What Should We Do with Unknowns in Schedule Risk Analysis?[1]

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Introduction

Schedule risk analysis explores how unknowns applied to the project schedules may derive a distribution of possible completion dates. Unknowns include:

- Known unknowns for which we know the cause but do not know whether the risk will occur and /or, if it occurs, its impact on activity durations. Interestingly risks with 100% probability of occurring, though usually called "issues," are included if their impact is unknown.

- Unknown unknowns are those risks that are not known today but we may reliably expect that they will occur in the future. It is not clear that these risks are "unknowable" because they have been experienced in many projects over time. People are often myopic about the risks they want to discuss, so near-term risks are the focus of attention during interviews or workshops. Whether other risks could be known or not with further inquiry, or whether benchmarking to historical data can help is an area of interest.

- "Unknown knowns" may be a new class of unknowns to some people. We know these risks exist and often know their parameters (probability and impact). The management does not want to discuss them in a public forum such as a risk workshop since they are sensitive or pessimistic, may conflict with public pronouncements or pledges to the Board of Directors or the customer, causing harm and even cancellation of the project. We find out about these risks because they are revealed during confidential interviews. These risks are not in the Risk Register but are agreed to by subsequent interviewees. On inspection some of these risks turn out to be the most important risks of all.

This paper describes the types of unknowns and the methods used to incorporate the unknowns to drive the Monte Carlo simulation of the schedule. Methods include: (1) using the 3-point estimate to represent inherent variability, estimating error and estimating bias, (2) expanding the 3-point range for "far future" (in the context of the project) activities for unknown unknowns, and (3) using the risk interview to uncover unknown knowns, and. A simple case study shows, through use of Monte Carlo simulation, examples of the methods and of their impact on final answers.

[1] This is a short version of a paper and presentation of the same title at the Association for the Advancement of Cost Engineering (AACE) International at the annual conference in Las Vegas, NV in June 2015.

Categories of Unknowns

Donald Rumsfeld, formerly the Secretary of Defense of the United States famously said, in February 2002:

> "Reports that say that something hasn't happened are always interesting to me, because as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know.
>
> And if one looks throughout the history of our country and other free countries, it is the (unknowns in the) latter category that tend to be the difficult ones." [12]

According to this description there are three categories of knowns and unknowns that need to be explored and modeled in a schedule risk analysis using Monte Carlo simulation of a project schedule.

Known Knowns

Known knowns are events or conditions that are known to exist and to have an impact known with near-certainty. Known knowns are items that should be included in the plan, schedule and budget. There are still assumptions behind these known knowns, but then the plan, schedule and budget is built on assumptions. Some plans do not include all the known knowns.

Variation Caused by Known Unknowns

Fundamentally "There are No Facts about the Future." [6] However, known unknowns are events or conditions that can be described well enough to know the cause. However, we do not know whether this event or condition will occur or, if it does, what its impact will be. These known unknowns include:

- Pure uncertainty for which there is no specific cause but it is known to exist with an uncertain impact on the schedule

- Risk events that can be described and for which the specific cause is known. These, in turn, may or may not occur or may be certain to occur but in either case their impacts are not known with certainty. [2]

[2] Some organizations might call these "issues" and are therefore excluded from consideration in a risk analysis. This is incorrect since their impacts are still in the future and still uncertain. It does not matter what these 100% likely conditions are called, they are still included in the risk analysis.

Components of Uncertainty

- The inherent variability in project activities that arise because people and organizations cannot do things reliably on plan.

- Estimating error – attaches to all types of estimates, especially activity durations and costs

- Estimating bias – estimates may be slanted, usually toward shorter durations, to make desired project results

Inherent Variability

Inherent variability is similar to "common cause" variation described by Walter A. Shewhart and championed by W. Edwards Deming. "Common cause variability is a source of variation caused by unknown factors that result in a steady but random distribution of output around the average of the data. Common cause variation is a measure of the process's potential, or how well the process can perform when special cause variation is removed. Common cause variation is also called random variation, noise, non-controllable variation, within-group variation, or inherent variation. A condition leading to common cause variability would be many X's with a small impact." [10]

In other words, inherent variability is random "noise" in the schedule attaching to activity durations reflecting the fact that individuals and organizations cannot be relied upon to perform to plan. There are many of these influences that will occur but cannot be catalogued or reduced in the span of one project.[3]

By being 100% likely to happen, inherent variability can be represented by applying a 3-point estimate with an impact distribution directly to the activity durations that will experience this variability. The uncertainty of impact is thought of as being a fairly tight probability distribution around the estimated duration, which becomes the most likely value (mode) of that distribution. The pure randomness of inherent variability indicates that the impact or degree of variation is symmetrical, that is plus or minus the same fraction of the estimated activity duration. For instance, the multiplier used may be 90%, 100% and 110% representing the low, most likely and high multiplier of the activity's durations.

