

PROJECT RISK MANAGEMENT

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PROJECT RISK MANAGEMENT

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PROJECT RISK MANAGEMENT

I. Introduction

Introduction to This Course

Merriam-Webster defines risk as “the possibility that something bad or unpleasant (such as an injury or loss) will happen; someone or something that may cause something bad or unpleasant to happen; a person or thing that someone judges to be a good or bad choice for insurance, a loan, etc.” Projects are inherently risky: The project may involve a potentially unsafe working environment, there may be new technology or design standards involved, the project may be a target for protests or terrorism, or the ever-popular scope creep. But risks can also be positive. There may be opportunities for a company to get into a new market, enhance their profit, or enhance their profit. In this course, we will examine both the positive and negative sides of risk management (RM).

Learning Objectives

By the end of this course, you will:

1. Understand what project risk management is, and why it’s so important to project management.
2. Be able to identify several categories of risks and to identify risks within those categories.
3. Appreciate that project risk encompasses not just negative events or threats, but opportunities as well.
4. Understand how to quantify and prioritize risks.
5. Be familiar with means to respond to project risks.
6. Know how to track and control risks throughout the project, and identify and handle new risks that emerge.
7. Be exposed to several methods for setting contingency.
8. Understand (from the viewpoint of the engineer or contractor) the key contract clauses that can typically cause headaches on projects, and how to protect the company’s interests.
9. Understand (from the viewpoint of the organization procuring the contractor’s or engineer’s services) how to protect the organization’s interests.
10. Be introduced to bonding to minimize project risk.
11. Be familiar with methods for handling risk during project execution.

Introduction to Project Risk Management

If you think about it, the art and science project management¹ exist to minimize threats and maximize opportunities. We don't know whether those who have developed project management over the centuries had risk management in mind, but project planning and management disciplines (listed below) collectively help reduce risk on a project (and conversely enhance opportunity)—but only if routinely practiced. These disciplines are:

- Defining and controlling scope,
- Creating and monitoring the schedule,
- Estimating and controlling costs,
- Defining and building to acceptance criteria,
- Identifying, recruiting, and melding the team members,
- Defining, managing, and educating stakeholders,
- Planning for and delivering the appropriate information to the stakeholders,
- Contracting for goods and services needed for the project, and
- Identifying and managing risk (threats **and** opportunities).

A risk is an uncertain event or condition that, should it occur, would affect at least one project objective. Risk is unpredictable. Risk involves uncertainty, whether threats or opportunities. Risk is always in the future. If we could see into the future, we could pick lottery numbers, become rich, and not have to work if we chose not to. We can predict, based on our experience, what may happen; however, when we become project managers (PMs), we're not automatically issued a crystal ball. Those risks we CAN predict based on our experience are called "known unknowns", which means that we've seen them before, they could happen again, but we don't know if they will. One example of a known unknown is that a key project person becomes unavailable for the project (transfer, new job, etc.) The risk response portion of risk management consists of addressing each high-priority risk and developing a risk response or countermeasure (for threats) or an enhancement plan (for opportunities).

On the other hand, those risks we could never have predicted are called "unknown unknowns". A few examples of unknown unknowns include the earthquake and tsunami at Fukushima, foreign government seizure of the project assets, or terrorist attacks. We can't proactively manage unknown unknowns. We need to have a contingency plan to protect the project budget, schedule, etc., from these eventualities.

¹ Please participate in our "Project Management" course for more details on project management.

Some are confused about the difference between “risks” and “issues”. Risks, as just stated, are in the future. An issue, on the other hand, is a problem right now, in the present, that the project team has to deal with. Risk management is proactive, whereas issue management is reactive. The purpose of project risk management is to be proactive rather than reactive regarding things that might go wrong on the project and just as important those things that would enhance project success. Planning for risks and then tracking them during the project will help us PMs feel we’re prepared for project success. The ideal project is one with no surprises. Project risk management not only tells us if the monster is in the house (a surprise), it also helps keep the monster out of the house in the first place (so we’re not caught off-guard).

There are five steps to project risk management (RM):

1. Planning your risk management approach
2. Identifying risks
3. Quantifying and prioritizing risks
4. Developing a response to each risk
5. Handling risk (planned and new) during project execution

This is VERY important, so pay attention: Right now many of us do risk management in our heads. At least we were thinking about it. As you work through this course, you may be thinking, “All the projects I manage are small, so I don’t have time to do this. None of this applies to me.” Au contraire! All of the risk management theory does apply to you. Use your professional judgment as to how detailed you want to get. Risk management should be part of every project; however, the larger, more complex, or high-visibility the project, and the more people involved on the team, the more important it is to follow the formal risk management steps in detail. It’s less stressful and more cost-effective to be proactive to think about and plan for risks than it is to be caught unprepared in the middle of the project.

Spoiler alert: The key parameters in project risk management are Impact (I) and Probability (P). Impact quantifies the answer to the question “If this risk did happen, what would it do to one or more of the project objectives (schedule, budget, etc.)?” Probability simply is a measure of the likelihood of this risk happening. To quantify and subsequently prioritize our risks, we multiply $P \times I$. No advanced calculus!

NOTE: This document uses the terms “client”, “engineer”, “consultant”, “contractor”, and “owner”. Sometimes just the terms “owner” and “contractor” are used, but depending on your job, you could substitute “engineer” for “contractor” and “client” for “owner”. No matter the term, the risk management principles apply to all.

II. Planning Your Risk Management Approach

Introduction

Many organizations have guidelines, templates, and processes for approaching risk management. Perhaps yours does, too, and you may not be aware of it. Whether your organization does or not, at the beginning of the project, you and your team should think about how you will approach each of the steps in the RM process shown above. Your deliverable or work product from this step will result in your Project Risk Management Plan (RMP), which will guide you and your team regarding how to handle risk throughout the project. Some people think this is a time-consuming and unnecessary task. It is neither. Don't skip it.

Individuals and organizations have what is called "risk tolerance". The risk tolerance indicates the individual's or organization's willingness to assume risk given the amount of money at stake. Some avoid risk, sometimes at all costs. For them, the more money at stake, the less they want to take the risk. They want more certainty and may be willing to pay more to make themselves feel more comfortable. On the opposite end of the scale are the risk lovers. They feel more energized by taking on risks if there is a higher payoff. In fact, they may be OK with paying a penalty after the fact if things don't pan out. In the middle are the risk-neutral, which is self-explanatory. The RMP must take risk tolerance into account.

Risk management is an iterative process with scope, schedule, and budget. In other words, you may have to adjust scope, schedule, and/or budget based on your risk analysis. Your risk management approach should spell out how to do this iterative process. It should also show you how to decide whether your organization should even proceed with the project (go/no-go).

The RMP should address the goals, approach, deliverables, and organizational policies you will use throughout the project. Your risk management approach should also list the categories of risk your organization has encountered before. Some example categories are Financial, Scope, Usability, Schedule, Environmental, etc. (We will discuss these categories in Section III (Identifying Risks.)) It should also spell out each team member's roles and responsibilities on the project, as well as their authority to make project decisions involving scope, schedule, or budget.

Risk Management Plan Contents

Your RMP outline might look something like this (you can add to or delete from this outline, based on project complexity):

1. Introduction/Executive Summary
2. Project Description

3. Project Scope, Assumptions, and Constraints
4. Risk Management Strategy for the Project
5. Risk Management Roles and Responsibilities
6. How to Identify Risks
7. How to Analyze, Prioritize, and Respond to Risks
8. How to Track, Control, and Close Risks

Introduction/Executive Summary gives a 30,000-foot view of the project risk management approach. Many stakeholders not directly involved in the project may read your RPM; therefore, it's important to include at least the first three sections. These sections also bring new team members up to speed on risk management for this project.

Project Description should briefly tell the reader about the history of the project, why it's being undertaken, and what the ultimate deliverable will be.

Project Scope, Assumptions, and Constraints is a very important section. If we don't nail the scope, we cannot estimate the costs, determine the schedule, or perform **any** of the other project management disciplines listed earlier. The RPM depends heavily on how well we incorporate our assumptions and constraints into our risk management process.

The assumptions make our scope even clearer. According to Project Management Institute's (PMI's) *A Guide to the Project Management Body of Knowledge (PMBOK®), Fourth Edition*, assumptions are "factors that, for planning purposes, are considered to be true, real, or certain without proof or demonstration". They are "beliefs of what you assume to be true in the future²". If your assumptions are wrong, it could impact your schedule, budget, quality, etc.

Some examples of assumptions are:

- Key personnel will be assigned 100% for the duration of the project.
- The owner's property will be accessible from 7 a.m. to 6 p.m. Monday through Friday.
- The client's PM is authorized to approve change orders up to \$15,000.
- The owner's drawings and maps reflect current, as-built conditions.
- The owner has obtained (or will be responsible to obtain) all necessary permits (list all required for the project), including building, wetlands, etc. Furthermore,

² From "Assumptions and Constraints in Project Management", by Fahad Usmani, at PMStudyCircle.com

the client will have obtained these permits by 1 April 2016, in order to start construction by 1 May 2016.

- The soil in the construction area has been tested by a Registered Professional Engineer with the specialty of geotechnical engineering. This engineer has deemed the soil to be suitable for the building as currently designed.
- Sufficient funding will be available throughout the project.
- The owner's representative will provide decisions within one business day.

Constraints, on the other hand, are “limitations imposed on the project, such as the limitation of cost, schedule, or resources, and you have to work within the boundaries restricted by these constraints. Constraints are out of your control and are imposed on you by your client, organization, regulatory agencies, etc. However, if the constraints are no longer applicable, that can benefit your project³”.

Some examples of constraints include:

- The project must be completed by 31 December 2017.
- Earth moving in specific project areas (itemize) is limited to March 31 through October 1 each year because of blue turtle migration at the site.

If your project is fairly straightforward, or if it's the type of work you do over and over, you can probably proceed directly to a risk register (to be discussed beginning in Section III (Identifying Risks)), building on it as you move through your RM process.

RM Strategy for the Project briefly explains how you plan to identify, analyze, prioritize, track, and control risks. We have devoted a section in this course to discuss each of these topics in depth. But in your RMP, you will show the guidelines and processes for tackling each of these items. If your organization has guidelines or mandated procedures, you can simply refer to those by name in this section of your RMP.

