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# Planning, Tracking, and Reducing a Complex Project's Value at Risk

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## Abstract

Uncertainty, risk, and rework make it extremely challenging to meet goals and deliver anticipated value in complex projects, and conventional techniques for planning and tracking earned value do not account for these phenomena. This article presents a methodology for planning and tracking cost, schedule, and technical performance (or quality) in terms of a project's key value attributes and threats to them. It distinguishes four types of value and two general types of risks. The "high jumper" analogy helps to consider how high the "bar" is set for a project (its set goals) and therefore how challenging and risky it will be. A project's capabilities as a "jumper" (to clear the bar and meet its goals) determine the portion of its *value at risk* (VaR). By understanding the amounts of value, risk, and opportunity in a project, project managers can design it for appropriate levels of each. Project progress occurs through reductions in its VaR: Activities "add value" by chipping away at the project's "anti-value"—the risks that threaten value. This perspective on project management incentivizes generating results that eliminate these threats, rather than assuming that value exists until proven otherwise.

## Keywords

project value, uncertainty, project planning, project monitoring, technical risk, earned value, value at risk

## Introduction: Why Is Consistent Project Success So Elusive?

Despite the presence of a copious body of knowledge about project management practices, completing complex projects to their full scope, on time and within budget, remains extremely difficult. It seems rare that complex projects actually achieve all of their goals. According to the Standish Group's Chaos Reports (e.g., Standish, 2001) over the past 20 years, about two-thirds of small (up to six people and six months) information technology (IT) projects failed to meet all of their goals—even after receiving 250% of their proposed budget. Including larger projects, over 20% of U.S. IT projects are over budget, and 20% are behind schedule (www.itdashboard.gov). Perhaps even worse, as reported by the U.S. Government Accounting Office (www.gao.gov/assets/120/117799.pdf), over 70% of U.S. IT projects are poorly planned and/or underperforming. Although equally extensive data on non-IT projects are less available, many large and complex design, development, and construction projects have also exhibited high-visibility problems—for example, the F-35 aircraft (e.g., IDA, 2010), Boston's Central Artery Tunnel (the "Big Dig"), and Denver International Airport (e.g., Calleam, 2008), just to mention a few.

Granted, complex projects are quite challenging. Yet, knowing this, why can't planners make better estimates of project costs, durations, and results—and why can't they correctly measure an ongoing project's progress? A number of potential explanations could contribute to this. First, there is always poor project definition and planning (Pinto, 2013). Second, projects may aim at the wrong targets—setting the wrong goals—because of poor understanding of customers and other stakeholders, or deliberately, to increase the chances of project approval (Flyvbjerg, 2014). Third, when the path to a project's chosen destination (goals) is complex, novel, dynamic, uncertain, and ambiguous, this translates into not knowing exactly what to do (and when to do it) throughout the project. Fourth, add to this a generally poor understanding of uncertainty and risk throughout many projects, including the failure to apply proper techniques of risk management (Hubbard, 2009) and an unfortunate preference among some for blissful ignorance (Browning & Ramasesh, 2015). Some project managers naively assume that their plans will become reality, only to be surprised by unexpected problems along the way. For

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example, one common problem, the “green until red” status syndrome, has project status as “green” (good) until it suddenly becomes “red” (very bad). What happened to a gradual decay through “yellow” (potential problems)? Problems are often hidden as long as possible, until they are more difficult to solve. Part of this has to do with behaviors and incentives, but another key factor has to do with the absence of appropriate monitoring systems. Fifth, we cannot discount the poor application of project management tools—not just a lack of use, but also misuse and sometimes overuse. Sixth, many project managers fail to account explicitly for rework, which can unexpectedly consume double-digit percentages of project time and cost budgets (e.g., Cooper, 1993; Love, Irani, & Edwards, 2003). Seventh, with the reality of uncertainty and rework, existing project management tools may simply be inadequate for planning, scheduling, monitoring the quality of interim results, integrating sub-project results, and supporting fuzzy tradeoffs in time, cost, and quality. With existing tools, it is actually still hard to tell if a project is really making appropriate progress. This list could go on, but it already motivates the need for better methods and practices.

This article presents an approach to conceptualizing, planning, and monitoring project value and the risks to it. The approach does not solve all of the problems in the preceding paragraph, but it does address several—specifically, improving project definition and planning, clarifying the implications of project goals, including appropriate activities at appropriate times in the project, accounting for uncertainties, providing improved monitoring of project status, making accommodations for rework, and supporting tradeoffs in project time, cost, quality, value, risk, and opportunity. The approach elaborates on techniques originally developed by Browning et al. (Browning, 2014; Browning, Deyst, Eppinger, & Whitney, 2002)—two papers strongly recommended as background reading. After briefly discussing the foundational concepts of project quality, value, goals, uncertainty, risk, and opportunity, this article notes some shortcomings of the conventional earned value management (EVM) method. Using the analogy of a “high jumper” helps consider how high the “bar” is set for a project, and therefore how challenging and risky it will be. Taking a project’s capabilities as a “jumper” (to clear the bar and meet its goals) into account helps determine how much of the project’s value is being put at risk by uncertainties about its outcomes. By understanding the amounts of value, risk, and opportunity in a project, project managers can design and tailor the project for appropriate levels of each. The approach is also helpful for comparing projects in terms of difficulty. Project progress occurs through reductions in the portion of its value being put at risk. Activities add value by chipping away at the project’s “anti-value,” the consequential uncertainties (risks) that threaten value. From this perspective, projects must prove their value through progress in risk reduction rather than assume that value exists until proven otherwise. This article describes these concepts and presents a detailed example of their application to a drone aircraft development project.

## Foundational Concepts

An approach for planning, tracking, and reducing a project’s value at risk requires a clear definition and overview of some foundational concepts, including work quality, project value, uncertainty, risk, opportunity, and value at risk (for further details, see Browning, 2014, and Browning et al., 2002).

### *Interim Work Quality*

In a classic paper about rework in projects, Cooper (1993) highlighted two key drivers of project progress: the quality of activities’ results and the length of time it takes to discover any problems with them. Most project planning and tracking methods assume that all work is done correctly. Operations managers call this 100% yield, which can be difficult to achieve in well-understood, repetitive activities, so it is even less realistic for the activities in complex, novel projects. Moreover, because it is possible to start work based on assumptions (in lieu of complete and accurate information), value-adding activities often experience a “garbage in, garbage out” problem—beginning work without a sure foundation and then having to fix things later (Browning, 2003). Meanwhile, their successor activities start, assuming complete and accurate inputs from their predecessors. The longer it takes to discover any problems (Cooper’s second rework driver), the more the flawed results will have undermined downstream activities, thereby amplifying the cascade of rework and its cost and schedule impacts (Browning & Eppinger, 2002). Cooper thus distinguished real progress in projects from perceived progress, with the former always lagging behind the latter. Undiscovered rework accounts for the difference between them. Real progress and “added value” depend on results (accomplishments), not “doings” (activities). Most project management methods and software tools do not address these effects; they focus on activities planned and done rather than on the value of their results.

### *What Is Project Value?*

A project’s value[1] depends on its actual result, not just on what activities it does. The value of a project’s result depends on its stakeholders’ preferences for a combination of attributes, called *project value attributes* (PVAs).[2] Stakeholders generally want more of some PVAs (such as features, functions, reliability, size, speed, availability, design aesthetics, etc.) and less of others (such as price, operating cost, weight, project duration, delivery time, etc.). Different stakeholders have competing preferences for some attributes—such as a customer or client who wants a lower price versus employees who want higher wages and shareholders who want greater profitability. PVAs may also include stakeholder objectives such as the creation of new business opportunities or the enlargement of potential value for future projects. Overall project value is a

**Table 1.** Four Types of Project Value

| | |
|---|---|
| Actual value | A project's final value at completion, based on how things turn out and where the project ends up |
| Desired value | The value that stakeholders ideally desire (explicitly and tacitly) from a project |
| Goal value (GV) | The value of a project that meets its chosen goals/ targets/objectives/requirements |
| Likely value (LV) | The estimated value of an incomplete project, given its resources and capabilities |

composite of the relevant PVAs. Most of a project's value depends on a few (e.g., 5–10) salient PVAs. Major problems with any of these may doom a project. However it is ascertained, a project's actual value cannot be known for sure until the project is complete and its result delivered (and sometimes not even until well after that). Until then, measures of project value are just estimates, forecasts, or predictions, fraught with uncertainty.

