PS-2412

Protect Your Project Schedule Using the Unified Scheduling Method

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Abstract— Many projects suffer schedule overruns. Building a schedule that leads to on-time delivery requires balancing the need for schedule safety with the need to complete the project as quickly as possible. Using the Unified Scheduling Method (USM), project planners can forecast how many critical path activities will suffer schedule delays, then create a schedule contingency to buffer the schedule so the project still finishes on-time. USM relies on the binomial distribution functions inside Microsoft Excel® to determine how many activities are at risk of schedule failure. Once that is determined project planners can choose from among a conservative, moderate, or aggressive schedule contingency. This approach gives project sponsors and planners a way to balance their need for schedule safety with the competing need to finish projects quickly.

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This paper was originally submitted for publishing in the 2017 AACE® International Annual Meeting Transactions

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Introduction

Projects may be deemed failures for many reasons. The triple constraint for every project includes *scope, schedule* and *budget*, and failure to deliver the promised scope, on-schedule and on-budget contributes to project failure. Beyond the triple constraint, projects may be deemed failures because they did not achieve their expected benefits for the organization, or because the project's stakeholders were unsatisfied with the result of the project, or because public perception during or after the project irreparably damaged an organization's credibility—even if the project team met their scope, schedule, and budget metrics.

Since 2006, the Project Management Institute (PMI®) has created its annual *Pulse of the Profession®* report that provides an executive-level picture of project performance across the globe and in every industry. PMI's most recent *Pulse of the Profession®* has startling findings as it pertains to delivering projects on-time—the schedule constraint. Among institutions where project management has a high degree of maturity, only 61 percent of projects finish on-time, but among institutions where there is a low degree of project management maturity, only 35 percent of projects finish on-time [1, p.10]. PMI's report slices its collection of project performance data in different ways, but in all cases projects finish on-time with nothing greater than 70 percent success, and in some cases, the success rate is half that amount [1]. In a different research report from 2015, a typical construction project has only a 22 percent chance of finishing on-time using the static Critical Path Method (CPM) algorithm [5]. In Canada, the oil and gas industry had massive schedule overruns in the 2000s which have persisted, not abated, in this current decade [6, p.57]. Schedule overruns are a serious problem across every industry and in every country of the world.

Although project management has matured into a profession with its own code of ethics, supporting institutions, bodies of knowledge, and academic degrees, this maturity has not solved the problem that many projects continue to fail and schedule overruns are a major contributor to their failure. There is still more work to be done to develop project schedules that reflect the wishes of the sponsor, project team, and other key stakeholders, and that successfully guard against schedule overruns, too. Schedules must anticipate unexpected developments that will invariably disrupt the planned progress of a project. Schedules must have protection built-in and right-sized so the project's final delivery of its outcome or result is on-scope, on-budget, and *on-time*.

This paper presents one innovative way to protect the project schedule using the Unified Scheduling Method (USM). USM is a way for project planners to include a right-sized schedule contingency into the project schedule. USM anticipates unexpected developments that disrupt the planned progress of a project, and calculates a necessary contingency to match the expected impact of those disruptions.

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Unified Scheduling Method Overview

The Unified Scheduling Method was developed in 2009 by Dr. Denis Cioffi and Dr. Homayoun Khamooshi at The George Washington University, Washington DC [7]. Cioffi and Khamooshi noted that two divergent approaches are used for creating project schedules: CPM, which uses single-value, deterministic values; and PERT or Monte Carlo simulation, which uses probabilistic values [8, p.489]. Yet their earlier research found that Monte Carlo simulation is often used only for very large projects, and even with PERT, the resulting project schedule will still have a single value stipulated for each activity in the schedule [7, p.565-566; 8, p.489]. Their approach to addressing schedule risk was to assert, firstly, that the "accuracy and the resulting reliability of estimates should be taken into account more seriously in developing project schedules" [8, p.489]. Thoughtful project planners should state how reliably their estimates will satisfy the actual project result and, conversely, how much risk there is that their planning estimates may be exceeded during the project execution phase. Then, project planners should create a sufficient schedule contingency to guard against instances where their planned estimates fail to allot enough time to complete activities on the project schedule. The Unified Scheduling Method (USM) is a relatively easy way to do that.

USM is a seven-step process that begins after the project planner has identified all the work activities of the project, entered those activities into a master schedule, and sequenced those activities to create a network diagram. Here are the seven steps for USM[1]:

1) Create probabilistic planning estimates for each activity in the project schedule
2) Determine the critical path using any scheduling software package
3) Determine the maximum, potential schedule delay for each critical path activity
4) Sort all activities in descending order by their maximum, potential delay
5) For any high confidence level (like 95 percent), use the binomial distribution to calculate the maximum number of activities that will be delayed
6) Sum the maximum delay for the number of activities calculated in Step 5
7) Choose from among a conservative, moderate, or aggressive schedule contingency, depending on the need for schedule safety

While this appears to be extra work for project planners, the level of effort is greatly diminished by using an Excel-based, USM template called Soothsayer™[2]. Soothsayer makes it easy to complete Step 4, and it automates the work of Steps 5, 6 and 7.

[1] These seven steps appear somewhat differently in the published works of Drs. Cioffi and Khamooshi. The seven steps listed in this paper are simplified and rely on Microsoft Excel® to perform USM's binomial distribution calculations. As such, the seven steps listed in this paper are both easier to understand and easier to use.
[2] Soothsayer™ is a freely licensed Excel template under the GNU General Public License (GPL), published by the Free Software Foundation. It is available as a free download at: https://www.statisticalpert.com.

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The Seven Steps of the Unified Scheduling Method

Step One: Create a probabilistic planning estimate for each activity

After all activities are entered and sequenced in the master schedule, the first USM step is to create a time duration (or work effort) estimate for each activity in the master schedule. These estimates are called *planning estimates*. CPM requires *deterministic* (single-value) estimates, but USM requires a *probabilistic* estimation technique to determine the risk that a duration estimate will fail—that is, the risk that an activity will take longer to complete than the activity's planning estimate.