Risk Management Roles and Responsibilities defines who will be involved in managing risk on the project, and what they are expected to do. It is imperative that the PM emphasize that ALL project team members, including the client/owner, are responsible for risk management. Some PMs make the mistake of just copying and pasting RM roles and responsibilities from previous plans—or worse, they skip this. It is very important to involve the RM team in defining these roles and responsibilities, even if it means having them simply say, “Yes, the RM roles and responsibilities from Project A look suitable for this project, and I commit to the role specified for me as the lead structural engineer”.

³ Usmani, *Ibid.*

An example Risk Management Roles and Responsibilities matrix is shown in Table 1⁴.

Table 1: Project Risk Management Roles and Responsibilities (Example)

| Role ⁵ | Responsibilities |
|------------------------------|--|
| Project Manager | <ul style="list-style-type: none"> • Direct RM for the project • With team, identify risks and responses • Maintain risk register and update risks • Report risks (to client/owner/sponsor) • Include RM as an agenda item for status meetings • Monitor effectiveness of risk responses |
| Project Sponsor/Client/Owner | <ul style="list-style-type: none"> • Assist PM with RM requirements • Provide timely sign-offs |
| Team Member | <ul style="list-style-type: none"> • With PM, identify risks • Develop risk responses • Take ownership of assigned risks • Document risk response actions and report to PM • Communicate new and retired risks to PM |
| Task Managers | <ul style="list-style-type: none"> • Same as Team Member, but for risks applicable to their task(s) |

The section on **How to Identify Risks** lists the categories of risk to be evaluated. Some organizations require specific categories be addressed. It helps immensely if you and your risk identification team start by thinking of categories of risks, both threats and opportunities. Typical categories include:

- Schedule
- Scope
- Financial
- Design
- Environmental
- Safety
- Security

These threat categories can also be used to identify opportunities.

⁴ Loosely adapted from *CalTrans Project Risk Management Handbook: A Scalable Approach, Version 1 (June 2012)*.

⁵ There may be additional roles based on project complexity and/or organizational structure. Such additional roles may include Chief Engineer, Project Management Office (PMO) Director, Division Heads, Functional (Department) Managers, Project Risk Manager, etc. See *Ibid* (Appendix D, pages 44-46) for examples.

The section on **How to Analyze, Prioritize, and Respond to Risks** spells out the procedures for assigning Impact (I) and Probability (P), prioritizing the risks based on their scores (P x I), determining the risk response cutoff to prioritize risks, determining which risks to analyze further (based on the cutoff), and deciding what to do about each of the high-priority risks.

Some organizations or large projects make these aspects of risk planning relatively simple, such as defining the Impact and Probability of identified risks. They begin by giving definitions for assigning numerical values to P and I, as shown in Table 2⁶. Note that the table focuses on cost and schedule impacts, as well as both threats and opportunities. Note also that this table is from CalTrans, which has major projects. A schedule slippage of 1 month may not be considered a Low Impact on your project or in your organization. Note further that the bottom row gives Probability definitions for Very Low through Very High. This table ensures that, with respect to risks, your “Low” means the same as my “Low”; it takes some of the subjectivity out of the risk analysis process.

Table 2: Definitions of Impact and Probability Ratings

| Impact → | Very Low | Low | Moderate | High | Very High |
|--------------------------------|------------------------------|----------------------|------------------------|------------------------|-----------------------|
| Cost Impact of threat | Insignificant cost increase | <5% cost increase | 5-10% cost increase | 10-20% cost increase | >20% cost increase |
| Cost Impact of opportunity | Insignificant cost reduction | <1% cost reduction | 1-3% cost reduction | 3-5% cost reduction | >5% cost reduction |
| Schedule Impact of threat | Insignificant slippage | <1 month slippage | 1-3 months slippage | 3-6 months slippage | >6 months slippage |
| Schedule Impact of opportunity | Insignificant improvement | <1 month improvement | 1-2 months improvement | 2-3 months improvement | >3 months improvement |
| Probability → | 1-9% | 10-19% | 20-39% | 40-59% | 60-99% |

These definitions are then sorted into a simple matrix, often called a “Boston Square”, for guidance on sorting the risks numerically for prioritization. See Table 3⁷. The risk score (or risk rating) for each cell is calculated by P X I for each cell. The results are shown in the corresponding cell.

⁶ From CalTrans document (*Ibid.*), page 20.

⁷ From CalTrans document (*Ibid.*), page 21.

Table 3: Example Risk Categorization Matrix (Boston Square) for Threats

| | | | | | | |
|---------------------------|--------------------|---------------------------|------------------|-----------------------|-------------------|-----------------------------|
| Probability Rating | 5-Very High | 5 | 10 | 20 | 40 | 80 |
| | 4-High | 4 | 8 | 16 | 32 | 64 |
| | 3-Moderate | 3 | 6 | 12 | 24 | 48 |
| | 2-Low | 2 | 4 | 8 | 16 | 32 |
| | 1-Very Low | 1 | 2 | 4 | 8 | 16 |
| | | 1 Very Low | 2 Low | 4 Moderate | 8 High | 16 Very High |
| Impact Rating | | | | | | |

Note that, in this example, the Impact ratings have been assigned numbers, and that the values are non-linear. In some organizations, a scale of 1-10 is used for both Impact and Probability. You can decide for your project (or your organization may have guidelines for) what values you will assign to the impact scale. Using the risk scores (P X I) allows you to prioritize the project risks. You can use the scores to determine the cutoff point for further risk analysis and response development. In this example, the PM and team could choose a cutoff point of 16 (all of the red scores), or they could choose to address both red and yellow (i.e., 8). You can construct a similar matrix for the opportunities, as shown in Table 4. As with the threats, the team would most likely choose to focus on the red items.

Table 4: Example Risk Categorization Matrix for Opportunities

| | | | | | | |
|---------------------------|--------------------|---------------------------|------------------|-----------------------|-------------------|-----------------------------|
| Probability Rating | 5-Very High | 5 | 10 | 20 | 40 | 80 |
| | 4-High | 4 | 8 | 16 | 32 | 64 |
| | 3-Moderate | 3 | 6 | 12 | 24 | 48 |
| | 2-Low | 2 | 4 | 8 | 16 | 32 |
| | 1-Very Low | 1 | 2 | 4 | 8 | 16 |
| | | 1 Very Low | 2 Low | 4 Moderate | 8 High | 16 Very High |
| Impact Rating | | | | | | |

This section of the RMP may also spell out the fields for the Risk Register, which is a table listing the risks, their scores, and other information the team needs in order to track risks throughout the project. The risk register can have just a few fields, such as risk, impact, probability, risk score (P x I), risk response, revised risk score (based on the risk response), and person accountable (there needs to be someone accountable for each risk, so that the response can be implemented at the appropriate time). On more

complex projects, some have found it helpful to assign a risk number, identify the project phase (Design, Construction, etc.), dependency on other risks, and so on. The risk register is a dynamic document which will be updated throughout the project.

The section on **How to Track, Control, and Close Risks** gives guidance on how to see if the identified risks have indeed occurred and whether the response plans for each were implemented.

The US Department of Defense has an organization called the Defense Acquisition University (DAU). It is an outstanding resource for risk management and other aspects of project management and contract management. The website is www.dau.mil. Their *Risk Management Guide for DOD Acquisition* is particularly helpful, as is the DAU Earned Value “gold card”. (Earned Value Management is discussed in Section IX (Handling Risk During Project Execution.))

Some Helpful Questions to Get at the Scope and Other Aspects of RM

Risk management begins at the beginning of the project. Here are some questions you can ask your client, owner, or manager to help understand the project and begin to bring risks into focus. You can also use the answers to these questions to bring your team up to speed at the beginning of the project or at the kick-off meeting (the most important meeting of the project). You can also use these questions as a checklist while analyzing the Request for Proposal (RFP), to make sure you have all the information you need before getting too far into the proposal.

1. Why does the owner/client need to do this project? (e.g., new regulations, expand capacity, market demand, etc.)
2. What’s the end product or final deliverable? (e.g., plans and specifications, completed manufacturing facility, etc.)
3. What’s in scope? (e.g., plans and specifications ready to put out to bid) What’s out of scope? (e.g., bid assistance is not included in this scope). It’s very important to be clear about what you are and are not doing, to avoid misunderstanding AND risk.
4. Interim deliverables? (e.g., 30, 60, and 90% reviews) Interim approvals? (e.g., regulatory agency needs to review the plans in order to issue permits)
5. How will the owner/client judge the project to be “done”? In other words, what will make the final deliverable acceptable to the owner/client?
6. What kind of information does the client/owner need during the project? How often? How does it need to be delivered? Who are the other stakeholders for this project?
7. What is the desired delivery date? Is there any flexibility?

8. What are the interdependencies for the project? (i.e., what other projects does the client/owner have on his plate?) Are there any other projects that might impact this one? (e.g., construction at an adjacent property)
9. What is the client's/owner's budget for the project? Is there any flexibility?
10. Does the client/owner know of any obstacles? (e.g., community groups protesting this construction)
11. What is the risk of NOT doing the project?
12. Any constraints? (e.g., the owner/client may not be able to give 24/7 access to the work site)
13. What keeps the client/owner up at night?

III. Identifying Risks

Introduction

In order to manage risks, we first have to know what they are—or actually what they might be, because risk is always in the future. Risk identification is iterative; it's something we do throughout the project lifecycle. We begin to think about risks when planning the project, but planning is just our best guess as to how the project will go. Also, as noted in Section I (Introduction to Project Risk Management), there are often “unknown unknowns” that are unpredictable and can pop up at any time during the project.

Although many projects are small enough or routine enough that a project manager can manage risk in his/her head, it's best not to skip risk management planning. Regardless of the size of the project, it's also best practice to seek help from others—even those who won't be involved in the project—to identify risks. You can call a meeting or send out an email survey to ask people to think of potential project risks. You should first brief your risk identification team on the scope of the project.

Methods for Identifying Risks

The most widely used risk-identification methods are:

- Brainstorming
- Interviewing
- Referring to previous projects, particularly their risk registers and lessons learned

The project team can begin by brainstorming potential risks, based on their experience, and looking at risk registers from previous, similar projects. If the project is complex and/or high-visibility, some additional ways to identify risks include: interviewing individuals outside the project team to the risk identification meeting; and inviting individuals outside the project team, including the “curmudgeons” who might otherwise have said, “I could have told you that would happen”.

Threats & Opportunities

When most of us think of project risks, we think of the negative things that might go wrong on the project. Threats are the conditions or events that, if they do occur, will negatively impact the objectives of the project (e.g., profitability, schedule, etc.) Opportunities, on the other hand, are conditions that have a positive impact on the project objectives. In Section V (Developing Responses to Each Risk) we will discuss the options for protecting the project objectives from threats and encouraging the opportunities.