## Four Types of Project Value

It is helpful to distinguish four types of project value (see Table 1): actual, desired, goal, and likely (Browning, 2014). A project's *actual value* is its final value at completion, based on how things turn out and where the project ends up. Prior to that point, we can distinguish three other types of project value. First, a project's *desired value* is the value its stakeholders ideally desire (explicitly and tacitly). Because stakeholders may not know exactly what they want until they see it—and may otherwise have difficulty articulating their desires and preferences—project planners can only do their best to estimate a project's desired value with improved stakeholder understanding. Second, as project planners set goals for a project, they establish a *goal value* (GV), which may or may not match the project's desired value. GV is the value of a project that meets its chosen, explicit goals (which may or may not align with stakeholders' ultimate desires). Some projects aim at the wrong targets (choose the wrong goals) by mistake; others admit early on that their aims are short of what stakeholders might ideally want; others settle on a compromise among competing stakeholders. Either way, a project's GV and its desired value may not be identical. Third, depending on the resources and capabilities of the performing organization, an incomplete project has a *likely value* (LV), a forecast of where it is likely to end up, which could be more or less than its GV.

As a side point, note that a project's actual value may evolve post-completion. For example, a project may lead to greater-than-expected benefits, as in the case of the Sydney Opera House, which was initially deemed a failure but ultimately gained accolades. On the other hand, Motorola's Iridium satellite project met its goals but saw its value plummet soon afterward as desired value quickly shifted. In this article, we focus on project GV and LV, implicitly assuming that desired value is fairly well known and stable, although the approach described herein can still be useful in situations with dynamic value.

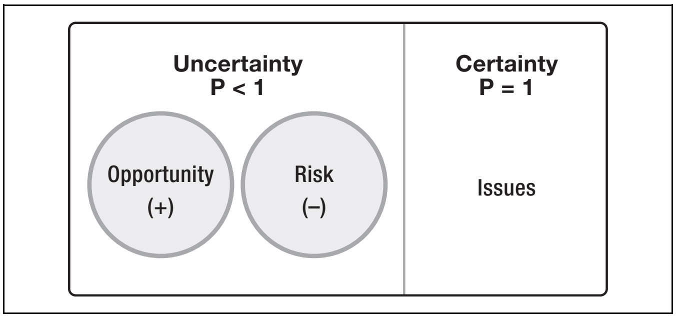



**Figure 1.** Project events categorized as certain or uncertain, and furthermore in terms of a positive or negative effect on a project's value.

## Project Goal Value (GV)

A project sets a goal for each PVA. (For simplicity, we use the term *goals* as a near synonym for a project's targets, requirements, and objectives.) Meeting these goals will provide some amount of value, the project's GV. For example, if a project develops a product with a particular combination of PVAs set at particular levels, it might expect to sell a number of units at a particular price, generating revenue. Falling short of the goals causes a value loss, either directly through contractual penalties or indirectly in terms of lesser revenue from future sales, whereas exceeding a goal may bring value rewards, either directly via contractual bonuses or indirectly from increased future revenue. Marketers and business developers commonly plan business cases around such projections. Overall project GV depends on a combination of the GVs of each PVA. The combination may occur in various ways, each with pros and cons. Later in the article, a detailed example compares two approaches to determining a project's overall value as a function of the values of its PVAs.

## Project Likely Value (LV)

Prior to its completion, a project has many potential outcomes—ranges of eventual, actual values for each PVA. The positions and sizes of these ranges, and the relative likelihoods of the outcomes within them, depend on the project's resources and capabilities. We quantify a project's LV as the probabilistically weighted average (expected value or mean) of its distribution of potential outcomes. As with GV, the LVs of all PVAs combine to determine a project's overall LV.

## Uncertainty, Risk, and Opportunity

A project's planned activities imply a chosen path toward its goals. This path is fraught with uncertainties—events that might or might not occur (probability <1), some of which could interdict the accomplishment of the project's goals and thereby affect its LV (Figure 1). Consequential uncertainties yield opportunities or risks depending on if they affect a project's LV positively or negatively, respectively.

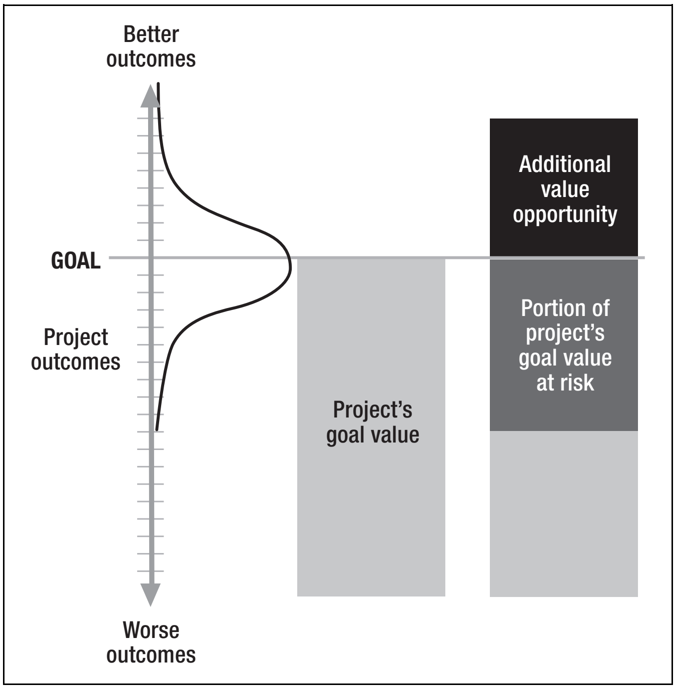



**Figure 2.** A distribution of project outcomes, some of which exceed the goal and others of which fall short.

### *Project Value at Risk (VaR)*

The left side of Figure 2 shows a distribution of project value outcomes. The greater the uncertainty in the project's outcomes, the wider this distribution will be. Increasing knowledge and predictability of project outcomes narrows the distribution. Increasing a project's resources and capabilities will typically shift the distribution upward, toward better outcomes. Some of the project's outcomes meet or exceed the GV "bar," whereas others fall short. The upside and downside of this uncertainty drive opportunity and risk, respectively. Outcomes that exceed the goal may provide some additional value opportunity, whereas outcomes that fall short put the project's GV at risk. The actual amounts of opportunity and risk depend not only on the shape of the outcome distribution but also on the rewards and penalties of the outcomes. For example, in a new laptop computer with a goal of a 15-hour battery life, missing the goal by 15 minutes will not hurt as much as missing it by 5 hours, so the fact that both of these potential outcomes fail to meet the goal does not imply that they carry equal risk. The fact that the distribution of possible outcomes is wide enough to include an outcome 5 hours below the goal puts the project's value at much greater risk than the outcome of only 15 minutes less. Later, we will quantify these differences to find a project's overall *value at risk* (VaR).

## Some Problems With Earned Value Management (EVM)

EVM is perhaps the most prominent method for planning and tracking project progress mentioned in *A Guide to the Project Management Body of Knowledge (PMBOK Guide®)* – Sixth Edition (Project Management Institute, 2017) and a number of other project management publications (e.g., Fleming & Koppelman, 2010; Project Management Institute, 2011), and it is the subject of dedicated conferences. EVM provides a clear boost in project management capability and maturity over the lack of any formal method. In light of the concepts and challenges mentioned above, however, EVM has significant shortcomings. First, despite some exceptions (e.g., Solomon & Young, 2007), most EVM implementations do not account for the quality or performance level of deliverables. Second, in taking a deterministic view of activity durations and costs, EVM does not account for their uncertainty, variation, and unpredictability—thus ignoring risk and opportunity as well. Third, EVM tracks what Cooper (1993) called "perceived progress," assuming that completed activities have perfect quality outputs and will not experience rework (even though rework has been shown to cause double-digit percentage overages in cost and duration). Fourth, EVM takes a linear view of activity progress, failing to account for the common situation where "the last 10% of an activity (or a project) takes half the time" because the tough parts were put off. The method does not force users to distinguish between easy and hard activities (or parts of activities), giving equal credit for both. Some versions of EVM even give half credit just for starting activities, making it easy to "game" project status simply by beginning a lot of work (often prematurely, which further increases the risk of rework). Fifth, the "value" managed by EVM does not clearly correspond to any of the four types discussed earlier (Table 1). EVM does not account for stakeholder value preferences, the value of new information about project outcomes, or a project's VaR. Sixth, the value added by activities is partly a function of *when* those activities occur in a project, regardless of their internal characteristics (Browning, 2003). For example, if an activity could reveal the viability of the entire project, it would be much more valuable to perform this activity near the beginning of the project than near the end. Yet, EVM does not account for this time-varying nature of activity value. All of these shortcomings motivate the need for an enhanced methodology. As former U.S. secretary of defense Robert McNamara (1961–1968) famously stated, "We have to find a way of making the important measurable, instead of making the measurable important." The approach described in this article illuminates some useful possibilities.