There are several ways to create probabilistic estimates for project activities. These ways generally require statistical modeling by choosing a probability distribution that best fits the risk characteristics of each activity. PMI's *Project Management Body of Knowledge* (PMBOK®) suggests that many activities are modeled using either the triangular or beta distribution, but PMBOK notes that normal, lognormal, and uniform distributions are also used [9, p.337]. PMBOK includes equations for finding the mean of an uncertainty using the triangular and beta distributions [9, p.171]. Both equations require estimators to use three-point estimation (minimum, most likely, maximum) to find the expected value of an uncertainty.

The expected value of a triangular distribution is found using Equation 1:

$$tE = (tO + tM + tP) / 3 \quad \text{(Equation 1)}$$

The expected value of a PERT distribution (which is a special form of the beta distribution) is found using Equation 2:

$$tE = (tO + 4tM + tP) / 6 \quad \text{(Equation 2)}$$

where, for both equations:
tE = expected time duration of an activity
tO = optimistic (minimum) point-estimate
tM = most likely point-estimate
tP = pessimistic (maximum) point-estimate

However, the expected value, or mean, for both equations is only 50% reliable[3] [7, p.489, 493]. Drs. Cioffi and Khamooshi argue that using activity estimates that are only 50% reliable is unwise because a project with a critical path having just 10 activities has less than one-tenth of one percent of finishing on-time, assuming activities will not finish earlier than expected, but only

[3] This is true for symmetrically shaped uncertainties. For uncertainties where the three-point estimate implies a skewed bell-shaped curve, the actual reliability will be slightly more or less than 50%.

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later than expected [7, p.490, 492]. They assert that for CPM-scheduled projects, activity estimates are inclined to be 80 percent reliable or more [7, p.490].

At the 2016 AACE® Annual Meeting, William Davis presented an easy solution for making probabilistic activity estimates called Statistical PERT®[4] [10]. Statistical PERT® Normal Edition is a freely licensed, Excel-based, estimation technique that uses Excel's built-in statistical functions for the normal distribution to model activities with bell-shaped risk properties. The normal distribution—also called the Gaussian distribution—is often used for risk analysis to determine scheduling delays [11, p.1232]. Statistical PERT requires the use of the same three-point estimate as used in the triangular and PERT formulas shown above, but it also lets project planners render a subjective judgment about *how likely* the "most likely" outcome really is. The planner's subjective judgment changes the standard deviation, which influences the implied shape of the normal curve for each activity estimated.

Using Statistical PERT, project planners can choose planning estimates with any reliability they want. Obviously, choosing activity estimates with longer durations lowers the risk that they will be exceeded, while choosing activity estimates with shorter durations increases the risk they will be exceeded. The key advantage of using Statistical PERT is that project planners can select estimates that all have the same reliability[5], such as 70 or 80 percent, and the risk of schedule failure is the same for each activity. To use USM, estimators must know how reliable their activity estimates are and, ideally, all activities should have the same estimation reliability.

Step Two: Determine the critical path using any scheduling software package

This step is no different than what any planner undertakes when constructing a project schedule. Whether the project planner uses Oracle Primavera®, Microsoft Project®, or one of the many other scheduling software packages commercially available, it is important to construct a network diagram that shows activity sequencing and dependencies of all activities in the master schedule to determine the critical path(s) of a project.

Drs. Cioffi and Khamooshi point out that while it is theoretically true that critical path activities that finish later than expected ought to have their schedule impact offset by other activities that finish unexpectedly early, the real-world experience of project execution suggests that is not the case [7, p.489].

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[4] This technique is now called Statistical PERT® Normal Edition. Another, similar technique called Statistical PERT® Beta Edition uses Excel's two beta distribution functions, BETA.DIST and BETA.INV. Both editions of Statistical PERT are freely licensed under the GNU General Public License published by the Free Software Foundation. Both editions of Statistical PERT are available as free downloads at https://www.statisticalpert.com.

[5] For simplicity, this paper describes an approach where all activities have planning estimates with the same reliability. Another option is to have activities with differing reliabilities (each having 70% reliability or greater), and then use a weighted reliability average for all activities with USM's binomial calculations.

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There are three reasons for this. One reason was described by Cyril Northcote Parkinson, who wrote an essay in 1957 describing *Parkinson's Law:* "Work expands so as to fill the time available for its completion" [12]. Most project managers can attest that this is true. When *Parkinson's Law* is in effect, a work activity that could be finished in 10 hours, but which is allotted 20 hours for completion in the project schedule, will typically not be finished in fewer than 20 hours.

A second reason is the *Student Syndrome*, which is simply planned procrastination [13]. Planned procrastination is not strictly the domain of students, but the condition was named for students because teachers often find students wait until the last possible minute before turning in homework assignments or studying for an exam. Among project teams, effort to complete a scheduled activity may be purposefully delayed if the resource assigned to that activity believes there is plenty of time to complete the activity within the time allowed in the project schedule.

A third reason for why activities rarely finish sooner than expected is explained by *Hofstadter's Law*, which humorously uses self-referencing to describe the problem: "It always takes longer than you expect, even when you take into account Hofstadter's Law" [14]. There is a strong propensity for project activities to take longer than expected—even when estimators choose estimates that they think have a high reliability of 80 or 90 percent. Hofstadter's Law asserts that, in the real-world of project execution, activities will rarely, if ever, finish sooner than expected.

For these three explanatory reasons, constructing a network diagram and finding the critical path is important to project planners because every activity on the critical path will be estimated with a reliability of less than 100 percent to keep costs low and avoid unnecessarily stretching out a project's timeline. Every activity on the critical path, then, can delay the project[6]. Therefore, project planners need a way to protect the project schedule by building in a schedule contingency to account for instances where activities take longer than expected.