Risk Categories

As mentioned in Section II (Planning Your Risk Management Approach), it helps to think of several categories where risks might occur. Typical categories include:

- Schedule
- Scope
- Financial
- Design
- Environmental
- Safety
- Security

Large organizations like the US Department of Energy⁸ (DOE) have identified additional risk categories such as:

- Site risks
- Contract/specification/statement of work risks
- Staffing risks (federal and contractor)
- Ineffective governmental oversight/contract administration risks

It helps when setting up the risk register by listing the appropriate categories. Then, as you brainstorm risks, you can slot them in under the appropriate category. See Table 5 for a simple example from a construction project (“Project A”). Notice that the table also includes associated triggers, which are the underlying causes of the risk. As you work through the remaining planning steps of Risk Management, you will be adding columns to the risk register. For a list of possible column headings for risk registers, see Appendix 1

When identifying each risk, it is important to be as specific as possible. For example, instead of saying “safety” (which is a category), the risk should be “excavation collapses”. Also, it is VERY important to stay focused on the risk and not jump to the risk response. For example, if the project is an outdoor concert, the team may identify “rain delays concert”, but someone else may say, “We don’t have to worry about writing that down, because we’ll have a covered stage”. “Rain delays concert” should be listed as a risk, and then when the team gets to figuring out risk responses, covering the stage will be one of them.

⁸ From *Department of Energy Risk Management Guide, DOE G 413.3.3-7A (1-12-11)*

Table 5: Starting the Risk Register (Identified Threats and Associated Triggers)

| Risk | Trigger | Project Phase |
|----------------------------|---------------------------------|----------------------|
| Cost/Budget | | |
| Material price fluctuation | Demand from other markets | Procurement |
| Late payments | Client financial situation | Design, Construction |
| Schedule | | |
| Material delays | Limited sources | Construction |
| Weather delays | Extreme weather | Construction |
| Late decisions | Client decision-making process | Design, Construction |
| Scope | | |
| Design changes | Unforeseen conditions | Design, Construction |
| Environmental | | |
| Leaking tanks encountered | Unforeseen conditions | Construction |
| New permit requirements | New regulations | Design, Construction |
| Safety | | |
| Excavation collapse | Shoring procedures not followed | Construction |
| Fall from structure | Safety procedures not followed | Construction |

An example risk register for opportunities is shown in Table 6. Some PMs like to keep separate risk registers for threats and opportunities, while others combine them into one risk register, but it's probably a good idea to separate threats and opportunities. This keeps opportunities top-of-mind, because if they are woven in with the threats, they tend to get overlooked. (Most people focus on the threats.)

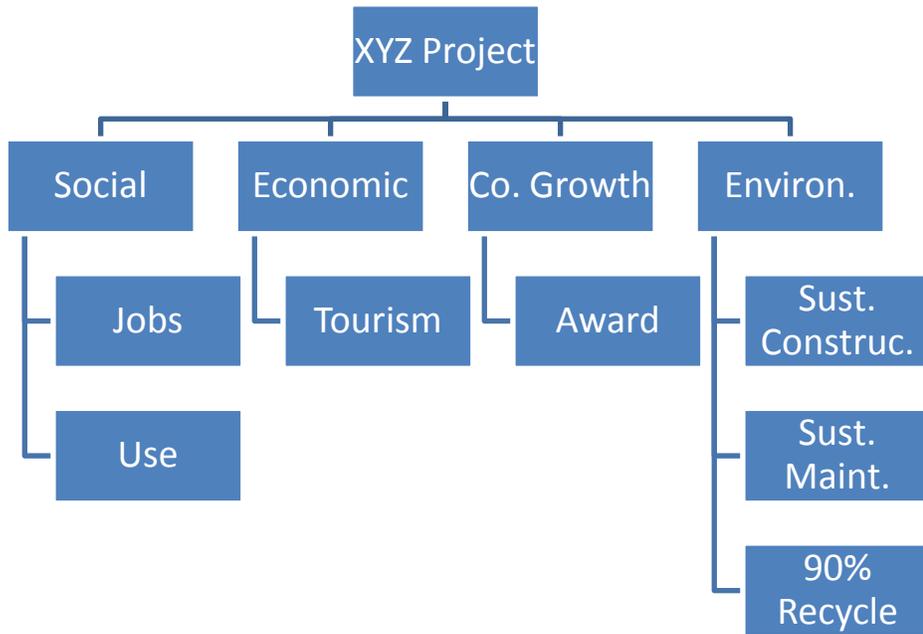
Table 6: Risk Register for Opportunities

| Risk | Trigger | Project Phase |
|---------------------------------------|------------------------------------|-------------------------|
| Social | | |
| Construction jobs for local community | Skills available locally | Construction, Operation |
| Community use of facility | Communications | Operation |
| Economic | | |
| Promote tourism | Other amenities to support tourism | Operation |
| Company Growth | | |
| Award-winning design | Owner support | Design |
| Environmental | | |
| Sustainable construction materials | Owner support | Construction |
| Design allows sustainable maintenance | Owner support | Operation |
| 90% recycling of construction waste | Owner support | Construction |

Risk Breakdown Structure (RBS)

A risk breakdown structure (RBS) shows the relationship of each risk to its category. There are two typical formats: outline and graphic. In the outline, the categories are shown as the main topics, with the associated risks indented below. Figure 1 is an example RBS (in graphic format) showing the same information as in Table 6. The graphic format looks like an organization chart showing risk categories along the top, and associated risks down each branch of the “tree”. Some project teams prefer to use the table style during risk identification, while others prefer the graphic format. The main benefit of using the graphic format is that, if your project is complex, high-visibility, or high-risk, you and your team can identify risks quickly and interactively if you gather around a flip chart or banner paper, write each category on a sticky note, put it on the paper, and then brainstorm risks, write each on a sticky note, and then post each on the paper under the appropriate category. It’s much more fun than emailing around the first column of the risk register.

Figure 1: Example Risk Breakdown Structure for Opportunities Shown in Table 6



IV. Quantifying and Prioritizing Risks

The Process

The next step in risk planning is to calculate a risk score for each identified risk. You will use the risk scores to prioritize the risks, and then focus on taking care of your higher priority risks. Not all risks are equal. You want to allocate your resources wisely.

In Section II (Planning Your Risk Management Approach), we discussed the risk categorization matrix or Boston Square. This allows us to put the risks into “buckets” based on our assessment of the risk’s impact on the project objectives and the likelihood the risk will occur. Now is the time to put the risk categorization matrix to work. If you work with others to quantify and prioritize risks, you will find that quantifying Impact and Probability can be subjective; however, the risk matrix brings objectivity to the process.

We need to determine:

Impact—i.e., how badly will the risk affect the project objectives? We can use Low/Medium/High, or we can assign numbers (scale of 1-5 or 1-10, or actual money expected to be lost, etc.). You can also use a nonlinear impact scale such as 1, 2, 4, 8, 16 to show more spread between scores. Use the Impact scoring system you laid out in your Risk Management Plan.

Probability—i.e., how likely is the risk to occur? We can use data from past projects or our professional judgment. We can express probability on a scale of 1-5 or 1-10, or 0.1-1.0, or percentages. Again, utilize the guidelines from your Risk Management Plan.

A quick way to go through the risk process with a team is:

1. Identify risks, writing each on a separate sticky note. Post each on banner paper or a flip chart.
2. Quantify each, starting with Impact. Record that score on the lower left of the sticky note. If the impact of a particular risk is zero, then we don’t need to consider it further.
3. Quantify the probability of each risk. Record that score on the lower right of the sticky note. If the probability of a particular risk is zero, then we don’t need to consider it further.
4. Multiply Impact x Probability, which is the Risk Score. Write the score large in the middle of the sticky note.
5. Prioritize based on Risk Score, from highest to lowest, rearranging the sticky notes.

6. Stand back and look at the Risk Scores. Determine a cutoff, by eyeballing, 80-20 rule, median value, or another means described in the Risk Management Plan. You will develop risk responses for any risks above the cutoff. Those below the cutoff will be dealt with as they arise, but we will not develop a response for them. We will establish contingency to help cover them. Be careful: If a risk has an Impact of 10 (on a scale of 1-10) but a Probability of 1 (on a scale of 1-10), you probably should still develop responses. For example, if you live near a nuclear power plant, and they identified “meltdown” as a risk with an Impact of 10 but a probability of 1, let’s hope they didn’t rip that sticky off the flip chart because it was below the cutoff. You will add the risks that are below the cutoff to the risk register so that you can keep an eye on them throughout the project.

As mentioned before, the risk register is a dynamic document that you will add to throughout the risk management process. You can now add columns for the risk scores. Note that—compared with Tables 5 and 6—Tables 7 and 8 have three additional columns in the risk register: Impact, Probability, and Risk Score.

Table 7: Risk Register with Scores (Threats)

| Risk | Impact | Probability | Risk Score | Trigger | Project Phase |
|----------------------------|--------|-------------|------------|---------------------------------|----------------------|
| Cost/Budget | | | | | |
| Material price fluctuation | 3 | 3 | 9 | Demand from other markets | Procurement |
| Late payments | 3 | 2 | 6 | Client financial situation | Design, Construction |
| Schedule | | | | | |
| Material delays | 4 | 2 | 8 | Limited sources | Construction |
| Weather delays | 4 | 1 | 4 | Extreme weather | Construction |
| Late decisions | 3 | 2 | 6 | Client decision-making process | Design, Construction |
| Scope | | | | | |
| Design changes | 4 | 2 | 8 | Unforeseen conditions | Design, Construction |
| Environmental | | | | | |
| Leaking tanks encountered | 5 | 2 | 10 | Unforeseen conditions | Construction |
| New permit requirements | 4 | 2 | 8 | New regulations | Design, Construction |
| Safety | | | | | |
| Excavation collapse | 5 | 1 | 5 | Shoring procedures not followed | Construction |
| Fall from structure | 5 | 5 | 25 | Safety procedures not followed | Construction |

Table 8: Risk Register with Scores (Opportunities)

| Risk | Impact | Probability | Risk Score | Trigger | Project Phase |
|---------------------------------------|--------|-------------|------------|------------------------------------|-------------------------|
| Social | | | | | |
| Construction jobs for local community | 9 | 5 | 45 | Skills available locally | Construction, Operation |
| Community use of facility | 7 | 5 | 35 | Communications | Operation |
| Economic | | | | | |
| Promote tourism | 8 | 3 | 24 | Other amenities to support tourism | Operation |
| Company Growth | | | | | |
| Award-winning design | 7 | 8 | 56 | Owner support | Design |
| Environmental | | | | | |
| Sustainable construction materials | 5 | 7 | 35 | Owner support | Construction |
| Design allows sustainable maintenance | 5 | 9 | 45 | Owner support | Operation |
| 90% recycling of construction waste | 7 | 5 | 35 | Owner support | Construction |

Methods for Further Quantifying Risks

On many complex projects, particularly large construction projects, the contractor will want to quantify the probability that he will meet the owner’s schedule or stay within the budget. Many task estimates (both cost and duration) are based on a single value, which implies that the probability of staying in schedule or budget is 100%. If we take additional steps, we can take risk into account and calculate the probability. This will help us decide the amount of contingency (time and cost) needed. It can also help us decide if we should even bid on the project.