## The High Jumper Analogy

Meeting all of a project's goals provides an amount of value, the GV. However, prior to its completion, the actual outcomes of a challenging, complex, novel project are uncertain. Not meeting some of its goals will diminish its actual value. This possibility threatens project value; it puts a portion of the project's GV at risk. Uncertainty may also have an upside. We might get an even better outcome than we expect. However, without proactive positioning to seize this opportunity, we still might get only the project's GV (when we could have done better).

As a helpful analogy, recall Figure 2 and consider a high jumper at a track and field competition. Project value depends on two main factors: its capabilities (how good is the jumper?) and its chosen goals (where is the bar set?). Shifting the distribution of outcomes upward (becoming a better jumper) increases the LV, whereas lowering the bar decreases the GV. With a given distribution, lowering the bar increases the jumper's chance of getting over it (i.e., it decreases the portion of the project's value put at risk by the uncertainty in the jumper's capability), but it also increases the value opportunity "left on the table" (i.e., it is more likely to waste a good jump that could have seized more value). Raising the bar increases the GV reward but also makes the project riskier. The analogy has limitations, however, because, whereas a high jumper receives no additional value from exceeding the bar by additional distance, and any size miss is a failure, a project's value may differ depending on an outcome's distance from the goal. Hence, narrowing the distribution of outcomes in a favorable region (becoming a more consistent jumper) can increase project value and decrease the portion of the project's VaR.

A project's capabilities as a "jumper" depend on several factors, such as available resources, tools, technologies, and expertise; chosen activities, processes, and approaches; and the capabilities of partners, suppliers, and management. These factors affect the range of potential outcomes for a project as well as the relative likelihood of particular outcomes across that range. Thus, project capabilities determine the location and shape of the distribution of project outcomes illustrated in Figure 2. As mentioned previously, this overall distribution is a composite of the distributions of outcomes for each of a project's key attributes, its PVAs. Thus, we need to evaluate a project's capabilities specifically in terms of each PVA.

A project's value also depends on where the bar is set. In Figure 2, raising the bar—the GV—relative to the distribution of project capabilities increases the risk of missing it. Figure 3 also shows general relationships between desired value, GV, and LV—and how these three quantities determine two general types of risk: project risk (the risk of not meeting the project's chosen goals) and market risk (the risk of not choosing the right goals). If we raise the bar, setting more challenging goals and increasing the GV, we reduce the risk of disappointing the market by missing stakeholders' desired value, but we also widen the gap between the goals and the project's capabilities (which determine LV), thereby making the project riskier. Conversely, easier goals (lowering the bar) decrease project risk at the expense of greater market risk.

So, where should a project "set the bar"? What should its goals be? These are interesting questions, ones that require further research to explore. Browning (2014) provided further discussion about setting project goals. For now, this article uses project goals as an input to the framework. The point here is merely to frame the situation and emphasize that stakeholders can adjust a project's goals and capabilities to tailor its levels of value, risk, and opportunity.

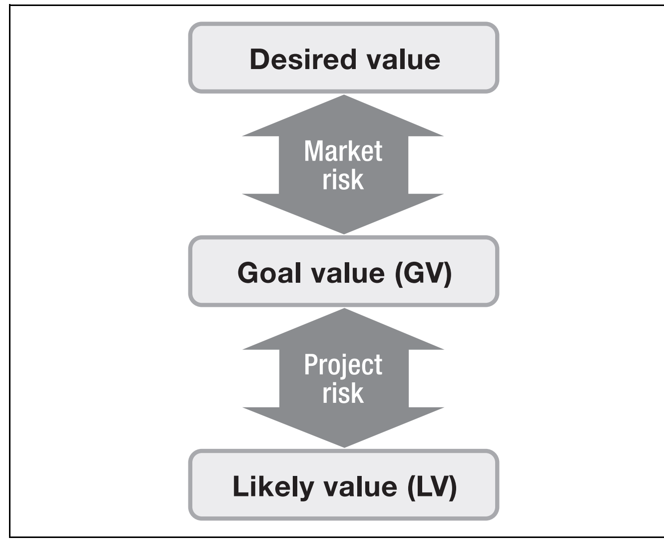



**Figure 3.** Relationships between three types of project value determine the amounts of two types of project risk (adapted from Browning, 2014).

## A Detailed Example

We apply the risk value method (RVM) (Browning et al., 2002) and the project value, risk, and opportunity (PVRO) framework (Browning, 2014) to model these factors for project planning and monitoring. Figures on the following three pages exemplify 15 steps for planning a drone aircraft development project, whose value depends on six PVAs: four technical PVAs and two PVAs, which relate to project duration and cost. (Six additional steps for project monitoring and control will be discussed later.) Although further details of these steps are discussed by Browning (2014), this section highlights some important points.

Steps 3 and 4 propose *value functions* (VFs) based on expected revenue. However, the VFs can be formulated in other terms, such as units sold, profits, utility, and so forth. Each of these options has pros and cons. VFs based on expected revenue have the drawback of not directly accounting for the relationship between product development project costs, product per unit costs, revenue, and profit. Although a more detailed revenue, pricing, and profit model could be used during these steps to handle the situation, this example uses expected revenue for simplicity of presentation.

Steps 7 and 9 include two alternative models, (a) and (b), for determining overall project value as a function of the six PVAs. Later steps in the example show results for each of these two models. Although one could use more sophisticated models here instead, all such possibilities have advantages and drawbacks. The *project capability distributions* (PCDs) developed for each PVA in Step 8 are based on expert assessments (e.g., a Delphi technique, a prediction market, or other techniques [e.g., Eggstaff, Mazzuchi, & Sarkani, 2014; Flanagan, Eckert, & Clarkson, 2007]).[3]

**Step 1:** Determine Project Value Attributes (PVAs)

- What are the 5–10 most important things about this project's result, the most salient determinants of stakeholder satisfaction and market success?
- Usually it is essential to include at least one PVA pertaining to price and one pertaining to lead-time.

**Drone aircraft development project example:**

1. Endurance (continuous hours in flight)
2. Maximum range (miles)
3. Reliability (mean time before failure [MTBF], hours)
4. Stealth (percent improvement over previous product)
5. Delivery lead-time (months from project start)
6. Unit price ($million)

**Step 2:** Estimate Market Size

- With an amazing product that excels in all PVAs, what is the maximum number of units that we estimate that we could sell?

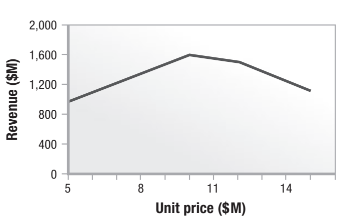
**Drone aircraft development project example:**

- 200 units

**Step 3:** Determine Price to Revenue Relationship

- A higher price per unit implies greater margin but fewer units sold.
- A lower price per unit implies smaller margin but more units sold.
- Estimate total potential revenue as a function of unit price.

**Drone aircraft development project example:**

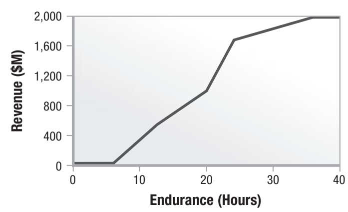


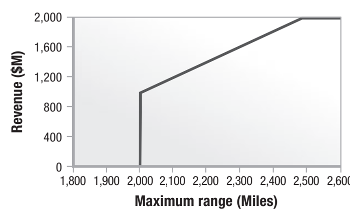

- The maximum revenue is $2,000M (achieved with a price of $10M for each of the 200 units)

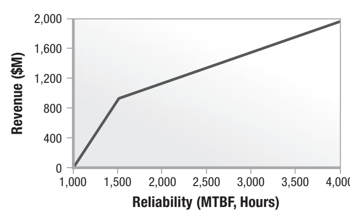
**Step 4:** Determine the Value Function (VF) for Each PVA

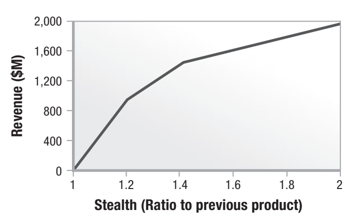
- How do various amounts of each PVA affect expected revenue?
- Use market research, customer data, and stakeholder inputs to define each VF, $V(x)$.