Step Three: Determine the maximum, potential schedule delay for each critical path activity

Having performed Steps 1 and 2 above, project planners will have a master schedule where each activity has the same reliability of, say, 60, 70, 80 percent or more. In this third step, project planners will determine the maximum, potential schedule delay (tD) for each critical path activity by subtracting the time planning estimate (tPE) from the pessimistic (maximum) time estimate (tP), as found in Equation 3:

tD = tP – tPE (Equation 3)

[6] Moreover, activities that are not on the critical path initially may impact the critical path if they have very little free float (slack). This whitepaper does not address this risk; however, a project planner can, optionally, use USM to evaluate near-critical activities, too, or even all project activities in the master schedule. Doing so will create a larger schedule contingency but afford the project planner greater schedule safety.

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where:
tD = maximum, potential schedule delay if the activity has a schedule failure
tP = pessimistic (maximum) point-estimate
tPE = time planning estimate of an activity

The sum of tD for all critical path activities is the maximum, potential schedule impact to the overall project schedule.

Of course, it is highly improbable that *every* activity on the project's critical path will exceed each activity's planning estimate during the project execution phase, and it is also improbable that activities that exceed their planning estimates will reach their worst-case, pessimistic (maximum) duration outcomes.

The purpose behind finding the maximum, potential schedule delay for each activity is to build a schedule contingency that appropriately guards against schedule failure by right-sizing the schedule contingency to match the amount of risk that the schedule realistically has.

For instance, a project schedule might be at-risk of a 20-day maximum delay, or it might be at-risk of a 200-day maximum delay. Knowing how much schedule risk is present will let project planners create a right-sized schedule contingency using USM.

Step Four: Sort all critical activities in descending order by their maximum, potential delay

The reason for this step is not apparent at this point, but soon will be. For any high confidence level (usually between 95 and 99 percent), USM calculates the *maximum number of activities* that *might* exceed their planning estimates. To fully protect the project schedule, USM can build a conservative schedule contingency by assuming activities that do have schedule failure are those which pose the greatest amount of schedule risk to the project. By sorting activities in descending order by their maximum, potential schedule delay, USM can evaluate the worst-case scenario where only activities that have the greatest schedule impact are the ones that fail.

Step Five: For any high confidence level (like 95 percent), use the binomial distribution to calculate the maximum number of activities that will be delayed

During the project execution phase, activities in the master schedule can be categorized into one of two categories: those that finish on-time (or early), and those that finish late. Project planners are not concerned about those activities that finish on-time (or early), rather, they are very concerned about the activities that finish late. USM provides a quick and easy way to forecast the maximum number of activities that may finish late using the binomial distribution. By forecasting the maximum number of activities that may finish late, USM can build a right-sized schedule contingency to protect the project schedule against those specific schedule failures. It is unnecessary to add time units to a schedule contingency for all activities in a master schedule

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since it is highly improbable that all activities will suffer schedule failure. Instead, project planners only need to build a schedule contingency to protect the master schedule for the maximum number of activities that are *likely* to fail.

The binomial distribution is a discrete probability distribution of a random, independent variable that finds the probability of some number of successes in some number of trials. An easy way to understand the binomial distribution is to evaluate the probability of flipping a two-sided coin. Everybody knows that the probability of obtaining a "heads" (or "tails") outcome in a single coin flip is 50 percent. But what if the coin were flipped 10 times, and someone wanted to learn the probability of obtaining three of fewer "heads" outcomes across all 10 coin flips? Or what if someone wanted to know, with 95 percent confidence, the maximum number of "heads" outcomes that will occur when a coin is flipped 10 times? Each coin flip is a random event and independent of all other coin flips. The binomial distribution answers both questions.

Microsoft Excel® (2010 and later) has two, built-in statistical functions for the binomial distribution: BINOM.DIST (binomial distribution) and BINOM.INV (binomial inverse). BINOM.DIST calculates both the cumulative and non-cumulative probability of obtaining *x* number of successes for *y* number of trials. BINOM.INV calculates the maximum number of successes for any cumulative probability between 0 and 100 percent.

The arguments for the BINOM.DIST function are: *number of successes, number of trials, probability of a successful outcome,* and *cumulative probability Boolean.* The arguments for the BINOM.INV function are: *number of trials, probability of a successful outcome,* and *alpha*. In USM, the *alpha* argument specifies a high confidence level, usually between 95 and 99 percent.

Equation 4 shows the Excel formula expression to learn the cumulative probability of flipping "heads" three or fewer times over 10 coin flips:

BINOM.DIST(3, 10, 0.50, TRUE) = 0.171875 ≈ 17% (Equation 4)

where:
3 is the *number of successes*
10 is the *number of trials*
0.50 is the *probability of a successful outcome*
TRUE is the *cumulative probability Boolean*

There is a 17% probability of obtaining three or fewer "heads" outcomes when a coin is flipped 10 times. This calculation does not tell *which* coin flips will result in a "heads" outcome, rather, it says there is a 17% probability that "heads" will occur *three or fewer times* over 10 coin flips. Conversely, there is an 83% probability that "heads" will occur *four or more times*.

Equation 5 shows the Excel formula expression to learn the maximum number of "heads" outcomes that could occur over 10 coin flips (with at least 95 percent confidence):

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BINOM.INV(10, 0.50, 0.95) = 8 (Equation 5)

where:
10 is the *number of trials*
0.50 is the *probability of a successful outcome*
0.95 is the *alpha*, that is, the confidence level for the BINOM.INV result

With at least 95 percent confidence, a coin flipped 10 times will result in "heads" no more than eight times; there is no more than a five percent chance that a coin flipped 10 times will result in "heads" 9 or 10 times[7].

USM does not use the binomial distribution to calculate the probability of coin flips; instead, USM uses the binomial distribution to calculate the maximum number of activities in a project schedule that may exceed their planning estimates (whether by very little or by a lot—the amount by which an activity exceeds its planning estimate does not matter at this point). USM cannot forecast which specific activities may have a schedule failure, but USM can forecast the maximum number of schedule failures on the critical path with a high confidence level, like 95 or 99 percent.

Example: A project schedule has 20 activities on the critical path. Each activity is estimated with 80 percent reliability. Therefore, each activity has a 20% risk of exceeding its planned duration. A project manager wants to learn, with 95 percent confidence, the maximum number of activities that may exceed their planned duration.