Different types of activities may have different levels of inherent variability. So, for instance, detailed engineering and construction may have different inherent variability so in the risk analysis of the schedule these categories of activities can have different "reference ranges" of uncertainty.

[3] Corralling this multitude of influences and their consequences in the space of a single project with a specific team is unlikely. Advances to narrow the inherent variation would take repetition of the project many times with the same teams, contractors and conditions. Such progress was made in World War II as thousands of airframes were produced and teams and their organizations learned how to be more routine and efficient. A project is not likely to experience such learning.

Estimating Error

Estimating error can be attributed to a lack of information concerning specific issues needed to make up an activity's duration, though it may also be a result of insufficient or inexpert resources applied to project scheduling. The contractor may not have specific vendor information until the vendors bid but vendor information is required for completed engineering.

Each of these sources of information can be helpful eventually to narrow the estimating error. Still, the estimates, and even after contractor bids are submitted, are uncertain.

The duration estimating range is often related to the "class" of estimate, determined by the level of knowledge and the method of estimating. With less knowledge the "plus and minus" range would be large, but as more information is known it may become smaller. However, at the time of the risk analysis the schedule is populated with estimates made with some stage of information-gathering. Like inherent variability, estimating error is 100% likely.

Research shows that the range of uncertainty around estimates is larger than recommended by professional associations (including AACEI). [3] These plus and minus estimates should be symmetrical around the most likely duration which, ideally, is included in the schedule. Perhaps adding estimating error to the inherent variability could increase the 3-point estimate to 80%, 100% and 120%.

Estimating Bias

Estimating bias is quite common whether talking about costs or schedule durations. The symmetry of uncertainty ranges around the estimates of duration in the schedule should always be explored. Only in optimum situations will the scheduler and the team leads who are responsible for building the schedule be free to install durations and costs based purely on their professional judgment. Optimum conditions mostly occur in text books and training courses – real scheduling is messy and fraught with compromises and pressures. Two such pressures, one for schedule and the other applying to cost estimates, are described by Edward M. Merrow: [5]

- "I want it NOW!" Merrow says that "Schedule pressure dooms more megaprojects than any other single factor." These pressures may come from ambitious managers who see early completion as ways for promotions. Customers usually want the project to finish early. Merrow says that every megaproject has an appropriate pace that becomes known early. Pronouncements about early, and unattainable completion dates, do not change this pace.

- "We need to shave 20 percent off that cost number!" Establishing a construction cost-reduction task force is a counterproductive exercise that may just reduce estimates, in Merrow's opinion. Reducing estimates this way is foolish, in part because the assumptions needed turn out to be unsustainable. The task force may actually identify scope to be eliminated in order to cut costs, but that scope needs to be added back in later to complete the project so the reduction in cost is only temporary.

In looking at the reasonableness of the duration estimates we typically like to ask the following question: "Was there pressure put to bear on the scheduler by management or the customer, by statements or directives, or was pressure for early finish implicit in the competitive process?" If the scheduler and the team leads are aware of management's commitment to an earlier date the schedule will have many activities estimated "on the short side." Activities will also be scheduled in parallel rather than in sequence.

Often the "most likely" impact multiplier is 1.05 or 1.1 or more, indicating that the estimates are viewed as being 5%, 10% or more above those in the project documents because the assumptions are slanted toward optimistic estimates. Sometimes the values in the schedule or estimate are viewed as the optimistic value, or even worse, are not even deemed possible, optimistically.

Contractors generally admit that the schedule would take longer without time pressure having been put upon them, and say that a nominally 24-month schedule should be anywhere from 26 to 30 months (8% to 25%) longer.

Summary of Sources of Uncertainty

In summary, these sources of uncertainty (e.g., inherent variability and estimating error) always occur and, if estimating bias exists it has already occurred. These, then, are 100% likely and can be represented by a 3-point estimate of multiplicative factors applied to activities' durations

The 3-point estimates representing these factors are often represented as multiplicative impacts. For the balance of this paper we will assume some fairly standard values:

- Inherent Variability might exhibit low, most likely and high multipliers of .9, 1.0, and 1.1
- Adding Estimating Error these multipliers may become .8, 1.0, 1.2
- Adding Estimating Bias, if it exists, these multipliers may become .8, 1.05, and 1.3.