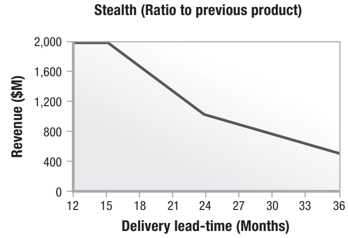
**Drone aircraft development project example:**




**Step 5:** Weight Relative Importance of Each PVA

- On a scale of 1–10 what is the relative importance of each PVA to the customer or market?
- Add the scores and divide by the total to determine the percentage of each PVA from the whole.

**Drone aircraft development project example:**

1. Endurance: 18%
2. Maximum range: 23%
3. Reliability: 18%
4. Stealth: 14%
5. Delivery lead-time: 16%
6. Unit price: 11%

**Step 6:** Set Initial Goal ($G$) for Each PVA

- Where should the "bar" be set for each PVA?

**Drone aircraft development project example:**

1. Endurance goal: 22 hours
2. Maximum range goal: 2100 miles
3. Reliability goal: 2000 hours MTBF
4. Stealth goal: 40% improvement
5. Delivery lead-time goal: 18 months
6. Unit price goal: $10M

**Step 7:** Determine Project's Goal Value (GV)

- What is the expected revenue from achieving the project's goals?
- Use the VFs from Step 4 to find the revenue expectation for each PVA individually
- To determine a composite revenue expectation for the overall project, two basic models are:
  a. Weighted average
  b. Worst attribute
- The greater the difference between a and b, the more model b should be favored.

**Drone aircraft development project example:**

a. GV = (.18)(1334) + (.23)(1200) + (.18)(1200) + (.14)(1500) + (.16)(1667) + (.11)(2000) = $1429M

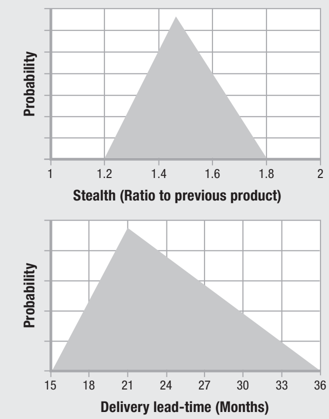
b. GV = MIN (1334, 1200, 1200, 1500, 1667, 2000) = $1200M

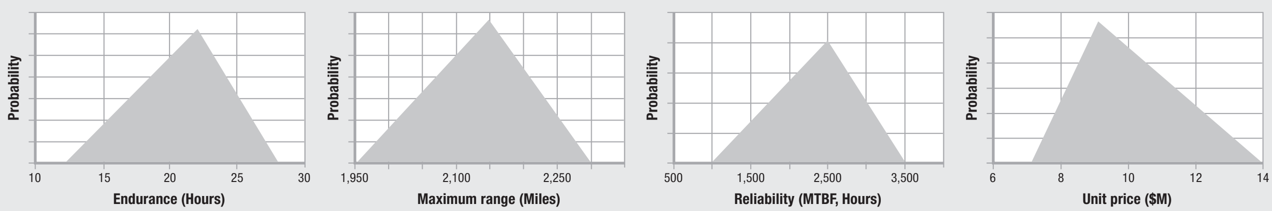
Steps 10 and 12 use the VFs from Step 4 and the PCDs from Step 8 to calculate amounts of risk and opportunity for each PVA. As a further explanation of Step 10, Figure 4 shows the PCD (left side) and VF (right side) for continuous flying time (Endurance), a key PVA of the drone aircraft. The PCD shows the probabilities of outcomes between 12 and 28 hours, and the VF shows the implications of outcomes on expected revenue. The goal set at 22 hours implies a GV of US$1,334 million. An Endurance outcome that exceeds this goal will provide a value bonus (the difference between the value of the outcome and VG), whereas an outcome that falls short of this goal carries a value penalty (again, the difference between the value of the outcome and VG, which in this case is negative). For instance, an outcome of 24 hours (exceeding the goal) implies an

**Step 8:** Characterize the Project Capability Distributions (PCDs), the Relative Likelihood of Potential Outcomes for Each PVA

- What is the worst possible result the project could have for each PVA?
- What is the best possible result the project could have for each PVA?
- What is the most likely result the project could have for each PVA?
- Consider the project's potential and likely resources, technologies, methods, approaches, skills, etc.
- Solicit inputs from a variety of subject matter experts.
- Use the responses to characterize the distribution of potential outcomes for each PVA, $\tilde{P}(x)$.
- A simple approach is to infer a triangle distribution from the three data points, but the distribution can assume any appropriate shape.

**Drone aircraft development project example:**




expected revenue of US$1,668 million (US$334 million more than the GV), whereas an outcome of 15 hours (missing the goal) implies a revenue of only US$688 million (US$646 million less than the GV). To calculate the risk, we cannot simply multiply the probability of missing the goal by a single value penalty, because the penalties vary depending on the actual outcome. Instead, we have to look at all possible adverse outcomes and find the overall weighted average (or expected) value penalty, where the weightings are the probabilities of the various outcomes. Practically, we can divide the region of adverse outcomes in the PCD into a large number of "slices" (e.g., 100), do the calculation for each, and add the results (making the integral formula shown in Step 10 a summation). This gives the average value loss (i.e., VaR) from the set of adverse outcomes. Doing the same for the positive outcomes (here, all outcomes between $G$ and $\infty$) quantifies the opportunity, or average value bonus (Step 12).

Step 15 considers ways to adjust project difficulty and challenge by tailoring the amount of the project's value put at risk. Options here include moving the "bar" (changing the goals) and/or using a different "jumper" (changing the PCDs by using different resources, technologies, etc.). Each PVA requires these decisions, although choices for one PVA may affect others. For example, adding resources may improve the technical PCDs but could worsen the Unit Price PCD (to recoup the project's increased cost). Thus, the framework supports integrated cost-schedule-performance/quality planning and tradeoff analysis. It may also be desirable to balance risks across PVAs rather than allow one PVA's risk to "stick out like a sore thumb" and dominate the project. Comparing results from the two models, (a) and (b), reveals these types of situations.

In summary, the PVRO framework provides a project manager with several useful key performance indicators (KPIs): the amounts of value, risk, and opportunity associated with each PVA, as well as the project's composite value (LV), risk (VaR), and opportunity (VaO).

## Anticipating and Tracking Project Progress

The PVRO framework also provides powerful capabilities for managing ongoing projects. To appreciate these, consider first the implications of uncertainty as a project unfolds. Figure 5 illustrates simply how a project begins with high potential value, albeit with many uncertainties that put that value at risk. Over time, (1) the project does value-adding work, (2) that produces useful information, and (3) that reduces the portion of the project's GV put at risk by threatening uncertainties (Browning et al., 2002). We can therefore think of a project as *the finite work done to eliminate the risk of not achieving its goals*. Chipping away a project's "anti-value" (i.e., VaR) reveals a clearer image of its actual value. Hence, it is important to track not only the best current estimate of project value but also the uncertainty bounds around that estimate, the associated penalties and rewards, and their implications for risk and opportunity. Uncertainty reduction narrows the PCDs (which start out wide). Design tradeoffs or resource reallocations shift the PCDs up or down along the range of outcomes (see Figure 2). As the PCDs change shape and location, this alters LV, risk,

### Step 9: Determine the Project's Likely Value (LV)

- Give the relative likelihood of the potential outcomes of each of the project's PVAs, what is the project's overall value likely to be?
- Using the expected value of each PCD, calculate the overall project's LV, again using models a and b.

**Drone aircraft development project example:**

a. LV = (.18)(1192) + (.23)(1233) + (.18)(1316) + (.14)(1540) + (.16)(1126)+ (.11)(1863) = $1336M

b. LV = MIN (1192, 1233, 1316, 1540, 1126, 1863) = $1126M

### Step 10: Determine the Risk in Each PVA

- The risk of achieving the goal for each PVA is modeled here as the sum of all adverse outcomes, each weighted by its probability.
- Adverse outcomes and their probabilities come from the PCDs.
- The negative impact of the outcome is the difference in value between the outcome and the goal (found from the VF). For "more is better" VFs, this is:

$$\mathcal{R} = -\int_{-\infty}^{G} \tilde{P}(x)[V(x)-V(G)]dx$$

- This number is the portion of the project's GV put at risk because of the uncertainty in achieving the goal for a particular PVA.