The project manager can answer this question using the binomial distribution. The project manager knows that there are 20 critical path activities (trials) and that each activity has a 20 percent risk of exceeding its planned duration. If the project manager wants to calculate the maximum number of activities that may exceed their planned duration, and be at least 95 percent confident in the calculated result, they can use Excel's BINOM.INV function, seen in Equation 6:

BINOM.INV(20, 0.20, 0.95) = 7 (Equation 6)

where:
20 is the *number of trials,* that is, the number of critical path activities
0.20 is the *probability of a successful outcome[8],* that is, the risk that an activity will be delayed
0.95 is the *alpha*, that is, the confidence level for the BINOM.INV function result

[7] Using the BINOM.DIST function, the precise reliability of obtaining eight "heads" or fewer outcomes out of ten coin flips is 98.93%. For example, BINOM.DIST(8, 10, 0.50, TRUE) = 98.93%. Therefore, the actual probability of obtaining nine or ten "heads" outcomes over ten coin flips is only 1.07%. When using the BINOM.INV function, the same output value can be obtained for a range of differing *alpha* input arguments.

[8] In USM, a "successful outcome" represents the risk that an activity will be delayed, not the likelihood that an activity will finish on-time or early. This distinction is explained later in this paper.

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With at least 95 percent confidence, the project manager must build a schedule contingency to protect the project for up to **seven** activities that may exceed their planned duration. The project manager does not know *which* seven activities on the critical path will fail, but if the project manager assumes that seven activities *with the most schedule delay impact* are the ones that may fail, they can safeguard the project schedule for that worst-case outcome plus any other outcome that involves activities that have a lesser schedule impact.

Moreover, the project manager does not know whether *fewer* than seven activities will exceed their planned duration. The BINOM.INV function provides a cumulative result: seven *or fewer* activities will have schedule failure at the 95 percent confidence level.

If the project manager wants to be at least 99 percent confident in determining the maximum number of activities that might exceed their planned duration, they can simply change the *alpha* argument in the BINOM.INV function to indicate this preference, seen in Equation 7:

BINOM.INV(20, 0.20, 0.99) = 8 (Equation 7)

where:
20 is the *number of trials,* that is, the number of critical path activities
0.20 is the *probability of a successful outcome,* that is, the risk that the activity will be delayed
0.99 is the *alpha*, that is, the confidence level for the BINOM.INV function result

With at least 99 percent confidence, the project manager must build a schedule contingency to protect the project for up to **eight** activities that may exceed their planned duration (not seven). Protecting the project schedule from eight potential schedule failures will necessarily require a larger project contingency, but in exchange for that, the project manager will have an even greater sense of confidence that the schedule contingency will sufficiently protect the project schedule from schedule failure.

Note that USM changes the meaning of the second argument for the BINOM.INV function. In Excel, the second argument is used to indicate the *probability of* ***success***. If each activity in the master schedule is planned with 80 percent reliability, a project planner might be tempted to insert "0.80" for the second argument since each activity has an 80 percent likelihood of finishing on-time (or early). Doing that, however, would calculate the maximum number of activities that will finish on-time (or early)—but that is not the question USM is trying to answer. USM's focus is on the maximum number of activities that will *exceed* their planned duration (schedule **failure**), not the maximum number of activities that will finish on-time (or early). Therefore, USM uses the second argument in the BINOM.INV function (and the third argument in the BINOM.DIST function) to indicate the probability of a trial (activity) **failure**—not success. Humorously, this is called a "successful failure" of an activity's planned duration.

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Step Six: Sum the maximum delay for the number of activities calculated in Step 5

In Step 5, project planners calculate the maximum number of activities that will exceed their planned durations. In Step 6, project planners calculate the worst-case schedule impact for the maximum number of at-risk activities in Step 5.

Remember that in Step 4, all critical path activities were sorted in descending order per their maximum, potential schedule delay. When a project planner sums the maximum, potential delay for the number of at-risk activities calculated in Step 5, the project planner chooses the worst-case scenario where only the activities with the most schedule impact are the activities that have schedule failure.

Step Seven: Choose from among a conservative, moderate, or aggressive schedule contingency, depending on the need for schedule safety

The maximum, potential delay to the project schedule calculated in Step 6 represents the most conservative approach for choosing a right-sized schedule contingency. However, it generally is not necessary to have such a large and conservative schedule contingency because this contingency guards the project schedule where:

- The maximum number of activities that could exceed their planned duration (for a given confidence level) actually do fail during the project execution phase, and
- All the activities that fail are only the ones that have the greatest schedule impact, and
- All the activities that fail have a worst-case, pessimistic outcome

There is very little likelihood that a project will encounter all three of these conditions.

In the unlikely event that the binomially-calculated maximum number of activities that could exceed their planned duration do, indeed, fail, *and* they are all the ones with the greatest schedule impact, they will not all likely fail to the point where they reach their worst-case, pessimistic (maximum) outcome. A more likely occurrence is that activities that fail will be a mix of low- and high-impact to the project schedule, and activities that exceed their planning estimates are more likely to exceed those estimates in minor or moderate ways, rather than suffer severe schedule failure.

Optionally, project planners can assume one of two different probability distributions for activity schedule failures: a uniform distribution, where there is an equal likelihood that an activity may need just one day longer to finish, or it may reach its pessimistic (maximum) outcome, or any value in-between; or a triangular distribution, where there is a declining probability that the activity schedule failure, should it occur, will reach its pessimistic (maximum) outcome. Either way, project planners employ the Central Limit Theorem and select a schedule contingency that is the expected value—that is, the mean or average—of the project's schedule delay.

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These three choices—conservatively choosing an unadjusted sum of the maximum activity delays for the number of activities determined in Step 5, or applying a uniform distribution to those delays and choosing a moderate schedule contingency, or applying a triangular distribution to the delays and choosing an aggressive schedule contingency—give the project planner flexibility to choose the best-fitting schedule contingency that balances the need for schedule safety and the need for execution speed.