Notice that the most likely multiplier does not necessarily equal 1.0. That means that the durations in the schedule are not necessarily the most likely values as seen by impartial, professional schedulers.

Two Issues about Implementing 3-point Estimates for Uncertainty

Two issues facing the risk analysis practitioner implanting arise from:

- Under-estimating the range of the distribution, whether from motivational bias or cognitive bias

- Narrowing of the total schedule uncertainty range because simulating the activity duration uncertainty ranges exhibits cancelling out of high and low values in the absence of correlation

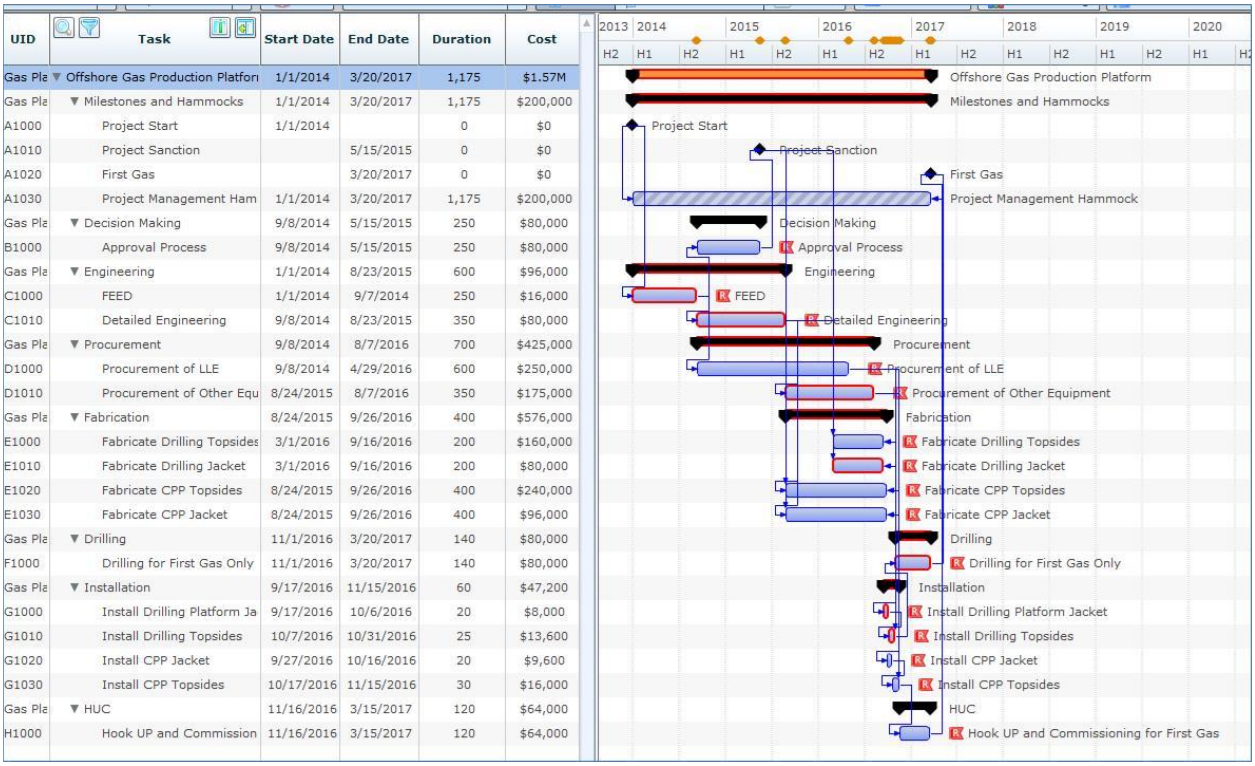
These two issues are addressed by using the TriGen (for “triangle generation”) function and correlation between uncertain activity durations.

