is a convenient way to see the progression of your work as well as to have a backup version of the diagram in case you need to revert to an older version. You can always delete these older versions when the final project diagram is complete.
 - Use the *first icon* (area F) to clear any existing drawings and start a new canvas.
 - Use the *third icon* (area F) to get started drawing the first task box (click the icon and then click on the drawing canvas where you want the task box to be).
 - To create a subsequent linked task, make sure to *click on and select an existing task* and then click the *fourth icon* (area F) to add a subsequent or follow-on task box.
 - You can *double click* on any task box to type in a short name for the task. Remember to use short names as longer texts will be truncated. You can use the *seventh icon* (the icon that looks like the letter “A” inside a box in area F) to add a new *Notes* box anywhere in the drawing canvas area to enter notes and to resize the notes box.
 - Sometimes one task continues on to more than one task, and some of these later tasks link back to another task. For example, in Figure



A3.9, Task 2 bifurcates to Tasks 5 and 6, and Task 5 eventually rejoins the network at Task 11. To create *Task Loops* and make this connection between Tasks 5 and 11, simply click on Task 5, hold down the *CTRL* key on the keyboard, and click Task 11. This will select the two task boxes at once. Then, click on the *fifth icon* (area F) to *Add a Line Connection* between these two tasks. You can use this approach to join any two tasks, or use the *sixth icon* to delete the connection between any two similarly selected tasks.

- In complex diagrams, the short texts of each node may sometimes be obstructed by a connection line. To solve this issue, click on the appropriate task box and click the *second icon from the right* (area F) repeatedly to move the location of the text around the task box to an area with an unobstructed view (e.g., see the text for Task 11, which was moved to the right of the box).
- The canvas has a default size that is appropriate for most network diagrams and is set up to optimize the screen capture (see next bullet) resolution. However, if needed, use the *last icon* (area F) to increase or decrease the size of the drawing canvas to accommodate your needs.
- Use the *Copy Diagram* button (area H) to copy the drawing into memory, and use *CTRL + V* to paste the diagram into another software such as Microsoft Word or PowerPoint.