Critical Path Method (CPM) vs. Program Evaluation and Review Technique (PERT)

The critical path method (CPM) was developed in 1957 by DuPont and Remington Rand to build manufacturing facilities more quickly, so that they could generate revenue as soon as possible. CPM assumes that durations are known with certainty, and therefore, a single duration estimate is assigned to each project task. Given the dependencies between tasks, in addition to their durations, CPM calculates the minimum total project duration. It also indicates the “critical path”, which is the path with minimum float (or

slack). At the beginning of the project, the float on the critical path is (usually) zero; however, during execution, some tasks may take longer than expected to complete, causing the float on the critical path to become negative.

Program Evaluation and Review Technique (PERT) was developed in 1958 by the US Navy and Booz, Allen & Hamilton. Because of PERT, the Polaris submarine came in ahead of schedule. PERT employs three duration estimates for each task: optimistic (t_o), most likely (t_m), and pessimistic (t_p). Unlike CPM, PERT takes risk into account by using t_o , t_m , and t_p to estimate the probability of completing the project by a specific date.

The most commonly used PERT equation is:

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

Where t_e = expected time of task completion

t_o = optimistic time for task completion

t_p = pessimistic time for task completion

t_m = most likely time for task completion

Total Project Completion Time, or T , is calculated by adding the expected time (t_e) values of those tasks along the critical path.

Here is a simple PERT example:

Tom commutes to his office in Chicago from his home in the suburbs. If he's lucky (or if he drives to his office at 4 a.m.), it will take him a half-hour. Normally it takes him about an hour, but if there is an accident or bad weather, it could take two hours. Using the PERT equation above, we can calculate his expected time (t_e):

$$t_e = (t_o + 4t_m + t_p)/6$$

$$t_e = (30 + 4(60) + 120)/6 = 65 \text{ minutes}$$

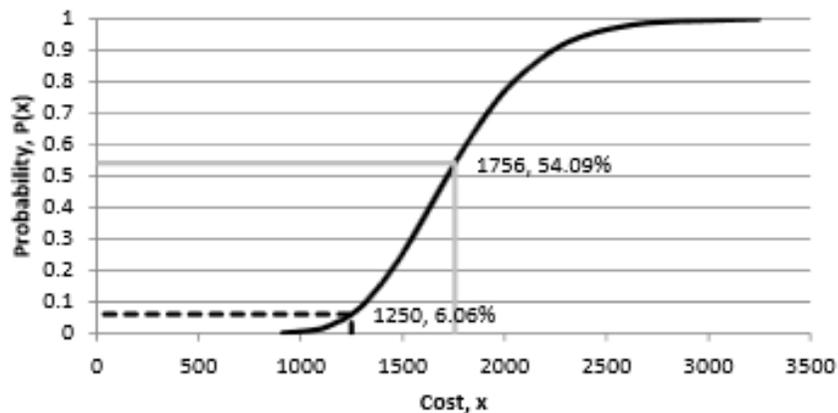
That doesn't seem like much additional time. That's because the equation assumes a normal distribution of probabilities, thereby weighting the most likely time (t_m) by 4. You could choose to assume that the probability distributions were beta or triangular, which would give slightly different t_e results from the normal distribution formula. You can use PERT to estimate the probability of completing a project by a certain date. PERT can also be used for cost.

Monte Carlo Analysis

Monte Carlo analysis is a risk quantification technique that uses a mathematical simulation to forecast the probability of completing the project on-time or within

budget. Without getting too deep into the details, the Monte Carlo analysis takes a range estimate (worst case and best case for either cost or duration) for each project task, and then generates a random number within that range for each of the project tasks. The software does this hundreds, even thousands, of times. The output is a cumulative curve showing the probability of completion by a certain date or within a certain cost. It is a good idea for the contractor to know (or guess), prior to running the Monte Carlo analysis, the owner's target probability—i.e., the likelihood of meeting a target date or cost such that he would consider the project a success. That way, the contractor can determine the contingency required to meet the owner's target. As shown in Figure ___⁹, if the owner has a budget of \$1250 in mind, and wants 80% probability of meeting that target, a budget of approximately \$2000 is needed. This represents a contingency of nearly 60% [$(\$2000-1250) / \1250].

Figure 2: Monte Carlo Results



Monte Carlo analysis takes the uncertainty of cost or duration estimates into account. If just a single duration or cost estimate were applied to each task, the total cost estimate or project completion date would be misleading, because it implies that the duration or cost estimates are exact and predictable. The results are only as good as your estimates. Monte Carlo represents probabilities, not certainty.

⁹ From NASA, *Analytic Method for Probabilistic Cost and Schedule Risk Analysis, Final Report*, 5 April 2013.

V. Developing Responses to Each Risk

Introduction

Now that we know our highest priority risks, it is time to develop a risk response or “Plan B” for each. The goal is to minimize our exposure (or maximize our opportunity) for the least cost. We follow the methods listed in the Risk Management Plan. If we put the risks into “High”, “Medium”, and “Low” buckets, we will focus on the high and medium risks. If the Risk Management Plan states that we will use numeric scales (e.g., 1-10), we will use the cutoff value to determine which risks we will develop risk responses for.

Risk Response Strategies for Threats

The risk response strategies for threats are:

Avoid should be the first strategy considered. Avoidance may involve changing the scope or schedule, removing the cause of the risk, or executing the project in a different way. Not all risks can be avoided or avoiding may be too expensive.

Transfer means that we engage a third party to take on the responsibility (usually financial) for the risk. It does not mean the risk vanishes. Insurance and bonds (see Section VIII) are the most common form of Transfer. Just like car insurance, project-related insurance is paid for via a premium and is an additional cost to the project. Project-related insurance may include liability, errors & omissions, property damage, product liability (usually for equipment suppliers such as elevators), and latent defects (for repairing the built product due to a defect in materials or construction).

Mitigate means that we take actions to reduce either the probability, impact, or both to an acceptable level. The goal is to lower the risk score to below the cutoff or to move the risk to the Low/Low bucket, if possible.

Accept means that developing a response to the risk is impossible, or you have decided that you will deal with the risk as it occurs.

Risk Response Strategies for Opportunities

The risk response strategies for opportunities are:

Exploit means to do whatever possible to increase the probability that the opportunity will come to fruition. Exploit is an aggressive strategy. We target risks in the High/High bucket. An example is to use a construction technique that will reduce the schedule by 15%.

Share means that you will use a third-party resource to help you realize the opportunity. Examples include a joint venture or partnership with a firm that has complementary

skills or equipment to complete the project more quickly or cost-effectively. You and the third party would then share in the profits, as detailed in your contract.

Enhance involves increasing the probability and/or impact of an opportunity. It involves identifying the root cause of a positive risk so you can have more influence on it. Examples are to provide training in a project-specific skill, or adding resources to tasks on the critical path.

Accept, on the opportunity side, means that you are aware of the opportunity but not actively chasing it. If it occurs, you will just let it fall into your lap.

Keep in mind that the risk response for each high-priority risk does not need to be a single strategy. For example, if you are heading the project to hold a reunion concert for a well-known band from the 1970s, and you identified one of the risks as “band member too ill to perform”, you could use a combination of Transfer (e.g., buy insurance) and Mitigate (e.g., contract with a nursing service to reduce the probability of the band member getting ill).

As you develop responses to threats and opportunities, you will add this information to the risk register. At this point, you will need to add at least the following fields:

- Risk response: What strategy will be used (Avoid, Transfer, Mitigate, Accept (or combination) for threats; Exploit, Share, Enhance, Accept (or combination) for opportunities)?
- Revised probability as a result of the response strategy.
- Revised impact as a result of the response strategy.
- Revised risk score as a result of the response strategy ($P \times I$).
- Risk owner: This is probably the most important field to add. Every risk must have an owner—someone who will keep an eye out on the horizon to watch for signs that the risk will happen AND take responsibility for putting the risk response into effect.

Some teams also add the following fields, especially on large, complex projects:

- Unique identifier: For example, using the categories listed in Section III (Identifying Risks), risks associated with Schedule might be numbered 1.1, 1.2, 1.3, etc., while Scope-related risks might be numbered 2.1, 2.2, 2.3, etc.
- Dependency: What other risks are dependent on this risk happening?

Once you have developed a response for each risk, whether threat or opportunity, the next step is to review the Boston Square developed for the Risk Management Plan (RMP). An example for “Project A” is shown in Figure 3.

Figure 3: “Project A” Boston Square¹⁰ (as Defined in Risk Management Plan)

| | | | | | | | |
|-------------------|-----------|---|---------------|-----|--------|------|----------|
| Likelihood | Very High | 5 | 9 | 10 | 21 | 24 | 25 |
| | High | 4 | 7 | 8 | 16 | 20 | 22 |
| | Medium | 3 | 5 | 6 | 12 | 16 | 18 |
| | Low | 2 | 3 | 4 | 8 | 13 | 14 |
| | VeryLow | 1 | 1 | 2 | 4 | 8 | 10 |
| | | | A | B | C | D | E |
| | | | Negligible | Low | Medium | High | VeryHigh |
| | | | Impact | | | | |

When you assigned Probability (P) and Impact (I) to each risk based on the definitions in the Boston Square, you recorded P and I, as well as the risk score (P x I) in the risk register. You also prioritized the risks and determined the cutoff. Now that you have developed risk management strategies for each of the high-priority risks (i.e., above the cutoff threshold), you calculate the revised risk score (revised P x revised I). Table 9 shows the (partial) updated risk register for “Project A”. (We saw the beginnings of this table in Section IV (Developing Responses to Each Risk)). The version in Table 9 has deleted the “trigger” and “project phase” fields, and added “revised P”, “revised I”, and “revised risk score”.