**Drone aircraft development project example:**

- Note: The integrals were approximated by dividing each PCD's region of adversity into 100 increments, multiplying each by its corresponding value loss, and summing.

1. Endurance risk: $236M
2. Maximum range risk: $66M
3. Reliability risk: $53M
4. Stealth risk: $44M
5. Delivery lead-time risk: $547M
6. Unit price risk: $137M

### Step 11: Determine the Project's Overall Value at Risk (VaR)

- Given the VaR due to each individual PVA, what portion of the project's overall value is at risk?
- Again use models a and b.

**Drone aircraft development project example:**

a. VaR = (.18)(236) + (.23)(66) + (.18)(53) + (.14)(44) + (.16)(547) + (.11)(137) = $176M

b. VaR= MAX (236, 66, 53, 44, 547, 137) = $547M

### Step 12: Determine the Opportunity in each PVA

- The opportunity to achieve an outcome beyond the goal for each PVA is modeled here as the sum of all such outcomes, each weighted by its probability.
- Outcomes and their probabilities again come from the PCDs.
- The positive impact of the outcome is the difference in value between the outcome and the goal (found from the VF). For "more is better" VFs, this is:

$$\mathcal{O} = \int_{G}^{\infty} \tilde{P}(x)[V(x)-V(G)]dx$$

- This number is the additional amount of value beyond the GV available because of the possibility of achieving outcomes that exceed the goal for a particular PVA.
- Note that when $\mathcal{R}$ is "high" for a particular PVA, $\mathcal{O}$ will be "low" and vice versa. "Raising the bar" on the goal ($G$) for each PVA will increase (decrease) $\mathcal{R}$ ($\mathcal{O}$) .

**Drone aircraft development project example:**

- Note: The integrals were approximated by dividing each PCD's region of positive outcomes into 100 increments, multiplying each by its corresponding value loss, and summing.

1. Endurance opportunity: $94M
2. Maximum range opportunity: $99M
3. Reliability opportunity: $169M
4. Stealth opportunity: $84M
5. Delivery lead-time opportunity: $8M
6. Unit price opportunity: $0M

### Step 13: Determine the Project's Overall Value at Opportunity (VaO)

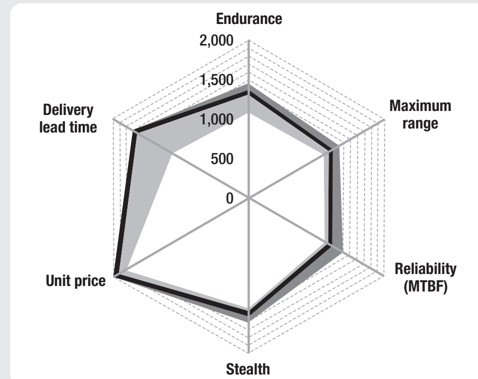
- Given the VaO due to each individual PVA, what portion of the project's overall value is at opportunity?
- Again use models a and b.

**Drone aircraft development project example:**

a. VaO = (.18)(94) + (.23)(99) + (.18)(169) + (.14)(84) + (.16)(8) + (.11)(0) = $83M

b. VaO= MAX (94, 99, 169, 84, 8, 0) = $169M

### Step 14: Evaluate the Project's Overall Value, Risk, and Opportunity




- As found in Step 10, the greatest risk contribution comes from the delivery lead-time PVA. This risk could be alleviated by finding a way to do the project (and/or subsequent unit production) faster (albeit perhaps pressuring margins if significant expense is involved), or by relaxing the lead-time goal (although this would decrease the project's GV).
- There is some opportunity to increase the project's GV while adding minimal risk by increasing the goal for Reliability.
- Overall, this looks like a fairly challenging project, because the overall VaR is much greater than the overall VaO (by both models).

### Step 15: If Desired, Revise Goal ($G$) for Each PVA

- Should the "bar" be raised or lowered for any PVA?

**Drone aircraft development project example:**

- All goals maintained except:

1. Reliability goal is raised to: 1140 hours MTBF
2. Delivery lead-time goal relaxed to: 21 months

**This caused the following changes:**

- Reliability GV increases from $1200 to $1300
- Reliability risk increases from $53M to $87M
- Reliability opportunity decreases from $269M to 103M
- Delivery lead-time GV decreases from $1667M to $1333M
- Delivery lead-time risk decreases from $547M to $269M
- Delivery lead-time opportunity increases from $8M to $63M

a. Overall GV decreases by $36M from $1429M to $1393M
b. Overall GV remains at $1200M
a. Overall VaR decreases by $38M from $176M to $138M
b. Overall VaR decreases by $278M from $547M to $269M
a. Overall VaO decreases by $3M from $83M to $80M
b. Overall VaO decreases by $66M from $169M to $103M

**What does all of this mean?**

- By resetting the bar, the jump (project) now has a slightly less ambitious GV, but much less of that value is being put at risk by excessive challenge.
- The project could also consider changing its PCDs through investments in technologies, skills, etc.

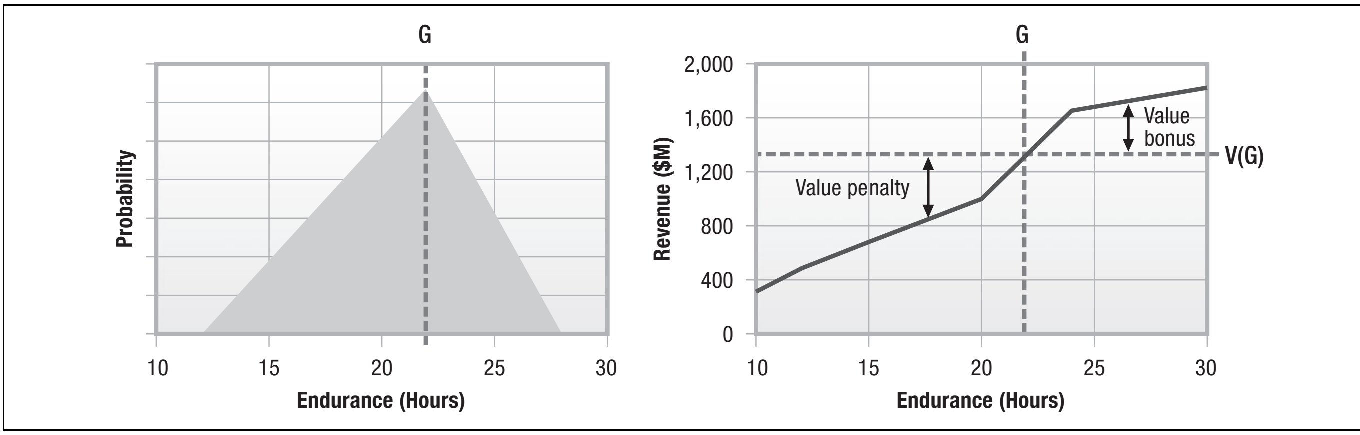



**Figure 4.** Example of PCD and value function for a PVA (with a goal of 22 hours).

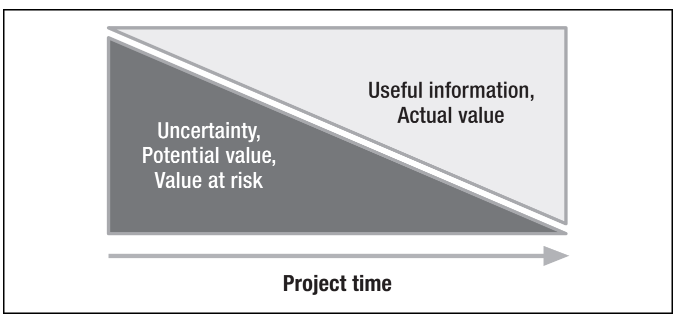



**Figure 5.** A simple view of project uncertainty, risk, useful information, and value over time (adapted from Browning et al., 2002).

and opportunity. Any changes to project goals also affect risk and opportunity. Project activities make progress (add value) when they reduce the project's VaR, bringing the project's LV closer and closer to its GV.

The further we try to forecast into a project's future, the greater the uncertainty. This implies that the bounds around our forecasts must get larger as we go further into the future, as exemplified in forecasts of likely hurricane and typhoon paths. The graph on the left side of Figure 6 depicts this perspective. However, a key insight about the future is that *we will know more then than we do now*. Knowledge of actual project outcomes will improve with learning. For example, consider the improving estimates of project duration in Figure 7. Initial estimates were off by years, but successive estimates improved due to additional knowledge about project status and remaining work. Therefore, we can also think of uncertainty bounds as getting *smaller* as we approach them in time, as shown on the right side of Figure 6. This other way of looking at uncertainty is helpful in projects, where uncertainty about final outcomes is greatest at project start.