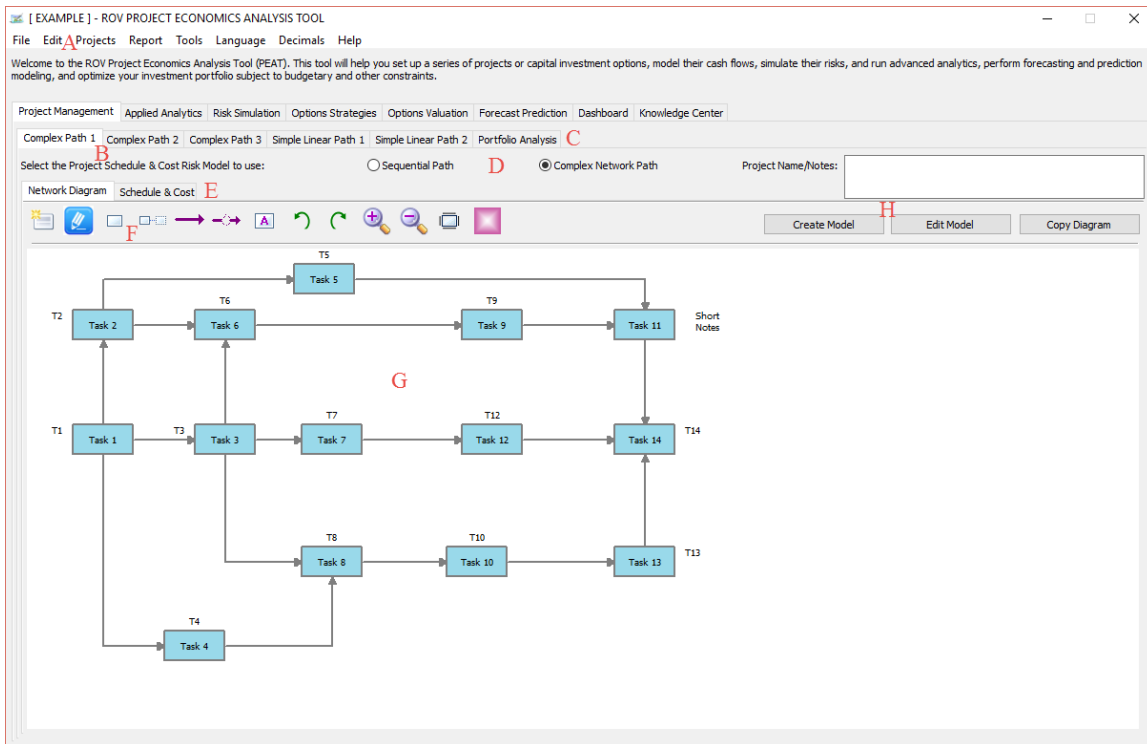


Figure A3.9: Complex Network Diagram

- Figure A3.10 shows the main modeling input assumptions screen.
 - The input assumptions for each project are located in the *Schedule & Cost* subtab (area I). Here, you start by selecting the relevant checkboxes (areas J and K). For NIPO projects, you need to select at least the *Include Schedule-Based Cost Analysis* and *Perform Risk Simulation* checkboxes. You can optionally select the *Include Budget Overrun & Buffers* item for an additional cushion to the input estimates, just as the analysis of this report has included (e.g., a typical 5% or 10% buffer is used). In most cases, for NIPO projects, the *Probabilities of Success* item is not used.
 - Remember to select the *periodicity* of the time schedule inputs (area L), whether it is days, weeks, months, or undated. Note in Figure A3.9 that the *Show* spinner box located around area A is not used as this is automatically determined when the *Create Model* is clicked (area H). This spinner is only used if the *Sequential Path* (area D) is selected, whereby you can create as many task boxes in a simple linear sequential path as needed.
 - At least *1,000* simulation trials are used, and it is recommended that *10,000 Trials* be set (area M) with a *Seed Value of 123* (make sure the checkbox is selected).
 - The software allows for various probability distributions (area O), but it is recommended that the *Triangular* distribution is used, due to the simplicity of its input requirements and its flexibility to generate skewed cost and schedule inputs.
 - Enter the data in areas P and Q and click on *Run* or *Run All Projects* (area N) to run either the current project or all projects saved in the file at once, allowing you a direct comparison across multiple projects side by side.
- Here are a few key tips when you are in this worksheet tab:
 - The input data grid in areas P and Q can be *pasted* directly from other applications such as Microsoft Excel (copy the data in Excel, select the data grid area, and use *CTRL + V* to paste the data into the data grid). Conversely, you can select the data grid and click *CTRL + C* to copy the data into memory, open Excel, and use *CTRL + V* to paste the input assumptions into Excel, creating perhaps a scratch work area for further analysis or as a means to archive the data.
 - Note that the data inputted needs to follow this simple rule: Minimum ≤ Most Likely ≤ Maximum. If all three items are identical in value (this is actually an allowed set of inputs), simulation will not be run for this particular input, as it is thereby assumed that there is no range and no uncertainty exists for this task.