¹⁰ From Neil Goldman and Siamack Massoum Zadeh, final presentation in Construction Project Risk Management (MCM 606), as part of the requirements for a Master of Construction Management degree, Philadelphia University, April 2014.

Table 9: Updated Risk Register for Project A (Partial)

| Risk | I | P | Risk Score | Risk Response | Revised I | Revised P | Revised Risk Score | Owner |
|----------------------------|---|---|------------|---|-----------|-----------|--------------------|----------------|
| Cost/Budget | | | | | | | | |
| Material price fluctuation | 3 | 3 | 9 | Avoid (lock in price now) | 3 | 2 | 6 | PM |
| Late payments | 3 | 2 | 6 | Avoid (50% at start) | 3 | 1 | 3 | PM |
| Schedule | | | | | | | | |
| Material delays | 4 | 2 | 8 | Mitigate (find alternate suppliers close to the site) | 2 | 1 | 2 | CM |
| Weather delays | 4 | 1 | 4 | Transfer (insurance) | 2 | 1 | 2 | PM |
| Late decisions | 3 | 2 | 6 | Mitigate (constant communication with owner) | 3 | 1 | 3 | PM |
| Scope | | | | | | | | |
| Design changes | 4 | 2 | 8 | Mitigate (30, 50, 65, 75, 90% reviews) | 3 | 1 | 3 | Lead Eng |
| Environmental | | | | | | | | |
| Leaking tanks encountered | 5 | 2 | 10 | Mitigate (perform GPR prior to work) | 4 | 1 | 4 | Enviro Lead |
| New permit requirements | 4 | 2 | 9 | Mitigate (meet with agencies early) | 4 | 1 | 4 | Enviro Lead |
| Safety | | | | | | | | |
| Excavation collapse | 5 | 2 | 10 | Mitigate (shoring) | 5 | 1 | 5 | Safety Officer |
| Fall from structure | 5 | 5 | 25 | Mitigate (protective gear, daily safety training) | 5 | 1 | 5 | Safety Officer |

Table 10 shows the total of all the risk scores for Project A before response. Table 11 shows the total of all the revised risk scores for Project A, expected as a result of the risk responses.

Table 10: Total Project A Risk Scores¹¹ (Before Response)

| | | | | | | | |
|-------------------|-----------|---|---------------|----------|----------|----------|----------|
| Likelihood | Very High | 5 | 9 | 10 | 0 | 0 | 0 |
| | High | 4 | 7 | 0 | 96 | 20 | 22 |
| | Medium | 3 | 10 | 6 | 12 | 32 | 36 |
| | Low | 2 | 0 | 4 | 0 | 26 | 28 |
| | Very Low | 1 | 0 | 2 | 0 | 24 | 20 |
| | | | A | B | C | D | E |
| | | | Negligible | Minor | Moderate | Major | Sever |
| | | | Impact | | | | |

| | | | | |
|--|-----------------|--|---------------|-------------|
| | Extreme | | Extreme Risk | =138 |
| | High | | High Risk | =197 |
| | Moderate | | Moderate Risk | =13 |
| | Low | | Low Risk | =16 |
| | | | TOTAL | =364 |

¹¹ Goldman and Zadeh, *Ibid.*

Table 11: Total Project A Risk Scores (After Response)¹²

| | | | | | | | |
|-------------------|-----------|---|---------------|-------|----------|-------|-------|
| Likelihood | Very High | 5 | 0 | 0 | 0 | 0 | 0 |
| | High | 4 | 0 | 0 | 0 | 0 | 0 |
| | Medium | 3 | 15 | 18 | 12 | 0 | 0 |
| | Low | 2 | 9 | 28 | 32 | 26 | 0 |
| | Very Low | 1 | 2 | 2 | 16 | 0 | 0 |
| | | | A | B | C | D | E |
| | | | Negligible | Minor | Moderate | Major | Sever |
| | | | Impact | | | | |

| | | | | |
|--|-----------------|--|---------------|-------------|
| | Extreme | | Extreme Risk | =14 |
| | High | | High Risk | =38 |
| | Moderate | | Moderate Risk | =66 |
| | Low | | Low Risk | =52 |
| | | | TOTAL | =170 |

The total risk score before risk responses were developed is 364; after response development, 170. This is an expected 53% reduction in risk scores due to the risk management strategies we have planned. Will all of the responses work as planned? Not necessarily. Even if you put a risk response into effect, there may still be some **residual risk**, which is a risk that remains after implementation of the risk management strategy. Residual risk is also called post-mitigated risk. Just because the risk remains does not mean that the risk management strategy was not effective. It just means that the strategy did not completely prevent a risk from remaining. We consider as “accepted” those residual risks for which no risk management strategies can be planned. The team, owner/client, management, and other appropriate stakeholders need to know about residual risks.

Business Risks vs. Insurable Risks

Business risks can be either threats or opportunities—in other words, the risk can cause either a gain or a loss (in profit or time). For example, implementing a construction project during a period of inflation can either cost us or save us money, depending on contract wording, pre-ordering, etc. If steel is readily available, it could be at a lower cost than planned; on the other hand, if the cost of steel has risen and we hadn’t locked in the price, our profitability could decrease.

¹² Goldman and Zadeh, *Ibid.*

Insurable risks, however, have potential only for losses and can be insured against (hence the name). Examples include design errors (which can be covered by errors and omissions insurance) and property damage (which can be covered by fire insurance, auto insurance, etc.)

You can also prepare detailed information about each risk, as shown in Table 12. It is a good idea to take the time to do this for projects with a very tight timeline and/or budget.

Table 12: Example Detailed Risk Description

| Risk Title | | Risk Owner | | | |
|---|------------|---------------------------|-----------|-----------|---------------|
| 3.2 Adverse Environmental Conditions Encountered | | Environmental Design Team | | | |
| Risk Summary | | | | | |
| The construction site is on the Steel River. It is a former industrial site. An environmental records search has been completed as a requirement for property transfer. It indicated that, at the portion of the site where the construction will take place, there were no operations using hazardous materials. However, given the site history, when excavation begins, contaminated soils, underground storage tanks, drums, etc., may be encountered. | | | | | |
| Risk Response | | | | | |
| An expedited environmental site investigation, including sampling and analysis of soil and water, as well as ground penetrating radar (GPR) to search for underground tanks, will be undertaken. We will conduct the GPR survey first, and then sample in areas of concern. Depending on the outcome of the investigation, the construction schedule could be significantly impacted. If that is the case, we will revise the construction means and methods, using (for example) elements fabricated off-site while remediation takes place. | | | | | |
| Original P | Original I | Original Score | Revised P | Revised I | Revised Score |
| 5 | 7 | 35 | 2 | 2 | 4 |

VI. Methods for Setting Contingency

As stated in Section I (Introduction), projects are inherently risky. Contingency is the amount of money added to the estimate to deal with the uncertainties inherent in the estimating process (whether cost or schedule). Contingency is required because estimating is not an exact science. The duration or number of man-hours and expenses associated with a task are all best estimates until the work is complete. Contingency is the reserve we allocate to the project schedule and/or budget to cover project risks. “Uncertainty can be defined as a lack of total conviction about present or future project outcomes due to a limited amount of project information.”¹³

Burroughs and Juntima¹⁴ state that “contingency is defined as the amount of money that experience has demonstrated must be added to the base estimate to provide for uncertainties related to (a) project definition and (b) technological uncertainty. Contingency is money that is expected to be spent. The contingency account is not intended to provide for changes in the defined scope of a project or for unforeseeable circumstances beyond management’s control (e.g., 100-year storms or strikes against equipment vendors). Contingency should not be viewed as a reserve or slush fund that the project team cannot spend without upper management approval. Likewise, management should not have the expectation that, if a project team does its job well, contingency will not be spent. A competitive approach is to set contingency at an amount that achieves a 50 percent probability of overrun. At a 50 percent probability, the project system, on average, is expected to spend its entire contingency.”

We cannot estimate contingency exactly (in fact, that’s an oxymoron), because we can’t predict the future; however, approaching contingency-setting in a systematic way can have several benefits: It can help us estimate future projects more accurately, and it can help keep costs on this project within a specific margin.

Project managers prepare cost estimates for two reasons:

1. To control costs during the project. Planning is the only way to track a project. Planning is simply comparing current status with the planned performance (cost, schedule, etc.). Without a plan, we cannot track or control a project.
2. To inform stakeholders. For a public sector project, cost estimates and negotiated costs are often shared with the public. For private sector projects, the client sees the estimated costs, as well as the expended costs.

¹³ *Sliding Scale Contingencies for the Highway Construction Project Development Process*. Master of Science thesis by Adeniyio Olumide, Jr. Texas A&M University, December 2009.

¹⁴ “Exploring Techniques for Contingency Setting”, by Scott Burroughs and Gob Juntima, *2004 AACE International Transactions*.

Risks and uncertainty are higher in the early stages of any project, because the scope may not be clearly defined. This may be especially true of large public sector projects such as highway construction, wastewater treatment systems, or transit. Project development (i.e., very preliminary planning for future needs) for these large, complex projects may begin 10-20 years prior to letting. Agencies and owners must make educated guesses about the need for and cost of these projects a decade or two in the future. Contingency at this point in a project may be $\pm 30\%$ or even higher. As scope clarity and direction increase during design and construction, the contingency usually narrows to $\pm 15\text{-}20\%$ and $\pm 5\text{-}10\%$, respectively.

The most commonly applied contingency-setting methods are:

- Perform a quantitative risk analysis
- Apply a predetermined percentage (typically an organizational guideline— e.g., Washington State Department of Transportation’s risk management policy states that Engineers’ Estimates must use a 4% contingency)
- Gray hair (recommendations from people with experience on similar projects)

Quantitative Risk Analysis

The most common form of quantitative risk analysis is the Monte Carlo simulation, discussed in Section IV (Quantifying and Prioritizing Risks). This technique allows estimators to evaluate the risk of individual project cost or schedule elements in a disciplined way. The main advantage is that it introduces probability to the game. It allows confidence levels to be considered. Monte Carlo and other quantitative risk analysis techniques are more time-consuming and complex than other contingency-setting methods and are, therefore, usually used only on very large projects.

Predetermined Percentage

Predetermined percentages are often mandated by the organization. This method gives consistency to the process and is also very easy to use; however, Burroughs and Juntima have found that this method tends to underestimate contingency on complex and/or poorly defined projects.