Case Study Showing the Application of Uncertainty

A simple illustrative case study of a large capital project, the construction of an offshore natural gas production platform, will show the elements of:

- Inherent variability
- Estimating error
- Estimating bias
- Discrete risk events

The schedule is presented in Figure 1 below:



UID	Task	Start Date	End Date	Duration	Cost
Gas Pla	▼ Offshore Gas Production Platfor	1/1/2014	3/20/2017	1,175	$1.57M
Gas Pla	▼ Milestones and Hammocks	1/1/2014	3/20/2017	1,175	$200,000
A1000	Project Start	1/1/2014		0	$0
A1010	Project Sanction		5/15/2015	0	$0
A1020	First Gas		3/20/2017	0	$0
A1030	Project Management Ham	1/1/2014	3/20/2017	1,175	$200,000
Gas Pla	▼ Decision Making	9/8/2014	5/15/2015	250	$80,000
B1000	Approval Process	9/8/2014	5/15/2015	250	$80,000
Gas Pla	▼ Engineering	1/1/2014	8/23/2015	600	$96,000
C1000	FEED	1/1/2014	9/7/2014	250	$16,000
C1010	Detailed Engineering	9/8/2014	8/23/2015	350	$80,000
Gas Pla	▼ Procurement	9/8/2014	8/7/2016	700	$425,000
D1000	Procurement of LLE	9/8/2014	4/29/2016	600	$250,000
D1010	Procurement of Other Equ	8/24/2015	8/7/2016	350	$175,000
Gas Pla	▼ Fabrication	8/24/2015	9/26/2016	400	$576,000
E1000	Fabricate Drilling Topsides	3/1/2016	9/16/2016	200	$160,000
E1010	Fabricate Drilling Jacket	3/1/2016	9/16/2016	200	$80,000
E1020	Fabricate CPP Topsides	8/24/2015	9/26/2016	400	$240,000
E1030	Fabricate CPP Jacket	8/24/2015	9/26/2016	400	$96,000
Gas Pla	▼ Drilling	11/1/2016	3/20/2017	140	$80,000
F1000	Drilling for First Gas Only	11/1/2016	3/20/2017	140	$80,000
Gas Pla	▼ Installation	9/17/2016	11/15/2016	60	$47,200
G1000	Install Drilling Platform Ja	9/17/2016	10/6/2016	20	$8,000
G1010	Install Drilling Topsides	10/7/2016	10/31/2016	25	$13,600
G1020	Install CPP Jacket	9/27/2016	10/16/2016	20	$9,600
G1030	Install CPP Topsides	10/17/2016	11/15/2016	30	$16,000
Gas Pla	▼ HUC	11/16/2016	3/15/2017	120	$64,000
H1000	Hook UP and Commission	11/16/2016	3/15/2017	120	$64,000

Figure 1 – Offshore Gas Production Platform Construction Project Schedule

Inherent variability is added by specifying ranges for uncertainty, in this case applying to all activities equally, as shown in Figure 2:

Figure 2 – Specifying Inherent Variability to the Uncertainty Range

Next, estimating error is added, expanding the ranges of uncertainty as shown in Figure 3:

Figure 3 – Adding Estimating Error to the Uncertainty

Finally, we complete the modeling of uncertainty by changing the uncertainty factor to reflect inherent variability, estimating error and estimating bias.[4]

Figure 4 – Adding Estimating Bias to the Uncertainty

The results for each of these steps are shown in Figure 10 below. Obviously the parameters will differ for each project, but these are representative of data used on real projects.

In addition to specifying the range (low, most likely and high or Min, Likely and Max) we have also considered and implemented 100% correlation so the results for the entire schedule will better approximate the input data from various interviewees.

The results for the simulations up to this point, representing various steps of uncertainty, are shown in Figure 5 below:

[4] In some cases there are many risk events that are each small in impact and will not be modeled individually. These risks may be swept into the final uncertainty range, widening the range and making it more pessimistic since most of these risks are more threat than opportunity.

Adding Inherent Variability, Estimating Error and Estimating Bias						
		Scheduled Finish Date		20-Mar-17		
P-5	P-50	P-80	P-95	Delay in Months @ P-80	Cal. Days P-5 to P-95	Probability of Scheduled Date
Inherent Variability .9 - 1,0 - 1.1						
19-Feb-17	28-Mar-17	15-Apr-17	2-May-17	0.9	72	37%
Adding Estimating Error .8 - 1.0 - 1.2						
4-Feb-17	12-Apr-17	17-May-17	20-Jun-17	1.9	136	29%
Adding Estimating Bias .8 - 1.05 - 1.3						
25-Mar-17	17-Jun-17	2-Aug-17	13-Sep-17	4.4	172	4%
Inherent Variability, Estimating Error and Estimating Bias 100% Correlated						
1-Nov-16	17-May-17	30-Aug-17	29-Nov-17	5.4	393	32%

Figure 5 – Results for Each Step Representing Uncertainty

Notice in Figure 5 that the P-80 date is highlighted along with the increase in schedule contingency reserve needed from the scheduled finish date of 20 March 2017. We have also highlighted the calendar day spread between the P-5 and the P-95 dates since the range of days compared to the total duration of the project, 1,175 days, provides some measure of the adequacy of the input data and hence realism of the results. Finally, the probability of completing on or before the scheduled date is shown. The effect of perfect correlation is to widen both the opportunity and threat tails of the distribution so the probability of finishing on time rises to 32%.