Unified Scheduling Method Example Project

Demonstrating USM can be done easily with a generically-described project that contains 100 activities, 15 of which are on the critical path. (The example project's objectives and activities are immaterial to this discussion.) In this example project, a project manager wants to create a right-sized schedule contingency to protect the project schedule. The project manager will follow the seven steps of USM to calculate an appropriately-sized schedule contingency.

Step One: Create probabilistic planning estimates for each activity on the project schedule

The project manager wants to create planning estimates that have 80 percent reliability. To do that, the project manager uses Statistical PERT® Normal Edition to model the bell-shaped uncertainty of each activity on the project schedule. (The time unit-of-measure for this example is *days*). For simplicity, the project manager chooses "Medium Confidence" in the most likely outcome for each activity (inside the Statistical PERT spreadsheet), and uses heuristics to define the optimistic (minimum) and pessimistic (maximum) outcomes for all 100 activities. This quickly creates three-point estimates for every activity in the project. The project manager decides that optimistic outcomes reduce the most likely outcome by 15 percent, whereas pessimistic outcomes increase the most likely outcome by 30 percent. From those three-point estimates, the project manager can choose probabilistic planning estimates with 80 percent reliability for each activity.

Figure 1 shows an example of the Statistical PERT output. For the first activity (ID 1), the most likely outcome is a 20-day duration. Two heuristics are used to calculate the optimistic (minimum) and pessimistic (maximum) outcomes, which are 17 and 26 days, respectively. The project manager chooses a planning estimate of 22 days, which is 80 percent reliable. There is a 20 percent risk that the activity will take longer than 22 days to complete.

Statistical PERT® (SPERT®) *Normal Edition*

	-15%	<< Heuristics >>	30%		
ID	**Minimum**	**Most Likely**	**Maximum**	**Most Likely Confidence**	**80%**
1	17	20	26	Medium confidence	22

Figure 1 – Statistical PERT Estimation Worksheet

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Step Two: Determine the critical path using any scheduling software package

The project manager uses Oracle Primavera® to create a master schedule containing 100 activities, and Primavera determines the project's critical path. Figure 2 shows the Statistical PERT results for just the 15 critical path activities. The last column shows planning estimates for every activity that are all 80 percent reliable. Summing all planning estimates for critical path activities determines the length of the overall project: 649 days.

Statistical PERT® (SPERT®) *Normal Edition*

	-15%	<< Heuristics >>	30%		
ID	**Minimum**	**Most Likely**	**Maximum**	**Most Likely Confidence**	**80%**
1	17	20	26	Medium confidence	22
2	17	20	26	Medium confidence	22
3	26	30	39	Medium confidence	33
4	34	40	52	Medium confidence	44
5	26	30	39	Medium confidence	33
6	68	80	104	Medium confidence	88
7	85	100	130	Medium confidence	110
8	51	60	78	Medium confidence	66
9	43	50	65	Medium confidence	55
10	34	40	52	Medium confidence	44
11	17	20	26	Medium confidence	22
12	9	10	13	Medium confidence	11
13	17	20	26	Medium confidence	22
14	34	40	52	Medium confidence	44
15	26	30	39	Medium confidence	33
	502	590	767		649

Figure 2 – Statistical PERT Estimate for All Critical Path Activities

Step Three: Determine the maximum, potential schedule delay for each critical path activity

The project manager uses a freely-licensed, USM Excel template called Soothsayer™ to calculate the maximum, potential schedule delay for the project. Although USM does not require a specialized Excel template, using a pre-constructed template like Soothsayer makes the USM process much easier to execute.

To begin using the Soothsayer spreadsheet, the project manager copies both the "Maximum" values and the "80%" planning estimates from the Statistical PERT spreadsheet and pastes those values into the "Maximum" and "Your Estimate" columns of the Soothsayer spreadsheet, respectively. Figure 3 shows how the Soothsayer spreadsheet subtracts the values under "Your Estimate" from values in the "Maximum" column to find the schedule impact that is "At Risk" for

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each of the 15 critical path activities. The project has a maximum, potential, and highly improbable schedule delay of 118 days.

Soothsayer™ *for Project Schedule Reserve*

ID	Maximum	Your Estimate	At Risk
1	26	22	4
2	26	22	4
3	39	33	6
4	52	44	8
5	39	33	6
6	104	88	16
7	130	110	20
8	78	66	12
9	65	55	10
10	52	44	8
11	26	22	4
12	13	11	2
13	26	22	4
14	52	44	8
15	39	33	6
	767	649	118

Figure 3 – Soothsayer At Risk Values

Step Four: Sort all activities in descending order by their maximum, potential delay

Using the sort function in Excel, the project manager selects the "ID", "Maximum", "Your Estimate" and "At Risk" columns and sorts them by the "At Risk" column in descending order. Figure 4 shows the sorted results in the Soothsayer spreadsheet; the activity with the greatest amount of schedule impact is Activity #7 (20 days at-risk), and the activity with the least amount of schedule impact is Activity #12 (2 days at-risk).

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Soothsayer™ *for Project Schedule Reserve*

ID	Maximum	Your Estimate	At Risk
7	130	110	20
6	104	88	16
8	78	66	12
9	65	55	10
4	52	44	8
10	52	44	8
14	52	44	8
3	39	33	6
5	39	33	6
15	39	33	6
1	26	22	4
2	26	22	4
11	26	22	4
13	26	22	4
12	13	11	2
	767	**649**	**118**

Figure 4 – Soothsayer At Risk Values, Descending Order

Step Five: For any high confidence level (like 95 percent), use the binomial distribution to calculate the maximum number of activities that will be delayed

The Soothsayer spreadsheet employs the BINOM.INV function to calculate, with at least 95 percent confidence, that no more than six activities will exceed the project manager's planning estimates. Figure 5 shows the summarized Soothsayer results which includes the use of the BINOM.INV function in Excel.