Gray Hair

Experts, working as a team, assign a level of contingency that their experience tells them is appropriate for the project. This method tends to be more accurate than the predetermined percentage, because the experts consider competitiveness of the bid. If experts leave or retire, the knowledge is lost to the organization.

Whether you work for a public sector entity with large, complex projects with long planning horizons, or you work for a design/consulting firm, you have (or would like to create) an archive for planned vs. actual project costs, so that your estimates can

be more accurate on future projects. Private sector firms want to be more and more competitive, and public sector entities want to show the public that they are good stewards of taxpayers' money.

The Project Management Institute (PMI) identifies two types of contingency: contingency reserves and management reserves. Contingency reserves are “allowances for unplanned but potentially required changes that can result from realized risks identified in the risk register. Management reserves are budgets reserved for unplanned changes to project scope and cost. The project manager (PM) may be required to obtain approval before obligating or spending management reserve. Management reserves are not a part of the project cost baseline, but may be included in the total budget for the project. They are not included as a part of the earned value measurement (EVM) calculations”¹⁵. Neither contingency reserve nor management reserve is a source of funds to cover scope changes.

¹⁵ *A Guide to the Project Management Body of Knowledge (PMBOK®), Fourth Edition, 2008. Page 177.*

VII. Impact of Contract Clauses on Project Risk

What Is a Contract?

According to dictionary.com, a contract is “an agreement between two or more parties for the doing or not doing of something specified”. Merriam-Webster.com defines it as “a binding agreement between two or more persons or parties”. Among other definitions on that site, a contract is “an order or arrangement for a hired assassin to kill someone”.

What Makes a Contract a Contract?

This is important to understand. For a contract to be legal and binding, it must meet the following requirements. If any of these elements is missing, there is no contract.

- **Mutual agreement** – Both parties must be equally bound by the contract and must each provide something of value in exchange for the promise. The contract must declare the service or good that will be provided in return for some desired promise given by the buyer. The offer must be communicated so that the accepting party can understand it and accept it or reject the offer.
- **Consideration** – Money or other payment (e.g., Neighbor A agrees to babysit Neighbor B’s kids in exchange for Neighbor B going grocery shopping for Neighbor A).
- **Contractual Capacity** – Both parties must be legally capable of playing the intended role in the agreement, be mentally sound and fully knowledgeable of the contract circumstances. For example, in many design firms, only officers of the company may sign proposals on behalf of the company.
- **Legal Purpose** – Does not contravene existing state and federal laws. Contracts are written and agreed to under the laws of one state specified in the contract. Provisions of the contract that are illegal under that state or federal laws invalidate the contract (i.e., hiring an assassin is not legal purpose, and, therefore, you do not have a contract).
- **Legal Form** – Uses the appropriate language and format required by the state or nation in which the contract will be executed (e.g., a lease agreement in Pennsylvania may contain legally required language, rights, etc., that are different from a lease agreement in Virginia).

Contract Types

The client or owner should consider the following factors when deciding on the type of contract:

- How firm is the scope of work? Can it be fully defined at this point?
- How realistic are the milestones? How firm is the deadline?
- Are we willing to assume the risk if the cost increases due to unexpected events?
- Do the costs of the project need to be predictable?
- Is the final deliverable something that has routinely been created in the marketplace and/or by our firm, or is this more of a research and development project?
- Will the contractor be building according to the plans and specifications we give him, or will we be giving him some performance criteria and allowing him to decide how best to complete the project?
- Do we want this to be a Design-Build project or a traditional Design-Bid-Build?

There are three general categories of contracts, each with its associated risks:

With a **Fixed-Price Contract**, the owner or client pays a pre-set price for a defined scope of work. From the owner's/client's point of view, a fixed-price contract is preferable, because most of the risk is borne by the contractor, who is bound by the contract to provide the deliverable(s) at a predetermined, rigid cost. The advantage to the owner is that the price is set, and any overruns are borne by the contractor. Only if there are legitimate changes to the scope, might the price change, and the owner and contractor would negotiate a change order.

There are several subcategories of fixed-price contracts:

- Firm Fixed Price (FFP), in which the contractor assumes risk for unexpected increases in labor, materials, etc. The FFP also includes all costs, including profit. The risk to the owner is that the scope must be not just well defined but precisely defined; otherwise, the owner may be exposed to scope changes.
- Fixed-Price with Price Adjustment (FP-PA) contracts are typically used for very long, multi-year projects. FP-PA contracts account for external conditions beyond the control of both the owner and the contractor, such as the price of currency fluctuation (international projects), inflation, cost of local labor and materials, volatility of commodities, etc. Although, as in a FFP contract, the contractor assumes most of the risk under the FP aspects, the owner must assume risk for the price adjustment (PA) features of the contract. Typically, the contract would specify the category of price volatility for which the owner is willing to assume risk.
- Fixed-Price with Incentive Fee (FPIF) contracts specify financial incentives for performing on the project above the established baseline defined in the contract. FPIF contracts might have an incentive for reaching a milestone early. On the

other hand, there are penalties if the work is not performed according to the contract. FPIF contracts typically have a set price ceiling. If the contractor goes over the ceiling, he is responsible for both bearing the excess costs and completing the work for the set price. In FPIF contracts with a price ceiling, there is often a maximum fee and a share ratio specified. If the contractor exceeds the cost, his fee is reduced by a certain percentage. Conversely if the contractor completes the work within the fixed price, he receives at least a percentage of the maximum fee, and he could earn the total maximum fee if all criteria are met.

In **Cost-Reimbursable (CR)** contracts, the owner pays the contractor for all legitimate costs, including the cost of materials, supplies, and raw labor costs (i.e., salaries or hourly wages not marked up with profit). CR contracts are typically used when the scope has not been very well defined or for research and development projects. The owner assumes more risk on a CR contract because the contractor knows he will be reimbursed for all costs; therefore, there is often no real incentive for the contractor to contain costs. Often contractors submit a low bid to account for the risks associated with potential cost increases, knowing that their costs will be covered.

There are several categories of CR contracts:

- Cost Plus Fixed Fee (CPFF) contracts give the contractor a fee, or specified amount for profit. The fee does not change. The contractor will still be reimbursed for all legitimate costs, but if he overruns the project, his profit will still be the negotiated fee, but the percentage of profit (based on total project cost) will be lower. Conversely, if the contractor contains costs his fee will be a higher percent of profit (based on total project cost).
- Cost Plus Award Fee (CPAF) reimburses the contractor for all allowable costs plus a fee that is based on performance criteria. Whether and how much fee the contractor is to receive is up to the owner, is mostly subjective and is left to the discretion of the owner. In most CPAF contracts, payment (and amount) of award fee are not allowed to be appealed or disputed.
- Cost Reimbursable with Incentive Fee (CPIF) contracts, like all CR contracts, reimburse the contractor for all legitimate costs, but they add a predetermined fee as an incentive, based on achieving specified performance targets. Unlike the CPAF contract, which is based on subjective evaluation of the contractor, CPIF is based on objective criteria. CPIF is intended to motivate contractors to save project cost and/or time. Often CPIF contracts have a pre-negotiated cost-sharing percentage or ratio (e.g., 70/30 or 80/20) in which the owner and contractor split cost savings or overages.

With **Time & Materials (T&M)** contracts, the contractor charges a negotiated hourly rate for each labor category. The hourly rate includes overhead and profit. The contractor also charges for materials (supplies, subcontractors, equipment, etc.), often with a mark-up (typically 5-10%) to cover for handling and for the fact that the contractor often has to pay the subcontractors and suppliers before the contractor is paid by the owner. In a T&M contract, engineering firms typically negotiate hourly rates with higher profit for lower-level employees, and rates with lower profit for higher-level employees. This is because the bulk of the work—and hours charged—will be from lower-level employees. T&M contracts usually require the contractor or engineer to submit timesheets and receipts with the invoice. T&M contracts are typically used when the scope is somewhat defined. It is also used when the owner needs to supplement staff for an internal project.

Troublesome Contract Clauses

Every engineer needs to understand the general concepts of contracts and the associated clauses. It is not necessary for every engineer to be an attorney; engineers must understand just enough about contracts to seek legal advice when needed. There are clauses that can be troublesome, but depending on whether you are the owner or the contractor, your viewpoint may be different. The clauses are designed to protect the parties from undue risk, and they must be negotiated in good faith.

Many engineers don't read the fine print, either at the bid/proposal stage or when the contract has been awarded and terms must be followed. Many engineers think, "This is boilerplate. It's OK for me to sign this." We need to take the time to understand the implications of certain contract clauses on the profitability of our projects. The best thing to do is to seek legal advice. Attorneys don't design bridges; engineers shouldn't be interpreting contracts. Any attorney will tell you that it ALWAYS goes back to the contract. (Please note: This section was written by an engineer who has learned the hard way the power of contracts. This section was not written by an attorney.)

Payment

The payment clause lays out how and when the contractor will be paid. It could be upon completion of certain milestones (e.g., 30%, 60%, and 90% design drawings) or monthly invoicing. Some municipal contracts require invoices to be submitted by (for example) the third Tuesday of every month so that the invoice can be approved by the municipal board, which meets only once a month on the fourth Wednesday.

Rather than wait until the end of the contract, the engineer or contractor will want to be paid for work completed. The contract specifies a schedule of payments. It is very important for the contractor to advise their accounting department the exact

name and address of the person receiving the invoices. In addition it is important for the PM to understand what the client will and will not reimburse. For example, a client refused to pay for an electrolyte replacement drink on a construction project in the summer. The invoices were held up for two months until the PM understood the client's requirements. The disallowance was clearly stated in the contract. Many firms cut into profit because of these preventable mistakes.

Changes

Projects rarely go according to plan. The scope of work defines what is included in the project and what work is outside the project. Often changes occur on the project that will require changes in the contractor's scope of work. The contract needs to specify how these changes will be managed during the life of the project. Identifying changes immediately, documenting what changed and how the change will impact the contract (scope, schedule, or budget), and negotiating a change to the contract are vital to maintaining project progress and budget.

The change process must be agreed to before the contract has been signed; otherwise, conflict, misunderstanding, and delayed payment could result. When executed properly, change orders are as binding on the parties as their original contract. It is important to know who on the owner's side is authorized to approve changes and to what level. PMs should also know who in their organization is authorized to sign change orders. In addition, changes must be brought to the owner's attention immediately and adjustments made and signed. If the engineer hoards all changes until the end of the project, the owner may be surprised and may be inclined to not pay. Clients and owners hate surprises.