Adding Discrete Risk Events as Risk Drivers[5]

Discrete risk events need to be added to the risk model that already contains uncertainty. Risk events have a probability of occurring that is usually less than 100%, an impact range if they do occur, and an identifiable set of activities that they influence if they occur.

Unlike common cause variability, special cause variation is caused by known factors that result in a non-random distribution of output. Also referred to as “exceptional” or “assignable” variation, special cause variation is a shift in output caused by a specific factor such as environmental conditions or process input parameters. It can be accounted for directly and potentially removed and is a measure of process control. [11]

Risk Drivers (called “Risk Factors” in Primavera Risk Analysis) represent these risks’ impacts as distributions of multiplicative factors not unlike those used above for uncertainties. Because the impact multiplier can be less than or greater than unity a Risk Driver can have both opportunity and threat “tails,” a smoother application than Risk Register.

[5] Introduced in reference [5], Chapter 8

To this model with uncertainty we add seven specific Risk Drivers and one Organizational Risk Driver assigned to all tasks as shown in Figure 6. Each Risk Driver is specified with a TriGen function to offset Anchoring and Adjusting Bias.

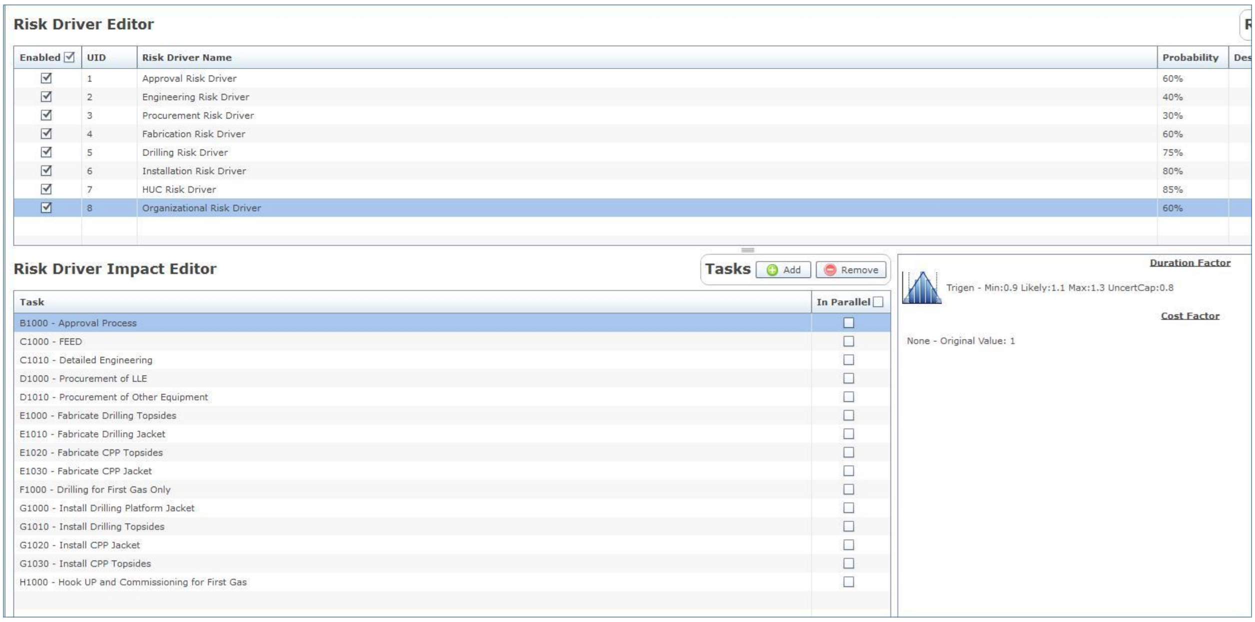


Figure 6 – Adding Risk Drivers to the Model

The results of simulation with uncertainty and risk events represented by Risk Drivers are shown below in Figure 7. Notice that risk drivers add over 7 months to the P-80 date and the spread from P-5 to P-95 almost doubles compared to the results from uncertainty only. These are illustrative data only, but are not illogical. The probability of meeting the scheduled finish date drops to 17%:

Adding Inherent Variability, Estimating Error and Estimating Bias						
		Scheduled Finish Date		20-Mar-17		
P-5	P-50	P-80	P-95	Delay in Months @ P-80	Cal. Days P-5 to P-95	Probability of Scheduled Date
Inherent Variability, Estimating Error and Estimating Bias 100% Correlated						
1-Nov-16	17-May-17	30-Aug-17	29-Nov-17	5.4	393	32%
Inherent Variability, Estimating Error and Estimating Bias 100% Correlated Plus 8 Risk Drivers						
26-Nov-16	22-Sep-17	19-Apr-18	19-Dec-18	13.0	753	17%

Figure 7 – Results from Adding Risk Drivers to the Model

Unknown Unknowns

While we do not know what unknown unknowns are or how significant they may be, we conclude from historical results that our knowledge of risk is limited and that more risks will be revealed as the project proceeds through its lifecycle. In other words, experience tells us there exist unknown unknowns that will potentially affect the project. They will become known in the future as events unfold. We need to try to reflect them in our analysis.

Adopt a conservative target for risk certainty given the risks we identify and quantify

Since unknown unknowns can reliably be expected to occur on this project we recommend a relatively conservative certainty target, e.g., the 80th percentile ("P-80") when discussing the need for schedule or cost contingency based on what we do know about uncertainty and risk events. In other words, we feel the need to be "ahead of the game" with respect to the risks we do know so that we are not "behind the 8-ball" already when unknown unknowns arise.

Use Confidential Interviews To Identify More Unknown Knowns

Interviews or workshops on risk often appear to focus on risks and uncertainties that are close-in or actually happening now. This myopia leads to insufficient consideration of risks that occur most likely in the "far future" of a project lifecycle. In practical terms, this might mean that risks more than two years out from the interviews will not be discussed and hence will not be included in the quantitative risk analysis. We need to do something to represent these far future risks. If these risks are "unknown" right now, extra effort to focus on down-stream risk could improve our understanding of risks, including making known some previously "unknown" risks. Some of the risks can be identified with practice at thinking forward.

Widen the Uncertainty Ranges Later in the Project Schedule

Even with attention to expanding the risks with in-depth interviews, there will still be unknown unknowns that have no known specific cause. We confidently anticipate that specific causes will occur as project execution continues. To represent the influence of these missing risks we can widen the range of uncertainty that is applied to future activities , beyond the ranges reported for the near-term uncertainty that are shown above, to represent these the effect of unknown risks before we know what they are. The degree of "widening" and the definition of "future" would be judgment calls for the project participants and the risk analyst. This idea of widening the uncertainty range for far future (within the project context) can be implemented as shown below in Figure 8:

Figure 8 – Applying Wider Ranges Representing Unknown Unknowns on Far Future Activities

The degree of widening the ranges in the "Far Future" for the project is obviously a judgment based on inputs from many and experience with benchmarking. Notice that the new range for Future Uncertainty is quite wide, since it needs to encompass both uncertainty and risk events.

The results in Figure 9 show adding about 4 months to the P-80 and other expected results.

Adding Inherent Variability, Estimating Error and Estimating Bias						
		Scheduled Finish Date		20-Mar-17		
				Delay in Months	Cal. Days	Probability of
P-5	P-50	P-80	P-95	@ P-80	P-5 to P-95	Scheduled Date
Inherent Variability, Estimating Error and Estimating Bias 100% Correlated Plus 8 Risk Drivers						
26-Nov-16	22-Sep-17	19-Apr-18	19-Dec-18	13.0	753	17%
Inherent Variability, Estimating Error and Estimating Bias 100% Correlated Plus 8 Risk Drivers, Wide Uncertainty for Far Future Activities						
3-Mar-17	7-Jan-18	21-Aug-18	8-May-19	17.1	796	6%

Figure 9 – Results with Wider Uncertainty Ranges on Far Future Activities

Considering Unknown Knowns

Some people, upon hearing the discussion initiated by Secretary of Defense Rumsfeld, feel that he missed one of the most important unknowns, the so-called "Unknown Knowns." These unknowns are often widely understood but cannot be discussed in public. These risks usually are detrimental to the project, contradict management's public position or promises to the Board of Directors or the customer, or are embarrassing. In some organizations these cannot be discussed in the halls, over coffee or in risk workshops.