With	**15**	*project tasks,*
where the average probability is	**80%**	*that each task will finish on-time (or early),*
(meaning that each task has a	**20%**	*average risk of EXCEEDING* ***Your Estimate***
		listed in column C),
you expect, with	**95%**	*confidence,*
that no more than	**6**	*tasks in your project will exceed* ***Your Estimate***
		in column C.

Figure 5 – Soothsayer BINOM.INV Calculations

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The actual BINOM.INV function calculation used in this step is shown in Equation 8:

BINOM.INV(15, 0.20, 0.95) = 6 (Equation 8)

where:
15 is the number of *trials* (that is, the number of critical path activities)
0.20 is the *probability of success* (of an activity delay—a "successful failure")
0.95 is *alpha*, that is, the confidence level for the BINOM.INV function result

Step Six: Sum the maximum delay for the number of activities calculated in Step 5

The six activities with the greatest amount of schedule impact are #7, #6, #8, #9, #4, and #10 with potential schedule impacts of 20, 16, 12, 10, 8 and 8 days, respectively. The sum of these maximum, potential schedule impacts is 74 days (as shown in the green-colored cell in Figure 6). This is the maximum schedule delay if up to six activities (with the greatest schedule impact) encounter schedule failure.

Soothsayer™ *for Project Schedule Reserve*

ID	Maximum	Your Estimate	At Risk	Full Reserve
				74
7	130	110	20	20
6	104	88	16	16
8	78	66	12	12
9	65	55	10	10
4	52	44	8	8
10	52	44	8	8

Figure 6 – Soothsayer Full Reserve Calculation

Step Seven: Choose from among a conservative, moderate, or aggressive schedule contingency, depending on the need for schedule safety

Choosing 74 days for the schedule contingency would be a conservative approach to creating a schedule contingency to protect the project. This approach says that if six activities with the greatest schedule impact exceed their planning estimates, they will all finish per their respective, pessimistic (maximum) time duration. However, there are two other, less conservative approaches that the project manager should consider.

A moderate approach to choosing a schedule contingency is to assume that when an activity exceeds its planning estimate, the extra time required to complete the delayed activity is a **uniform** distribution, where there is an equal likelihood of the activity finishing one day late and every day longer than one day, up to the maximum, potential delay for that activity. If a uniform

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distribution is assumed, then each activity will have an average delay that is one-half its maximum, potential delay.

For instance, activity #7 has a maximum, potential delay of 20 days. If a uniform distribution is assumed for all delayed activities, then activity #7 has an equal chance of finishing 1, 2, 3,…19 or 20 days over-schedule. The average delay (expected value), then, for activity #7 is:

{1+2+3+4+5+6+7+8+9+10+11+12+13+14+15+16+17+18+19+20} / 20 = 10 days (Equation 9)

In Figure 7, the column heading "Partial Reserve" shows schedule contingencies for each activity that is one-half the "Full Reserve[9]" amount. Using this approach, the project manager utilizes the Central Limit Theorem to create a schedule contingency that is less than the "Full Reserve" because it is statistically improbable that all delayed activities will be delayed to their respective, pessimistic (maximum) point-estimates.

Soothsayer™ *for Project Schedule Reserve*				Full Reserve	Partial Reserve
ID	Maximum	Your Estimate	At Risk	74	37
7	130	110	20	20	10
6	104	88	16	16	8
8	78	66	12	12	6
9	65	55	10	10	5
4	52	44	8	8	4
10	52	44	8	8	4

Figure 7 – Soothsayer Partial Reserve Assuming a Uniform Distribution of Delays

When Soothsayer calculates one-half of each activity's At Risk values, the Partial Reserve declines to 37 days, which is less than 6% of the project's planned duration of 649 days.

A more aggressive approach to choosing a schedule contingency is to assume that when an activity exceeds its planning estimate, the extra time required to complete the delayed activity is a **triangular** distribution having the appearance of a right-sided triangle. In this approach, it is exceedingly unlikely that an activity delay will reach its maximum, potential delay.

Looking at the bell-shaped curve for a project activity shows why this is a reasonable approach. Figure 8 shows the probability density function[10] for Activity #7, which has a most likely point-estimate of 100 days, an optimistic (minimum) point-estimate of 85 days (15 percent less than the most likely outcome), a pessimistic (maximum) point-estimate of 130 days (30 percent greater than the most likely outcome), and a planning estimate of 110 days (the 80th percentile).

[9] The Soothsayer template uses "Reserve" as a synonym for "Contingency"
[10] The bell-shaped curve was created using Statistical PERT® Beta Edition to show that Activity #7 is a skewed probability with slightly greater area under the curve to the right of the mode.

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The bell-shaped blue line to the right of the vertical red line slopes downward until it reaches Activity #7's pessimistic (maximum) point-estimate (130 days). The vertical red line marks the 80th percentile planning estimate that separates those outcomes which lead to on-time performance, and those outcomes that lead to schedule delay. If it occurs at all, a schedule delay has a *decreasing* risk of occurrence the further it moves away from the activity's planning estimate.