Doing work and obtaining new information reduces project uncertainty. Like each play in a football game (Figure 8), each activity performed by the project has an effect, positive or negative. The best activities for a project to do add the most value by providing the greatest return in risk reduction for the investment in time and other resources they consume. Poor choices of activities burn more resources for less reduction in VaR. The trajectory and rate at which project uncertainty reduction occurs vary greatly depending on such choices. Ideally, a project should drive out its most consequential uncertainties (i.e., its biggest risks) early (Browning, 2003),[4] thereby homing in as quickly as possible on the neighborhood of the final, actual outcome, as shown in situation "1" on the right side of Figure 6.[5] Conversely, lingering risks keep a project's actual value in the dark—i.e., in jeopardy. It is important to reduce these risks as soon as possible to confirm the project's viability and profitability. Lingering risks also force project decision makers to hedge their bets and tend to prolong the overall project (situation "2" on the right side of Figure 6). Hence, it is important to incentivize rapid VaR reduction, enabled by rapid learning about project outcomes, which equates to more rapid materialization of actual project value.

Based on these concepts, figures on the following pages exemplify six additional steps (Steps 16–21) for continued planning and monitoring of the drone aircraft development project. Steps 16–18 involve mapping project activities to their anticipated effects on PCDs, based on the information (or evidence) they are planned to produce. Activities produce information that reduces uncertainty and VaR, so the framework provides insight on the value of particular activities, including tests, evaluations, and analyses (Bjorkman, Sarkani, & Mazzuchi, 2013; Browning, 2003). Note that the graphs in this example show PCDs in an abbreviated style, using a vertical bar to mark the three key points in the triangle distribution, making it easier to see PCD evolution over time.[6] In Step 19, over project time, we desire behavior from each PCD along the lines of that on the right side of Figure 6—albeit ideally converging at or beyond the GV. Overall, in the stacked area graphs included in Steps 19 and 20, we desire VaR reduction to zero, as illustrated in Figure 5.

Step 20 replans the project by adding activities targeted to achieve further reductions in VaR. Hence, this approach also serves to incorporate and integrate risk management activities into the project's other planned work. It also reinforces the perspective that project management *is* risk management

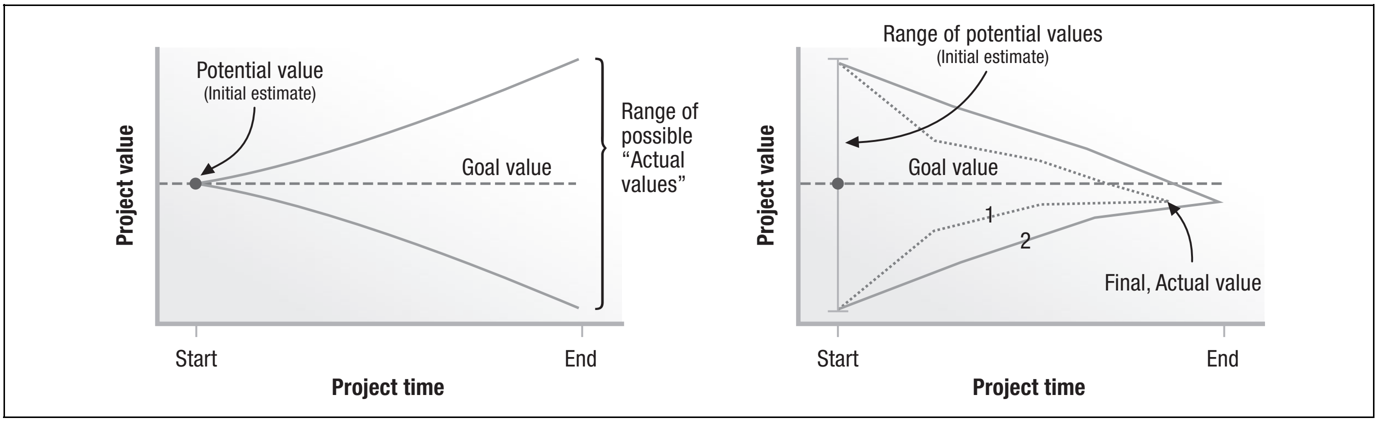



**Figure 6.** Two ways of conceptualizing the evolving uncertainty in project value.

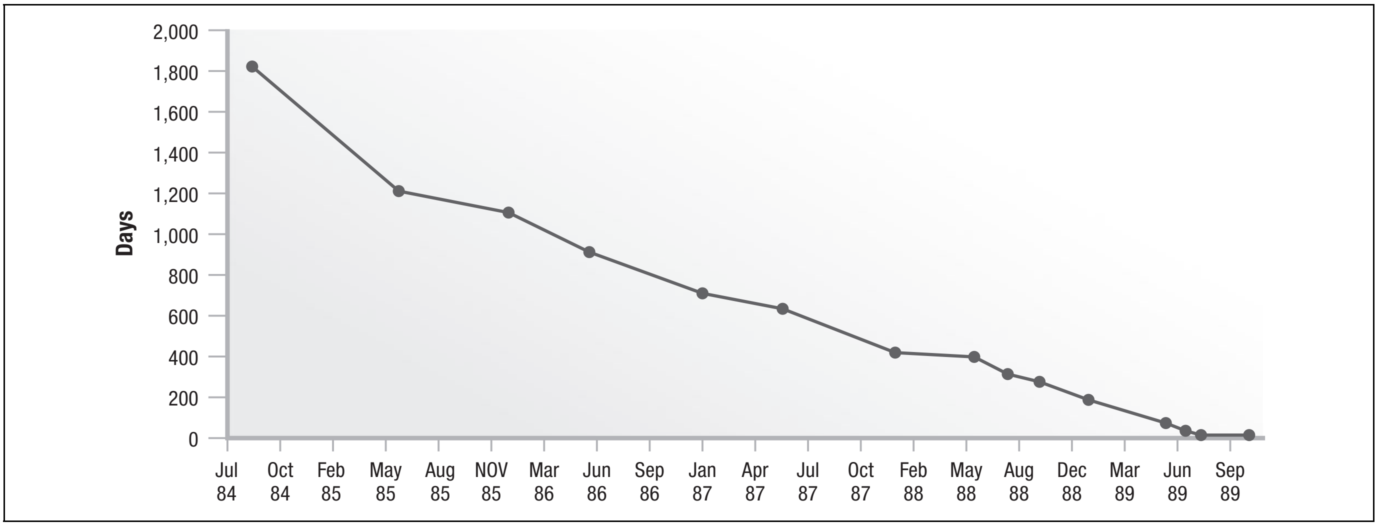



**Figure 7.** Difference between estimated and actual project duration for the first version of Microsoft WinWord® (precursor to Microsoft Word®) (data from Iansiti, 1994).