Psychoanalytic philosopher Slavoj Zizek says that beyond these three categories there is a fourth, the unknown known, that which <u>we intentionally refuse to acknowledge that we know</u>. German sociologists Daase and Kessler (2007) agree with a basic point of Rumsfeld in stating that the cognitive frame for political practice may be determined by the relationship between what we know, what we do not know and what we cannot know, but they also say that Rumsfeld left out <u>what we do not like to know</u>. [12, emphasis added]

Many risk events are known but they not be discussed in a public setting such as a risk workshop. We know this is true, and we find that the Risk Register is always incomplete. The evidence of this fact is that in confidential interviews with project team members a number of new risks, risks that are not included already in the Risk Register, are introduced and discussed with their parameters. Subsequent interviewees often recognize these new risks and contribute their information on without objection.

Many of these risk events introduced only in confidential interviews are later found to be most important in determining the schedule risk results. Among these risks are the "Unknown Knowns" that which we refuse to acknowledge that we know or do not want to know. Why are some of the most important risks not included in the Risk Register? We find that none of this matters if key risks never make it to the Risk Register.

We view the incompleteness of the Risk Register to be the result of social or hierarchal pressures or group dynamics that limit debate in open workshops, including: [2]

- Groupthink – people in groups often prefer unanimity, discourage dissent and make it difficult for people to raise new issues or voice an opinion different from that of the group.
- Moses factor – some people will suppress their own ideas, adopting influential person's ideas instead, in a group.
- Cultural Conformity – The decisions match the group norms

Use Confidential risk Interviews to Uncover Unknown Knowns

Risk Workshops usually involve many people getting together for several hours and often include project managers. Workshops can be serious wastes of time with people not willing to be candid in discussing risk or they are not able to talk much at all in a room full of other people including the boss.

A more successful environment to gain the best data possible by subject matter experts (SMEs) is the confidential interview approach. Confidential interviews bring people a degree of comfort not found in open meetings. In these interviews new risks are discussed, whether they are hurtful to the project or embarrassing. People more openly talk about "the good, the bad and the ugly" of a project in these interviews.

In the confidential 1-on-1 (or 1-on-few) the interviewees can talk in depth and with focus to someone who wants to know his/her opinion. Most interviewees open up and find it easy to discuss risks they cannot discuss even in the special purpose risk workshops. In addition, interviewees appreciate the opportunity to talk about risk and that someone is listening, taking their viewpoints into account.

Some Evidence on Project Overruns

Quantifying unknown unknowns by widening uncertainty ranges on far future activities' durations is a "best guess" strategy simply because we do not know what these unknowns are. As mentioned above, challenging the interviewees to think about future risks may reveal some of these unknown unknowns and unknown knowns. At the least we should be somewhat modest in claiming any specific insight into unknown unknowns – that is one reason they are included in an expanded uncertainty range rather than as risk events.

Evidence from well-documented projects tells a startling story, at least as to cost results. Bent Flyvbjerg and colleagues amassed some interesting findings: [1]

- Chunnel project was overrun by 80% (this was a commercial project but with heavy oversight and involvement of politics, regulations – e.g., safety)
- Great Belt Link – a bridge tunnel between east Denmark and Europe, was 54% overrun
- Oresund Link bridge between Sweden and Denmark was 68% overrun
- The Big Dig in Boston was 196% overrun

In addition, they found:

- Studies in Sweden on road and rail projects
    - Road projects average 86% overrun, range +2% to +182%
    - Rail projects average 17% overrun, range -14% to + 4%

- US Department of Transportation rail projects
    - Average overrun 61%, range -10% to +106%

- Aalborg University Denmark, 9 of 10 projects underestimated
    - Rail average overruns of +45%
    - Tunnels / Bridges + 34%
    - Roads + 20%

Flyvbjerg and colleagues concluded that cost underestimating is common, and when coupled with overestimating the benefits, which are often "non-measurable, insignificant or even negative some of these projects should not have been approved. These are large-scale infrastructure projects, but projects in other industries appear to be similar or worse. They believe that these results reflect both powerful incentives to underestimate to get projects started and weak disincentives to overrun.

A dissenting voice is that of Edward Merrow who has stated that: There is widely held belief that large public sector projects tend to overrun because the estimates are deliberately low-balled. Our (Independent Project Analysis) analysis of large private sector projects suggests that no Machiavellian explanation is required. Large projects have a dismal track record because we have not adjusted our practices to fit the difficulty that the projects present. Merrow was quoted in [3].