Indemnity

Indemnity clauses obligate one party to cover damages that have or might be incurred by another party. These clauses can be troublesome because they often go too far—for example, requiring Party A to indemnify Party B for losses caused by Party B's negligence. A fair Indemnity clause limits the indemnity "to the extent that the injury or property damage was caused by the negligent acts or omissions of the contractor..." For example, if a subcontractor is injured because of a contractor's negligence, the contractor must indemnify the owner against resulting claims.

Subcontractors

General

Many prime contracts actually shift most of the risk to the subcontractors via "flow-down" or "flow-through" requirements. Often these clauses make the subcontractor equally responsible for design errors and construction flaws—regardless of actual

responsibility—as well as for the same insurance, indemnity, etc., required of the prime contractor. This can be needlessly expensive for the subcontractor.

Note this language from an actual subcontract: “Subcontractor agrees to be bound to Contractor by **all** [emphasis added] of the terms of the Agreement between Contractor and Owner and by the Contract Documents and to assume toward Contractor **all** [emphasis added] of the obligations and responsibilities that Contractor by those instruments assumes toward Owner. All of the above documents are part of this Subcontract and shall be available for inspection by Subcontractor upon his request.”

More favorable wording would be to limit the responsibilities to the scope of the subcontractor’s work: “The Subcontractor agrees to assume toward Contractor all of the obligations and the responsibilities pertaining to the Subcontractor’s work that Contractor by those instruments assumes toward Owner and Subcontractor shall have the same rights and remedies against the Contractor as the Contractor has against the Owner.”

Payment

If you are a subcontractor, it is very important to understand when and how you will be paid. Some subcontracts are “pay when paid”, which means that you will not be paid until the prime is paid (and then it takes additional time for the prime to process your check). In some cases, the prime must include your invoice along with theirs, in which case you may not receive payment for 60+ days. Some contracts are “pay before paid”, which means that the contractor has to pay you and then send evidence of payment along with their invoice. This type is uncommon and is typically used on federal contracts where the subcontractor is a small firm. The worst form of payment clause for a subcontractor is “pay if paid”, which means that if the owner has a dispute with the contractor and the owner withholds payment, then the subcontractor’s payment is withheld by the contractor.

Additional Insured

If the contract requires that the prime and even the owner be named as “additional insured”, that should be a red flag to the subcontractor. It means that the prime (and perhaps other parties) become insured under the subcontractor’s insurance and are therefore entitled to coverage. The prime could turn over a suit to the subcontractor’s insurance company, who would be obligated to defend the prime, regardless of whether the subcontractor has been negligent. If this happens, the subcontractor’s insurance rating would be impacted, and his premiums may increase.

Timing of Performance

Many contracts state that the prime reserves the right to require the subcontractor to work at times convenient to the prime, and to perform their work in sequence per the prime's schedule. They may also state that changes in the project schedule will not change the project completion date or the subcontractor's contract amount. To make this more reasonable for the subcontractor, the clause should contain language about mutually agreeable times, subcontractor input to the project schedule, and "reasonable" changes.

VIII. Bonding

How Are Bonds Different from Insurance?

Surety bonds, like insurance, are a type of risk transfer. Surety bonds are legal relationships between the principal (the contractor), the owner (aka the obligee), and the surety (the company issuing the bond). A surety bond is not an insurance policy; rather, it is a guarantee that the contractor will perform the obligation stated in the bond. If the contractor fails to fulfill the obligation, both the contractor and the surety are on the hook. The owner may sue one or both parties to collect on the entire amount.

Bond Types

There are three typical bonds required on construction projects: Bid Bonds, Performance Bonds, and Payment Bonds. Most owners do not require a James Bond.

Bid Bonds

Bid bonds guarantee that the contractor will honor his bid and will sign the contract documents if he is awarded the contract. If the contractor does not honor his bid, the owner is protected from having to incur additional costs to re-let the contract. Usually the amount on the bond is the difference in dollar amount between the lowest bid and the second lowest bid.

Performance Bonds

Performance bonds guarantee that the owner will complete the work on the contract per terms and conditions. If the owner terminates the contract for default, or if the contractor defaults or delays, the surety bond will allow the owner to complete the work either by hiring a “completion contractor”, selecting a new contractor, or self-complete the work. The amount paid to the owner is usually the amount of the contract (plus the amount of any change orders that may have been issued).

Payment Bonds

Payment bonds ensure that the contractor will pay his subcontractors and suppliers for any work completed. This protects the owner from work stoppages due to non-payment by the contractor. The amount of the bond is intended to cover the anticipated subcontractor and supplier costs.

In the United States, the Miller Act of 1932 requires that all construction contracts issued by the federal government be backed by both performance and payment bonds. Most states have enacted “Little Miller Acts” requiring both performance and payment bonds on all state-funded projects.

IX. Handling Risk During Project Execution

Tracking and Controlling Risks

The risk register, which you created while planning your project, is your baseline for tracking risks throughout the project. The risk register is a dynamic document. In other words, the risk register you developed during planning is really your best guess at the threats that might happen or the opportunities you want to happen. As you execute the project, your risk register will be your guide to handling the risks. As risks come to fruition, the risk responses developed during planning will be activated. Some risks may be retired because they did not arise during the predicted project phase.

If additional risks crop up, you will want to go through the risk planning process (identify, qualify and quantify, develop risk responses) for each of these new risks. You will then add them to the risk register and manage them along with your other risks.

Part of tracking and controlling risks is to notice and document how well your risk responses are working, and whether the Risk Management Plan (RMP) is keeping risks at bay and/or ensuring opportunities. It also involves documenting the risk results, as well as the process effectiveness, so that others can benefit from these lessons learned.

Earned Value Management (EVM)

One of the best ways to flag risk on your project is to use earned value management (EVM). Unlike the investment world's caveat, "Current performance is not a predictor of future performance", a premise of EVM is that, using trend data, current performance is an indicator of future project performance. EVM was developed in the early 20th century by industrial engineers Frank and Lillian Gilbreth¹⁶ (some say they were the inventors of industrial engineering) but did not catch on until the 1960s, when the defense and aerospace industries embraced it.

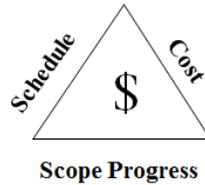
Before EVM, we had to measure project progress using just Planned vs. Actual. EVM incorporates the notion of progress on the scope of the project. Many PMs and project controllers used to say that, "If the project budget is 75% spent, the project must be 75% complete". All good PMs know this isn't necessarily the case. We may wish it to be true, but it often isn't.

EVM is a technique that takes the pulse of the project as of the date when you take the measurements (called the "data date"). EVM also predicts how the project may

¹⁶ The Gilbreths were a husband-and-wife team. There is a very interesting and funny movie about their work life and family life called *Cheaper by the Dozen*. (They had twelve children.)

finish (i.e., ahead of or behind schedule; over or under budget). You might envision the three legs of a triangle, as shown in Figure 4. The interpretation is that EVM takes Scope Progress, Schedule, and Cost and puts all in terms of dollars (or other currency) so that they can be compared.

Figure 4: Earned Value Management Components

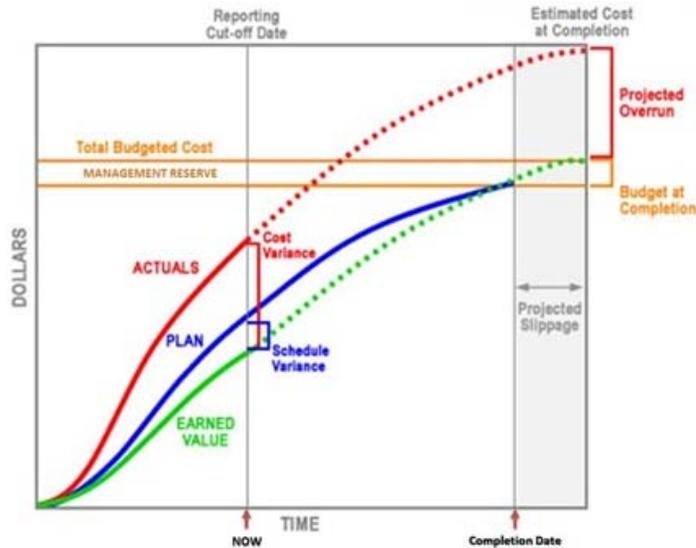


Periodically (usually weekly or at most monthly), earned value measurements (cumulative) are taken and plotted as shown in Figure 5. The S-curve labeled Planned Value (or PV) is the cost baseline. The cost baseline never changes unless the client/owner approves a change order, which could either increase or decrease the budget. Budget at Completion (BAC) is the approved budget. Actual Costs (AC) are, well, actual costs. Earned Value (EV), which is a calculated parameter in EVM analysis is “physical percent complete” multiplied by the budget. Physical percent complete is the measurement of scope progress. In other words, it measures how much of the scope has been completed. For example, if the task is to pour 100,000 cubic yards of concrete, and as of the data date, 50,000 cubic yards have been poured, the task is 50% complete.

The parameter EV represents the value or worth of the work actually completed as of the data date. The PV represents the value of the work we had expected to complete by the data date. The AC shows what it has actually cost to accomplish the work completed as of the data date. To calculate the EV, multiply the physical percent complete by the budget. If you want to find the EV of a task, multiply the physical percent complete for that task by the budget for the task. The EV for the overall project is calculated by summing up the EVs for each task.

Plotting the three values (EV, PV, and AC) as of the data date, as in Figure 5, gives a powerful visual. We can see immediately that both the AC and PV are above the EV. This means that the project is both over budget and behind schedule.

Figure 5: Earned Value Analysis Measurements



Selected EVM formulae (there are several more) are as follows:

Earned Value = Physical Percent Complete x Project Budget (aka Budget at Completion or BAC)

EV for a task = physical percent complete x task budget

EV for the project = the sum of task EVs

Overall physical percent complete for the project = project EV ÷ project budget

Cost Performance Index (CPI) = $EV \div AC$

Schedule Performance Index (SPI) = $EV \div PV$

Estimate at Completion (aka EAC) = $Budget \div CPI$

Projected cost overrun (or underrun) = $EAC - BAC$

Percent over (or under) = $(EAC - BAC) \div BAC$

Note that EV is a factor in all of these formulae. EV = physical percent complete x BAC. Therefore, the accuracy of the physical percent complete is key to the EVM analysis. Physical percent complete data come from the individual(s) managing each task. It is very important for the PM to verify the physical percent complete, especially for those tasks where the EV is very high (or low) compared with AC or PV.