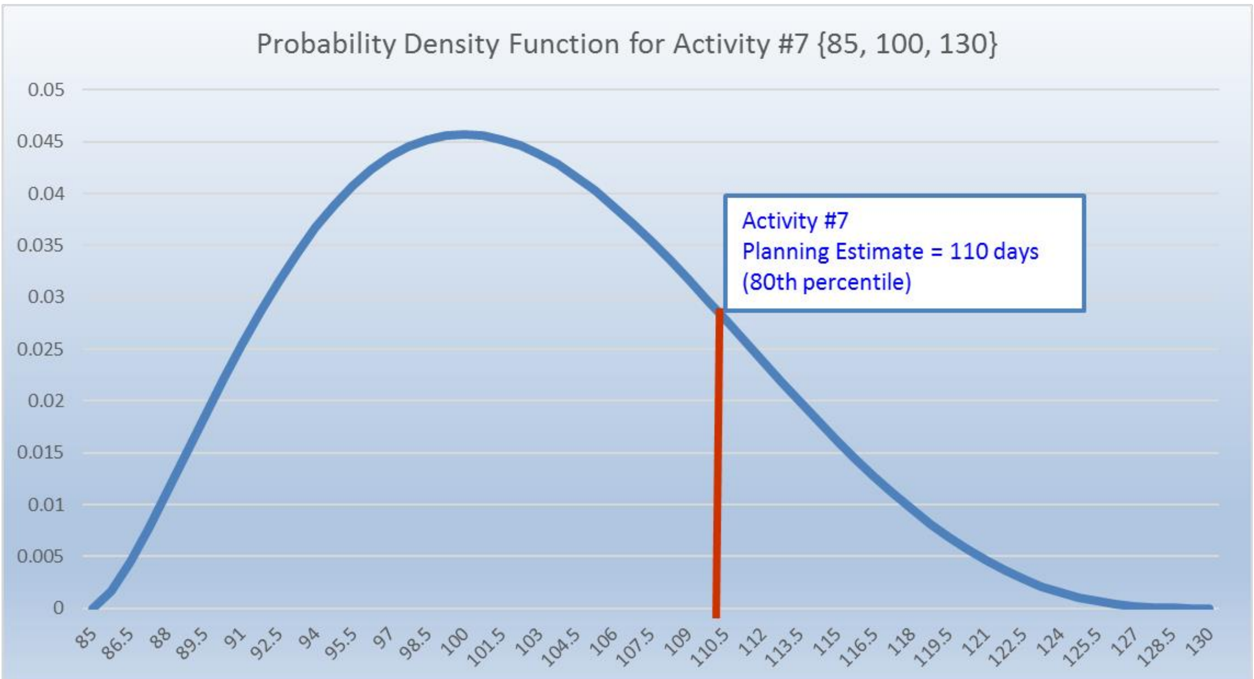

Figure 8 – Statistical PERT Bell Curve for Activity #7

Drs. Cioffi and Khamooshi suggest using an activity contingency equal to one-third of an activity's maximum delay because "it is approximately the point of 50% accumulated probability in a distribution shaped as a right angle" [7, p.495].

Figure 9 visually represents why choosing a contingency of one-third of Activity #7's maximum, potential delay is reasonable. Fifty percent of the area in the right triangle is between Activity #7's planning estimate of 110 days and 117 days, where a delay of seven days is approximately one-third of Activity #7's maximum, potential delay of 20 days (130 days maximum duration minus 110 days for the 80th percentile planning estimate). An expected delay (that is, the mean of Activity #7's delay), *should it occur*, is seven days, not 10 days as it is when a uniform distribution is assumed for an activity delay.

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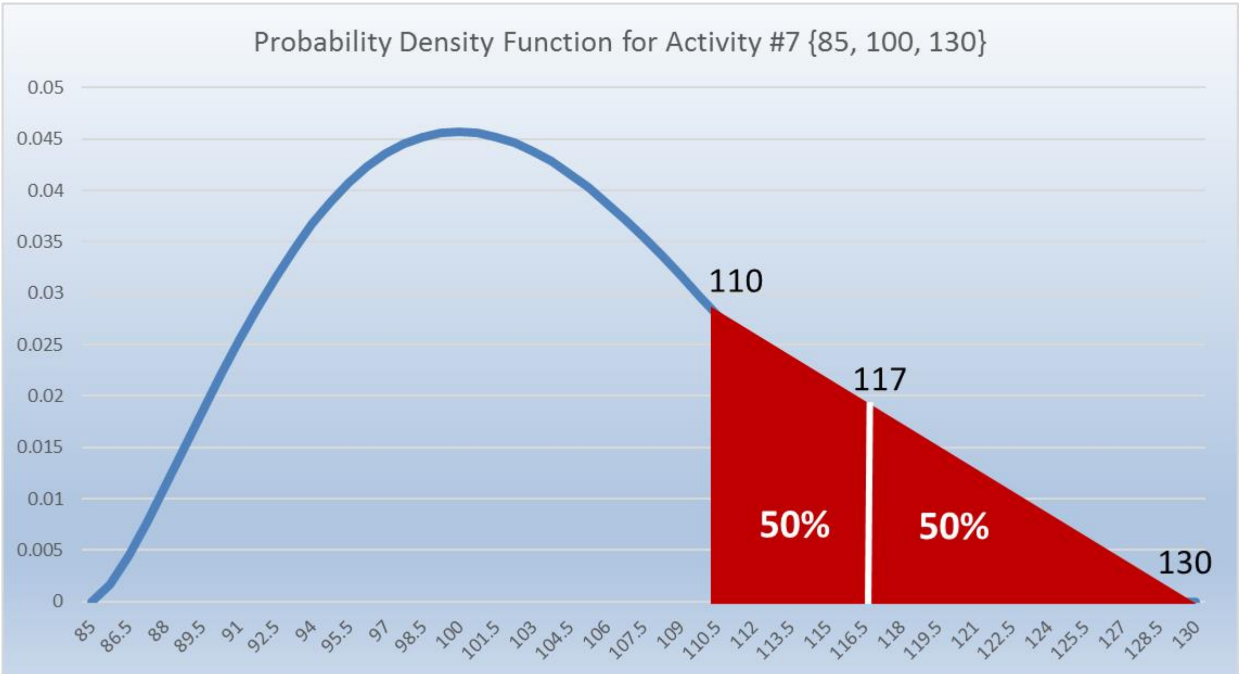

Figure 9 – Triangular Distribution of Activity #7's Delay

Figure 10 shows a Soothsayer Partial Reserve total of 24 days, which is one-third of the Full Reserve total (rounded). This treats any activity delay as a triangular distribution, where the expected value of each delay is one-third of the difference between the Full Reserve and each activity's planning estimate (which are entered in the Your Estimate column).

Soothsayer™ *for Project Schedule Reserve*				Full Reserve	Partial Reserve
ID	Maximum	Your Estimate	At Risk	74	24
7	130	110	20	20	7
6	104	88	16	16	5
8	78	66	12	12	4
9	65	55	10	10	3
4	52	44	8	8	3
10	52	44	8	8	3

Figure 10 – Soothsayer Partial Reserve Assuming a Triangular Distribution of Delays

When Soothsayer calculates one-third of the At Risk values, the Partial Reserve declines to just 24 days, which is less than 4% of the project's planned duration of 649 days. Yet 24 days protects the project schedule for up to six activities that will exceed their planning estimates, and which collectively have an average schedule impact of 24 days.