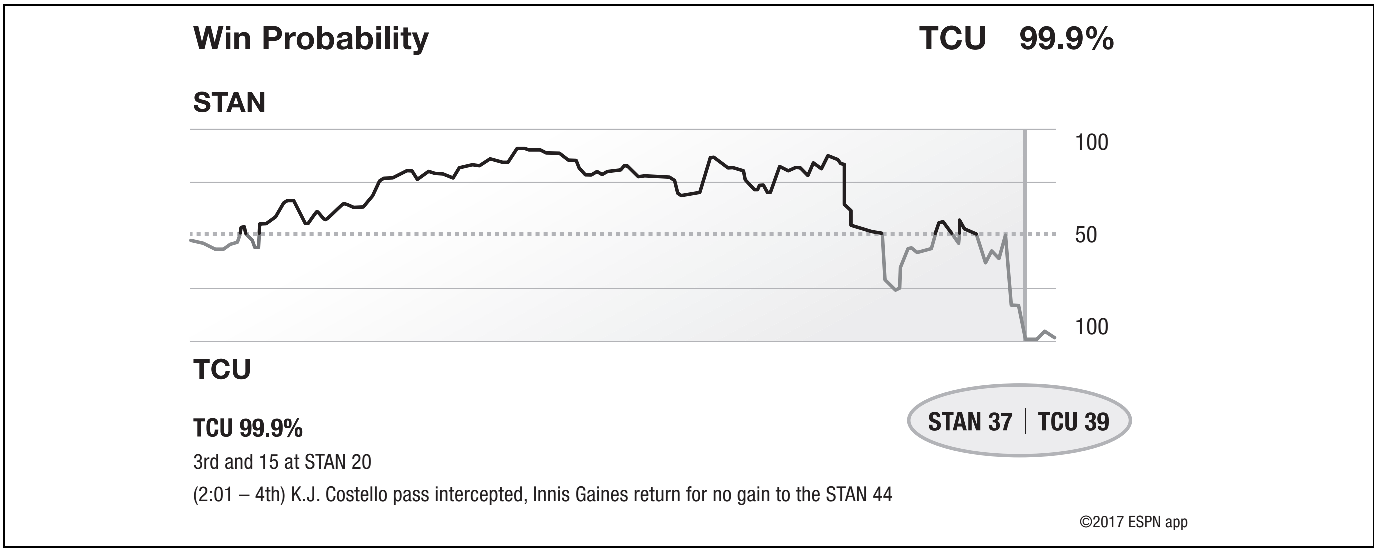



**Figure 8.** Like each activity in a project, each play in a football game affects the probability of its outcome.

**Step 16:** Map PVA-Information-Generating Activities (PIGAs) to PVAs

- Project activities generate information that enables revision of the PVAs' PCDs—i.e., that updates the distribution of potential project outcomes for each PVA.
- Some activities do not directly affect any PCDs, but others can affect one or more PCDs.
- This step notes the particular activities anticipated to have a direct effect on one or more PVAs' PCDs.

**Drone aircraft development project example:**

- The PIGA-PVA table shown on the lower right side of this page captures the final result of Steps 16–18.
- Step 16 entails putting the initial list of project activities in the rows and noting in the body of the table where the results of one of the activities are expected to include information that will enable an update of a PVA's PCD—i.e., when the activity will enable generation of an updated estimate of a PVA's best case, worst case, and/or most likely outcome.
- Any blank rows (i.e., activities that do not directly update any PCDs) are deleted from the table.
- The preliminary design phase of the drone aircraft development project had 14 activities, nine of which produced results that directly enabled revision of one or more PCDs.

**Step 17:** Estimate Information's Typical Effect on PCDs

- What is the effect of the new information (generated by particular activities) on the PCDs?
- Does uncertainty decrease (or increase)?
- Does the estimate of the most likely outcome typically improve or get worse?
- Are these effect small, medium, or large?
- This step answers these questions by choosing a **type** and **magnitude** of PCD revision.
- **Type** is given by one of the nine possibilities in the figure to the right, which show the potential combinations of PCD range changes over a time interval. Type 5 is chosen in cases of complete uncertainty about the direction of effects. (For "smaller is better" (SIB) PVAs, exchange the labels for rows 1 and 3.)
- **Magnitude** is given by a percentage of the range between best and worse case outcomes.

**Drone aircraft development project example:**

- The PIGA-PVA table shown to the right captures the final result of Steps 16–18.
- Step 17 entails replacing the initial notes in the body of the table with more specific information about the type and magnitude of effects of activity results on the PCDs. Type is a number from 1–9 and magnitude is indicated by the cell shading (red = high, yellow = medium, green = small).
- These forecasts were made based on interviews with subject matter experts for each activity.

**Step 18:** Map PIGA Completion Times to PCD Revisions

- Possible PCD revisions can occur when PIGAs finish.
- Capture planned PIGA completion times from the project schedule in the PIGA-PVA table.

**Drone aircraft development project example:**

- The PIGA-PVA table shown to the right captures the final result of Steps 16–18.
- Step 18 entails completing the "When Available" column by pulling information from the project schedule.

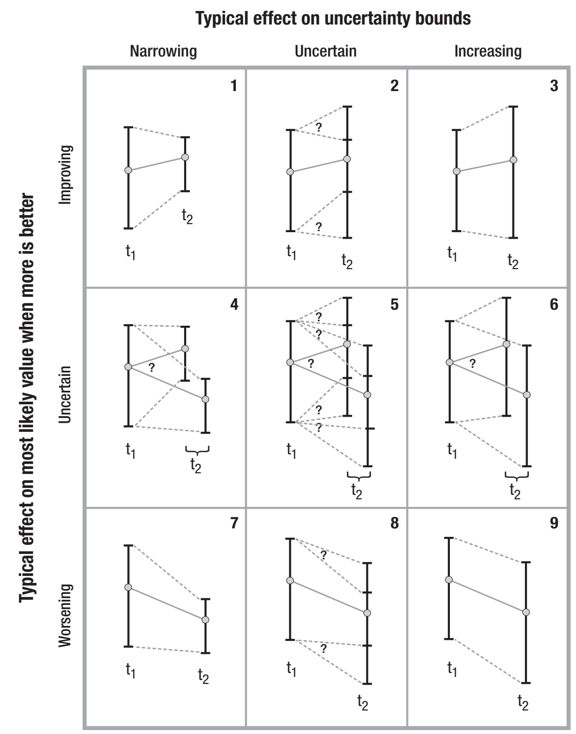



Figure adapted from (Browning et al. 2002)

**PIGA-PVA Table**

| PVA-Information-Generating Activities (PIGAs) | When available (weeks since project start) | PVAs: Endurance | Maximum range | Reliability | Stealth | Delivery lead time | Unit price |
|---|---|---|---|---|---|---|---|
| Create UCAV preliminary design configuration | 2 | 4 | 4 | | 4 | 5 | 5 |
| Perform aerodynamics analysis and evaluation | 5 | | | | 5 | | |
| Create initial structural geometry | 6 | | | 5 | | | |
| Perform weights and inertias analysis and evaluation | 10 | 7 | 7 | | | | |
| Perform S&C analysis and evaluation | 14 | | | 4 | 5 | | |
| Establish internal load distributions | 16 | 4 | 4 | | | | |
| Evaluate structural strength, Stiffness and life | 19 | 4 | 4 | 4 | | | |
| Perform preliminary manufacturing planning and analysis | 26 | | | 8 | 8 | 1 | 1 |
| Prepare proposal | 27 | | | | | 4 | 4 |

(Browning et al., 2002), as *all choices and decisions made by a project manager should serve to reduce the risk of the project failing to achieve its GV*. For additional examples applying these concepts, see Lévárdy and Browning (2009) and Wang, Lin, and Huang (2010).

## Conclusion

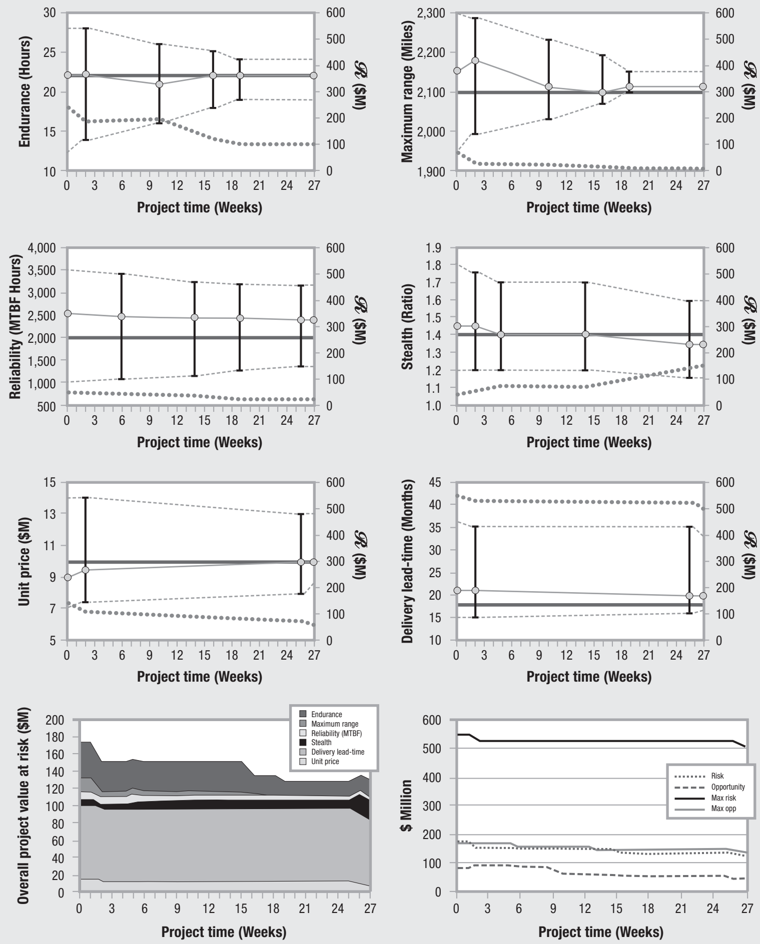
This article reinforces some key concepts pertaining to project value and some shortcomings in these areas with mainstream methods such as EVM. Using the analogy of a high jumper

**Step 19:** Forecast PCD Revision and VaR Profiles

- The anticipated PCD revisions and overall VaR profile may now be forecast over project time.