Finally, John Hollmann[3] concludes that "results vary dramatically from those ranges recommended in professional association guidelines, and that the approximate ranges for accuracy or uncertainty around the reference amounts are as follows:

- P10: -32% to +8% (average about -9%)
- P50 or mean: 0% to +88% (average about 21%)
- P90: +34% to 190% (average about 70%)

The point of benchmarking against some real results is to put a check on the results of a risk model based on the CPM schedule, using data gathered at least in part by talking with SMEs and employing Monte Carlo simulation techniques.

We can learn by comparing results from two quite different methodologies – Monte Carlo simulation vs. historical benchmarking – and data collection approaches – confidential interviews or risk workshops vs. amassing large project databases, than if we just stick to one method.

Conclusion

This paper presents four different concepts of knowns and unknowns and shows how they are, or could be, represented in a schedule risk model using uncertainty, risk events and confidential interviews.

Known knowns are those facts of which we are sure. They should be reflected in the baseline and current updated schedule. This is not new or controversial.

Known unknowns include several concepts of uncertainty and risk events. The uncertainties include:

- Inherent variability, which is known to exist even if its origins are non-specific. It is inherent and thought to be irreducible.
- Estimating error is also known to exist and to depend on the quality and maturity of the information at hand at the time of creating the schedule. This can only be improved upon with more and more data.
- Estimating bias may or may not exist but if it exists it has already occurred in the baseline schedule that is used as a platform for the schedule risk analysis.

The category of known unknowns that contains risk events is neatly addressed and handled by the use of Risk Drivers. In this paper the common failing of underreporting the risk impact because of anchoring and adjusting bias is addressed by creating TriGen functions that widen the ranges of the triangular distribution that are too narrow even in confidential risk interviews.

The new category of unknown knowns is introduced as a class of risks that is known about but not spoken of in the context of public meetings such as risk workshops. Conducting data gathering in confidential interviews allows focused discussion of the “far future” of the project where some of the unknown unknowns may become better known. Interviews also allow people to talk about unknown knowns that people know but are not permitted to discuss in the organization’s culture.

It is not surprising that the method of handling unknown unknowns, applying wider ranges on far future activities, is the least satisfying method mentioned in this paper. We do expect there to be risks in the project that are revealed as the progress occurs, so the existence of unknown unknowns is well established, at least early in the lifecycle. They must be handled as uncertainty rather than as Risk Drivers since their nature is unknown at the point of analysis.

We propose to implement an expanded range of uncertainty to take account of unknowns that are yet to be discovered in the future. This begs the questions of how much to expand the range and when the far future begins.

Finally, some sobering data from recent studies of Flyvbjerg and Hollmann about project cost overruns needs to be factored into the mix when explaining and calibrating unknowns of whatever type. Coming at project schedule results using quite different methods, in this case database examination of comparable projects and parametric estimating, may improve our ability to understand the degree to which project performance does not match project plans.

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No.	Description
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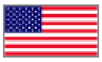

David Hulett is recognized as a leader in project cost and schedule risk analysis and project scheduling. He has conducted many risk analyses focusing on quantifying the risks and their implications for project cost and schedule estimating and mitigation, and many schedule assessments. He is a Fellow of AACE International.

Clients of Hulett & Associates, LLC represent many industries and are in the US, Canada, Europe, South America, South-East Asia and the Middle East.

Dr. Hulett is well-known as a leader in the Project Management Institute (PMI) for project risk standards, including leading the risk management chapter in the Guide to the Project Management Body of Knowledge (PMBOK® Guide) and the Practice Standard for Project Risk Management. He is the author of Recommended Practice 57R-09 published in 2011 by the Association for the Advancement of Cost Engineering (AACE) International on Integrated Cost and Schedule Risk Analysis and 85R-14 Use of Decision Trees in Decision Making.

Dr. Hulett has published *Practical Schedule Risk Analysis* (Gower, 2009) for which he was recognized by the PMI College of Scheduling for "contributions to the scheduling profession" in 2010 and *Integrated Cost- Schedule Risk Analysis* (Gower, 2011).

Dr. Hulett has held strategic planning positions at TOSCO, an oil shale company, and at TRW in aerospace and defense. In the Federal government, Dr. Hulett managed offices in the Federal Energy Agency (FEA), the Department of Energy (DOE) and the Office of Management and Budget (OMB). He was also an economist with the Federal Reserve Board of Governors. Dr. Hulett was an Instructor in the Economics Department at Harvard University. His Ph.D. in Economics is from Stanford University and his B.A. is from the Special Program for Public and International Affairs (Woodrow Wilson School) at Princeton University.

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