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The project manager for this example project can now choose from among three different schedule contingencies to protect the project schedule. The most cautious approach is to assume that if up to six activities are delayed, they will all be delayed by their respective, pessimistic (maximum) point-estimates, and those activities with the greatest schedule impact will be the ones that are delayed. The schedule contingency would be the sum of the maximum, potential delay for six activities with the greatest schedule impact.

A more moderate approach is to sum the total schedule impact of the six activities that may fail, and assume a uniform distribution for those delays; the schedule contingency would be one-half the sum of the maximum, potential delay for the six activities with the greatest schedule impact.

Finally, an aggressive approach is to assume that if any or all of six activities are delayed, they will be delayed with a triangular distribution where the probability of occurrence declines between the planning estimate and the pessimistic (maximum) point-estimate; the schedule contingency will be one-third the sum of the maximum, potential delay for the six activities with the greatest schedule impact.

The project manager can now choose a schedule contingency that best balances the need for protecting the schedule from unplanned delays with the need to maintain the shortest schedule possible.

Conclusion

Project failure occurs for one or more of many reasons, and among those reasons for failure is that projects finish later than expected. This is true in every industry and in every country of the world, despite the increased maturity of the project management profession.

One way of protecting the project schedule is to anticipate how many critical path activities may be delayed by using the Unified Scheduling Method, which relies on the binomial distribution to forecast how many project activities will exceed their planning estimates.

Microsoft Excel® has two, built-in, binomial distribution functions: BINOM.DIST (binomial distribution) and BINOM.INV (binomial inverse). A project planner can use the BINOM.INV function to calculate, with a high degree of confidence, the maximum number of activities that may be delayed on a project. Then, a project planner can protect the project schedule by creating a schedule contingency for those activities that—if they do fail—are the ones that pose the greatest impact to the project schedule.

Using USM, project planners can choose from a conservative, moderate, or aggressive schedule contingency. Choosing a conservative schedule contingency entails summing the difference between pessimistic (maximum) point-estimates and the planning estimates used on the project schedule, without making any adjustments to that sum. Choosing a moderate schedule contingency involves assuming a uniform distribution for the schedule delay for each delayed

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activity, and taking one-half of the conservative schedule contingency. Choosing an aggressive schedule contingency requires assuming a triangular distribution of the schedule delay for each delayed activity, and taking one-third of the conservative schedule contingency.

When choosing between a conservative, moderate, and aggressive schedule contingency, project planners balance the need to protect the project schedule with the need to finish the project as quickly as possible.

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References

1 Project Management Institute. (2016). *2016 Pulse of the Profession: The High Cost of Low Performance.* Newtown Square: Project Management Institute. Retrieved January 17, 2017, from http://www.pmi.org/learning/thought-leadership/pulse/pulse-of-the-profession-2016

2 Yosha, R. (2012, June). Make It Not Go Wrong. *Industrial Engineer, 44*(6), pp. 36-41. Retrieved January 17, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/1556011137?accountid=33473

3 Progressive Digital Media. (2015, April 29). Ten of the world's most amazing stadium designs. *Progressive Digital Media Design Build News*. London, England: Progressive Digital Media. Retrieved January 17, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/1677305755?accountid=33473

4 United States Federal Government. (2009). Review of the Award and Administration of Task Orders Issued by the Department of Veterans Affairs for the Replacement Scheduling Application Development Program (RSA). Department of Veterans Affairs, Office of Inspector General. Washington DC: United States Federal Government. Retrieved January 20, 2017, from http://www.va.gov/oig/52/reports/2009/VAOIG-09-01926-207.pdf

5 Plotnick, F. L. (2015, Summer). Rewriting the CPM scheduling specification to better support the project owner. *The Construction Lawyer, 35*(3), pp. 31-38,51. Retrieved 17 2017, January, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/1727756911?accountid=33473

6 Oilweek. (2016, September). The new project era. *Oilweek, 67*(9), 49,51-62. Retrieved January 18, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/1828127504?accountid=33473

7 Cioffi, D., & Khamooshi, H. (2009, April). A practical method of determining project risk contingency budgets. *Journal of the Operational Research Society, 60*(4), 565-571.

8 Cioffi, D. F., & Khamooshi, H. (2013, May). Uncertainty in task duration and cost estimates: fusion of probabilistic forecasts and deterministic scheduling. *Journal of Construction Engineering and Management, 139*, pp. 488-497.

9 Project Management Institute. (2013). *A Guide to the Project Management Body of Knowledge* (5th Edition ed.). Newtown Square: Project Management Institute.

10 Davis, W. W. (2016). Easily estimate projects using Statistical PERT. *2016 AACE International Transactions.* AACE International.

11 Love, P. E., Sing, C.-P., Wang, X., Edwards, D. J., & Odeyinka, H. (2013, August). Probability distribution fitting of schedule overruns in construction projects. *Journal of the Operational Research Society, 64*(8), 1231-1247. Retrieved January

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This paper was originally submitted for publishing in the 2017 AACE® International Annual Meeting Transactions

18, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/1371225684?accountid=33473

12 Harrison, T. (1962). Parkinson's law, and other studies in administration. *Personnel Journel, 41*(11). Retrieved January 17, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/203590980?accountid=33473

13 Wei-Ming, O., & Kang-Wei, C. (2007, September). Use of Leadership and Differentiation Strategies by Professional Service Firms: A Case Study. *International Journal of Management, 24*(3), 477-488,619. Retrieved January 18, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/233229388?accountid=33473

14 Perina, K. (2007, November/December). No End in Sight. *Psychology Today, 40*(6), 7. Retrieved January 18, 2017, from http://proxygwa.wrlc.org/login?url=http://search.proquest.com/docview/214485146?accountid=33473

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