**Drone aircraft development project example:**

- A PCD revision profile is projected for each PVA. For example, for the Endurance PVA, its PCD is revised at weeks 2, 10, 16, and 19. Overall, uncertainty in the PCD is expected to decrease over time. The portion of PCD outcomes that fail to meet the goal (which is represented by the solid, flat line) are penalized by their value to get $\mathscr{R}$, which is shown as the dotted line (and measured by the secondary y-axis).
- Below, the project's overall VaR is also shown in terms of its six components (as weighted by model a), and, on a separate plot, as model b (maximum $\mathscr{R}$ and $\mathscr{O}$).




seeking to jump over a set bar, it compares each major project goal to the range of potential outcomes in that area to find the implications for value, risk, and opportunity. It then shows how managers can use the PVRO framework to quantify these factors and tailor a project's goals, capabilities, and implied levels of value, risk, and opportunity. Using these techniques during project planning facilitates designing a project with appropriate levels of risk and value, balanced across the project's key attributes. Using these techniques for ongoing project monitoring supports project control decisions such as renegotiated goals and resource reallocations among the PVAs. The quantified amounts of value, risk, and opportunity also provide an enabler for applying options- and scenario-based methods to project planning and valuation (e.g., Lévárdy & Browning, 2009; Wang & Yang, 2012). They also provide an opportunity for the direct integration of project management methods with emerging techniques in the engineering literature on value-based design (e.g., Kannan, Mesmer, & Bloebaum, 2017; Lee, Binder, & Paredis, 2014; Lee & Paredis, 2014; Yang, Ishii, & Karandikar, 2005).

The approach provides a perspective on project management where projects must prove their value from the outset rather than assuming that value exists until they fail. Instead of assuming that all project indicators are "green" at the start of a project, this approach essentially starts them all at "red," thereby incentivizing project managers to authorize the activities that will produce the information needed to "burn down" the VaR and get to "yellow" and then to "green." From this perspective, *a project is the finite work done to eliminate the risk of not achieving its goals*. Chipping away at a project's "anti-value" (i.e., the threats to its value, risks) reveals a clearer image of its actual value.

Actual projects have already applied this framework, albeit in proprietary settings. In future research, it would be interesting to explore further applications and implications of this approach in highly dynamic situations where desired value changes rapidly (and thus *any* set goals are problematic). In such situations, perhaps one could characterize a project as a market risk reduction effort (see Figure 3), where its goals are essentially to figure out the right goals for the next (phase of

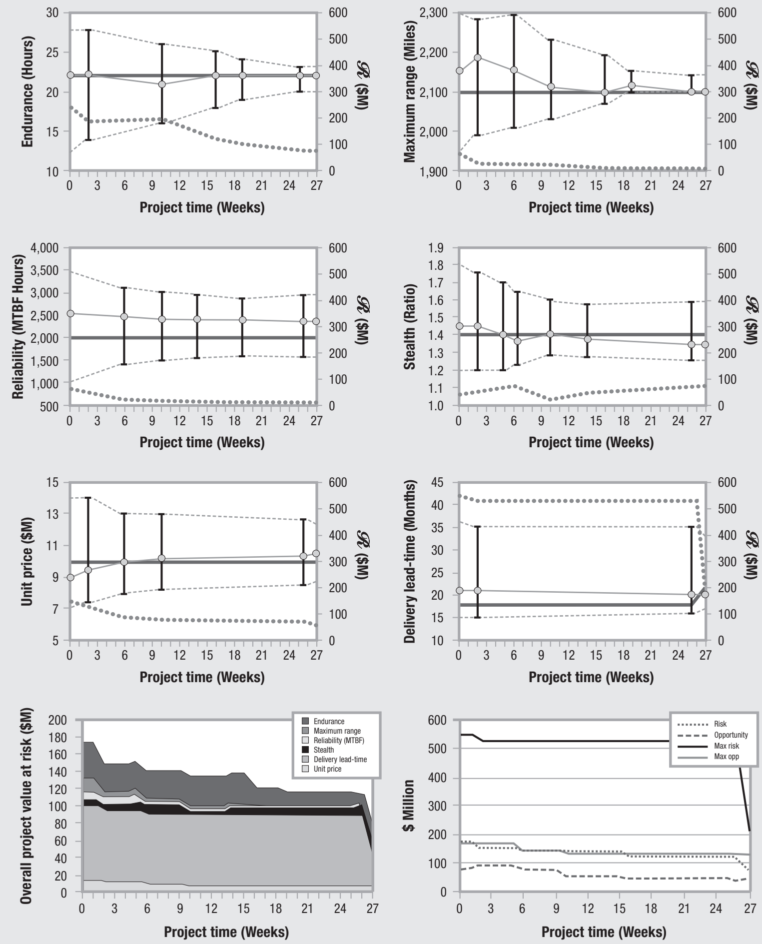
**Step 20:** Add or Reschedule PIGAs to Improve Profile (Adjust Plan)

- The forecast VaR profiles show a very high proportion of the project's value remaining at risk by the end of the preliminary design phase.
- It was proposed that additional activities be added to the preliminary design phase to help remove more of the consequential uncertainty in the PCDs.

**Drone aircraft development project example:**

- See the addendum to the PIGA-PVA table below. These additional activities reflect that the initial plan was predominated by structural designers.
- Based on these additional activities, a new PCD revision and VaR profiles were forecast (see graphs to the right).
- This additional work serves to reduce the anticipated VaR much earlier, thereby equipping the organization to make a more confident proposal based on firmer understanding of the product design.
- However, the bulk of the VaR, due to the Delivery lead-time PVA, has still not been addressed. It may be necessary to accelerate the project at some additional cost and/or renegotiate the deadline goal. The goal is shown as changed at the end of the preliminary design phase (as the proposal for detailed design is being prepared).

| Additional PIGAs | When available (weeks since project start) | PVAs: Endurance | Maximum range | Reliability | Stealth | Delivery lead-time | Unit price |
|---|---|---|---|---|---|---|---|
| Analyze and evaluate propulsion | 6 | | 5 | 4 | 4 | | 1 |
| Design avionics subsystem (Preliminary) | 6 | | | 4 | | | 1 |
| Design communications subsystem (Preliminary) | 6 | | | 4 | | | 4 |
| Design electrical and mechanical subsystems (Preliminary) | 10 | | | 4 | | | 1 |
| Analyze and evaluate radar signature | 10 | | | | 4 | | |
| Analyze and evaluate overall performance | 26 | 4 | 4 | | 7 | | 1 |




**Step 21:** Monitor and Control Actual Results Versus Plan

- As the project proceeds and revised PCD estimates are gathered, recalculate the project's VaR.
- If risk increases (or does not sufficiently decrease) in any area, consider control actions such as the following:
  - Adding further risk-reduction activities
  - Reworking existing activities at a higher level of fidelity, with firmer input information
  - Renegotiating goals
- Also monitor the value functions (VFs) and weightings in case stakeholder preferences change, perhaps due to situations such as:
  - A new technology captures stakeholders' imaginations
  - A competitor releases a new product
  - User needs change significantly

the) project. Further research should also explore the implications of varied risk attitudes or preferences on implementation of the PVRO framework, which assumes a "risk neutral" attitude in aspects of its current formulation. With appropriate framing, viewing all types of projects as risk reduction efforts seems to be a useful and generalizable perspective with many promising applications, including allowing stakeholders to design and tailor projects to desired levels of value, risk, and opportunity.

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The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Notes

1. The concept of value used in this article should not be confused with the concept of "value engineering" sometimes used to pare a project down to its bare essential contents.
2. The term *critical-to-quality characteristics* (CTQs) is a near synonym.
3. PCDs do *not* directly correspond to some other formal notions of project capabilities (e.g., Davies & Brady, 2016).
4. Compare the concepts of failing fast, front-loading (Thomke & Fujimoto, 2000), and discovery-driven planning (McGrath & MacMillan, 1995).
5. Verworn, Herstatt, and Nagahira (2008) provided empirical evidence associating the early reduction of uncertainty with increased success in new product development projects.
6. A fan diagram (Kreye, Goh, Newnes, & Goodwin, 2012) might provide an even more effective two-dimensional display of the evolving uncertainty distribution.

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## Author Biography

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