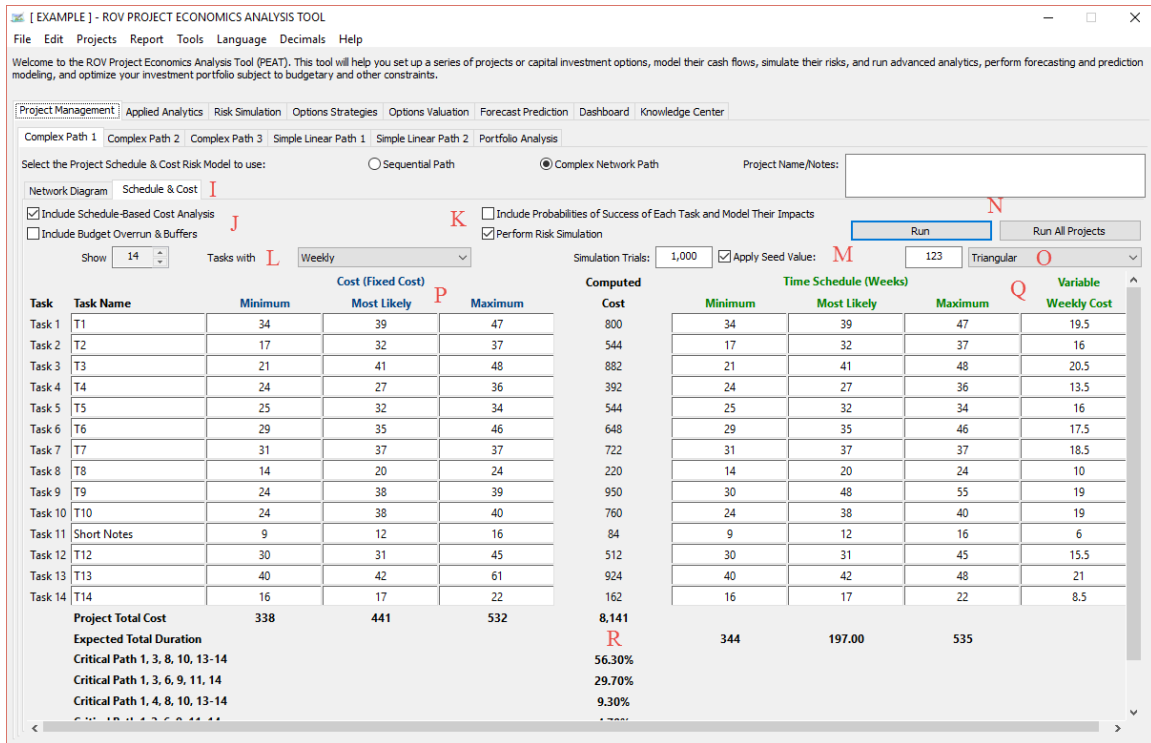


Figure A3.10: Input Assumptions Worksheet

- Figure A3.11 shows the simulation results after the model is run.
 - The *Simulation Results* are located as a subtab (area AD) under the main *Risk Simulation* tab.
 - Start by selecting the *Project* or product line droplist (area AE). Note that this droplist shows all the project tabs' (area B of Figure A3.9) project costs and schedules.
 - Area AF shows the *Simulation Statistics* such as the mean or average value for the schedule or cost, as well as other related items such as the percentiles (0%, 5%, 10%, and so forth).
 - You can now select the *Tail Type* (*Two Tails*, *Left Tail* \leq , *Right Tail* \geq , etc.) and enter in some *Percentiles* or *Values* (area AG). Note that if you enter *Percentiles* and hit *TAB* on your keyboard, the corresponding *Values* will be computed. Alternatively, entering some *Values* and hitting *TAB* will get you the calculated *Percentiles*. See elsewhere in this report for details on interpreting these percentiles and confidence levels.
 - You can *Copy Chart* or *Show Gridlines* in the chart (area AJ) or use any of the *chart control icons* located above the chart to modify the look and feel of the resulting chart (colors, size, zoom, custom text, custom lines, etc.).



- Remember to *check the box* in area AI if you wish to save the simulation results. Remember that if you do not check this box, the next time you open this file, the simulation results tabs will be empty and you will need to re-run the simulation. You will usually not check this box when the analysis is still in progress and the final model is not yet ready or when you are trying to reduce the model's file size by not having to save all the simulated data points. However, if the model and input assumptions are correct and finalized, checking this box will allow the results to be saved and retrieved the next time the file is opened. Remember that checking this box will clearly increase the file size by several megabytes, although not by a lot.
- As there are multiple charts and results that can be created, modified, and customized, area AH allows you to save the various charts. Just modify the charts as you see fit, adding any percentiles or certainty values, gridlines, and so forth, then enter a short but descriptive name in the *Name* box and click *Save As* to save this chart. To retrieve the chart, simply *double-click* on any of the saved *Models* list (see the model names in area AH).

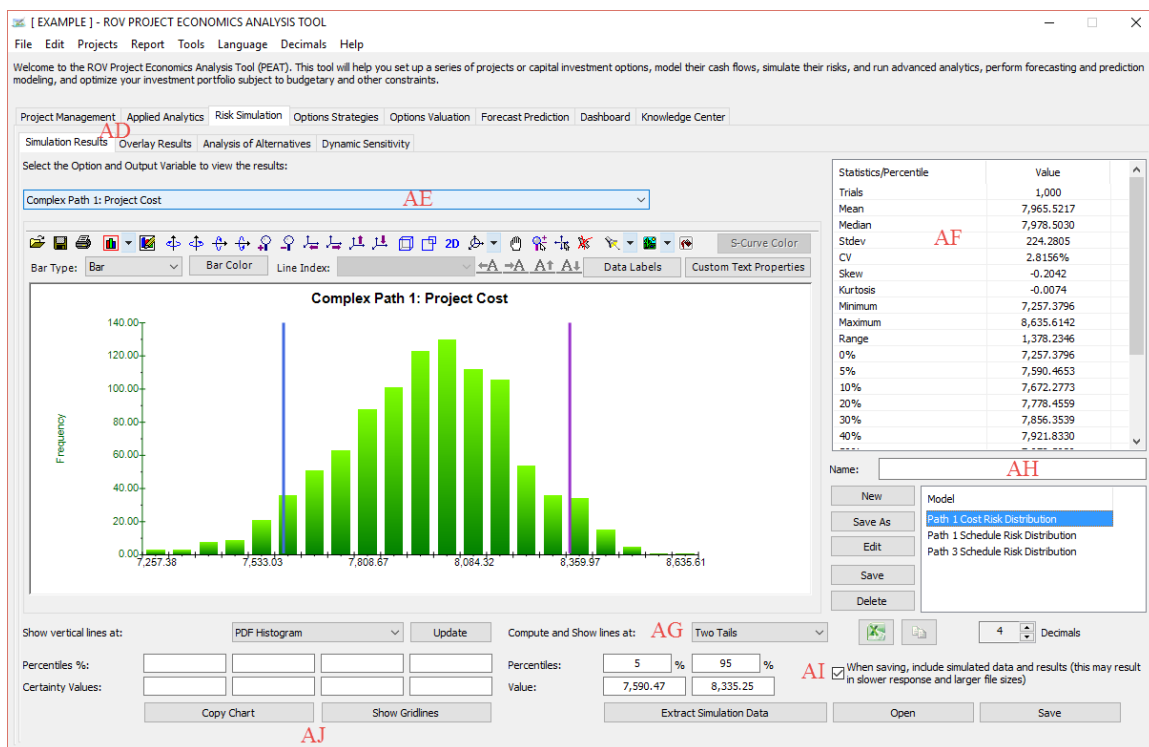


Figure A3.11: Simulation Results

- Now, a quick word on *Saving your work and Data Encryption/Security*.
 - Saving. Area AH allows you to save multiple charts and their settings, while area AI's checkbox requests that the simulation data points (tens of thousands to millions of data points) be saved so that the results will be readily available and visible the next time the file is opened. In addition, area C in Figure A3.9 shows that you can create multiple projects, and each project can have its own complex network diagram (see Figure A3.9) and unique input assumptions and settings (see Figure A3.10). Finally, data and charts can be copied and pasted (e.g., area AJ) into Microsoft Word and PowerPoint for future archiving and saving. All of these generated input assumptions, charts, diagrams, settings, results, and miscellaneous items are saved into a single file with the extension **rovprojecon* when you click on the menu item *File | Save* or *File | Save As*. This single file incorporates all the items in the multitude of tabs and data grids as described previously.
 - Security. The ROV PEAT software provides three levels of security protection for your saved **rovprojecon* file:
 - This **rovprojecon* file is digitally encrypted and can only be opened by someone using the ROV PEAT software. Unauthorized personnel with access to this file will not be able to view its encrypted contents.
 - In addition, the PEAT software has a Hardware Fingerprint capability whereby software licenses can be provided to authorized end-users and are linked to their computers. Licenses issued for a unique hardware fingerprint cannot be used in another computer. This constraint facilitates proper access control of the software only to authorized users.
 - Finally, the PEAT software itself has an additional layer of data encryption. The **rovprojecon* data file can be password protected using the *File | Password Protect* menu item. However, please be aware that any file that is protected in such a way cannot be retrieved unless the correct password is entered.



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Biographies

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Lehigh University, Doctor of Philosophy, Finance and Economics, 1998

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