All of these parameters can raise warning flags at any time. Cost Performance Index (CPI) and Schedule Performance Index (SPI) are the two most commonly used EVM parameters. Both indices are ratios.

Here are quick interpretations for **SPI** values:

SPI < 1.0 means that, as of the data date, the project is behind schedule

SPI = 1.0 means that the project is right on schedule

SPI > 1.0 means that the project is ahead of schedule

For **CPI**:

CPI > 1.0 means that the project is under budget as of the data date

CPI = 1.0 means that the project is on target budget-wise

CPI < 1.0 means that the project is overrun as of the data date

CPI also indicates the value of the deliverables for the money expended to date. In other words, if CPI = 0.89, it means that, for every dollar spent on the project to date, we got 89 cents' worth of work done. If CPI = 1.1, for every dollar spent, we got \$1.10 worth of work done.

CPI can also be used to forecast or predict the final project cost. The following formula is used when we assume that current performance will predict future performance:

Estimate at Completion (or EAC) = Budget at Completion (aka approved budget) / CPI

Therefore, if the CPI > 1.0, the BAC (or predicted final project cost) will be less than the current approved budget. There are several other formulae for EAC, depending on assumptions about current performance, original planning, etc. For more information on EVM, read pages 181 through 186 of the *PMBOK® Guide*¹⁷.

This has been a very brief overview of EVM. Bottom line: EVM can flag risks you might not have predicted, or that the response planned is not having the desired effect. Remember, percent spent is NOT the same as physical percent complete.

¹⁷ *A Guide to the Project Management Body of Knowledge (PMBOK®), Fourth Edition, 2008, Project Management Institute.*

X. Closing a Risk

Closing a Risk Is Pretty Simple

Your risk management plan (discussed in Section II, Planning Your Risk Management Approach) should list criteria for considering a risk “closed”. There might include:

- The risk is no longer considered a risk
- The risk has already occurred
- The risk can no longer occur

Lessons Learned

The lessons learned process is a project management best practice. It involves talking with the team and the client/owner to document the following:

- What went well on the project
- How the organization can continue these good practices
- What didn’t go well on the project
- What to do to prevent future occurrences

The very best practice is to document lessons learned throughout the project—not to wait until the project is complete. Too often memories get fuzzy by the end of the project, or people are glad the project is over and want to move on to the next project. A simple way to gather lessons learned is to update the risk register. If you do the updates throughout the project, your lessons learned task at the end of the project will be simple. Remember, though, to have conversations with team and client/owner to get feedback, and add that information to the lessons learned.

As you might imagine, information from past projects is valuable when identifying and managing risks for your project. Most PMs and team members skip the lessons learned step, or they carry the lessons learned in their heads. This is a missed opportunity to keep good practices front-of-mind. The lessons learned process can also help clear up any misunderstandings. For example, an environmental consulting company was under contract with a chemical company to investigate environmental conditions on many sites across the US. At the lessons learned meeting, the client expressed disappointment at not receiving hard copies of reports first thing in the morning. He had assumed that the company’s print shop was a 24/7 operation.

In many organizations, there is a lessons learned database where PMs and team members can quickly find information on the risks encountered and managed on previous projects, so that they can learn from their peers and predecessors. Another very valuable type of lessons learned database is one for subcontractor performance.

This typically includes the subcontractor name, contact name, etc., project name, service provided, and rating of subcontractor performance.

Lessons Learned: An Opportunity for Continuous Improvement

If you keep seeing the same risks (threats) over and over again, you may need to reconsider the way you do your work. For example, on a lot of projects, “not getting environmental permits on time” is a huge risk. Based on your experience, however, perhaps you know exactly what the permitting officer is looking for in the application. You can save time if the up-front paperwork is complete. It also helps to insist on a sit-down meeting with all the relevant environmental departments (e.g., hazardous waste, storm water, wastewater, stream encroachment, etc.) to agree exactly on the requirements. Most environmental entities appreciate the opportunity, because it saves them time, too. Of course, it also greatly reduces the risk on your project.

On some projects, particularly design-build (DB), you can ask the permitting agencies to use “progressive permitting¹⁸”. “Interim” permits are issued, allowing (for example) the site work and other limited construction to proceed before the final permit is granted. In DB projects, the construction begins although the design is still being completed. In “normal” (i.e., DBB) projects, permitting agencies review the entire design before issuing the permit(s). They may even require design changes, which may slow the project down.

Many organizations that see recurring risks often perform a root cause analysis (RCA). This is an objective method for digging deeper to find out why errors or challenges continue to happen, identifying a specific problem, why it happens (contributing factors, barriers, etc.), and developing ways to prevent or minimize future occurrences. The main RCA technique is cause-and-effect diagramming (also known as fishbone or Ishikawa). There are many references online to learn how to do the RCA, including the American Society for Quality (www.asq.org).

¹⁸ For a more detailed discussion of progressive permitting, please see *Preparing for Design-Build Projects: A Primer for Owners, Engineers, and Contractors*, by Douglas D. Gransberg, Ph.D., P.E., James E. Koch, Ph.D., P.E., and Keith R. Molenaar, Ph.D., ASCE Press, 2006.

Appendix 1

List of Possible Additional Column Headings for Risk Registers

There may be additional fields you want to put in your risk register. In addition to those already discussed, the list below show some examples. These lists are by no means exhaustive; however, you do not always need to have so many columns in your project's risk register. Use just what you think you and your team will need in order to manage risks—no more, no less.

From CalTrans¹⁹

- Status (active or retired)
- Unique ID #
- Risk type (i.e., threat or opportunity)
- Category (e.g., schedule, right of way, etc.)
- Description of risk
- Current status
- Person responsible
- Date updated or resolved

From US Department of Energy²⁰

- Success metric (how the team will know that the RM strategy worked)

¹⁹ From *CalTrans Project Risk Management Handbook: A Scalable Approach*, Version 1 (June 2012), page 18

²⁰ From *US Department of Energy Risk Management Guide, DOE G 423.3-7A*, 12 January 2011

Examination
Project Risk Management

PDH Now LLC
857 East Park Avenue
Tallahassee, FL 32301

1. Which of the following is NOT a method for contingency setting?
 - a. Gray hair
 - b. Pareto analysis
 - c. Monte Carlo
 - d. Fixed %
2. The formula for determining risk score is:
 - a. $P \times I$
 - b. $EV \div PV$
 - c. $(t_o + 3t_m + t_p)/6 = t_e$
 - d. $y = mx + b$
3. All of the following are methods of identifying risks EXCEPT:
 - a. Brainstorming with the project team
 - b. Talking with others who have worked on similar projects
 - c. Assigning probability rankings to risks
 - d. Reviewing lessons learned from past projects
4. The risk breakdown structure (RBS) shows:
 - a. Which individual is responsible for a given risk
 - b. What happens when the project breaks down
 - c. The relationship of each risk to its category
 - d. Both a and c
5. Which of the following is NOT a risk response method for Opportunities?
 - a. Accept
 - b. Avoid
 - c. Mitigate
 - d. Both b and c
6. All of the following are risk response methods for Threats EXCEPT:
 - a. Exploit
 - b. Accept
 - c. Transfer
 - d. Mitigate

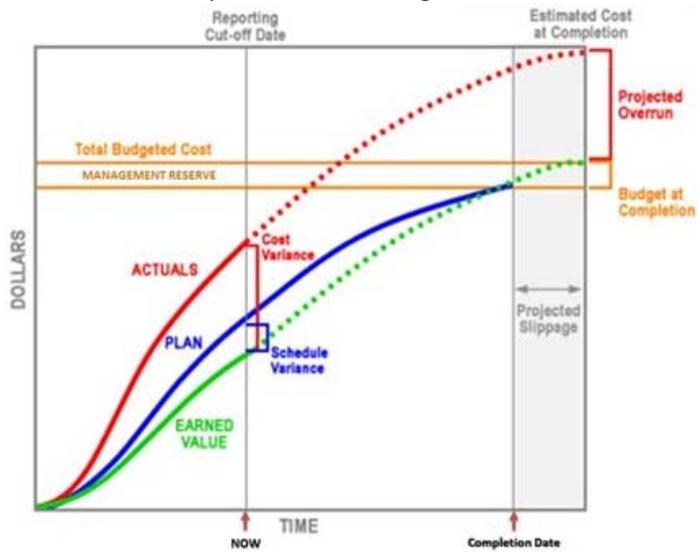
7. The method developed by the US Navy to incorporate elements of schedule and/or cost risk is called:
- PERT
 - CPM
 - GERT
 - Monte Carlo
8. The main drawback of critical path method (CPM) is:
- It uses a single duration estimate
 - It doesn't take risk into account
 - It can lull the project team and the client/upper management into thinking "this IS the finish date"
 - a, b and c
9. The type of risk that has the potential only for losses is called:
- Business risk
 - Acceptable risk
 - Insurable risk
 - Unacceptable risk
10. The risk response method that seeks to ensure that an opportunity comes to fruition is called:
- Enhance
 - Accept
 - Exploit
 - Share
11. The most widely used PERT equation is:
- $(t_o + 3t_m + t_p)/6 = t_e$
 - $(t_o + 4t_m + t_p)/6 = t_e$
 - $(t_o + 4t_e + t_p)/6 = t_m$
 - $(t_o + t_m + t_p)/6 = t_e$
12. The formula for CPI is:
- BAC x EV
 - EV x physical percent complete
 - EV ÷ PV
 - EV ÷ AC

13. The category of contracts that places more risk on the contractor is:
- Award fee
 - Cost plus percentage of cost
 - Cost plus incentive fee
 - Fixed price
14. Which of the following safeguards the owner if the contractor fails to finish the work?
- Breach of contract
 - Unforeseen conditions
 - Performance bond
 - Payment bond
15. Which of the following is true about contingency?
- Management reserves are under the project manager's control
 - Management reserves are a key element in the earned value calculations
 - Many organizations have a standard practice to add a specific percentage to the total cost to arrive at the contingency (e.g., 5% or 10%)
 - Management reserves are a part of the cost baseline
16. An issue:
- Is the same as a risk
 - Can be handled only by upper management
 - Is managed proactively
 - Is a problem in the present
17. Project risk is highest during the early stages of the project because:
- The contingency is small.
 - The scope may not be clearly defined.
 - Poorly made decisions at this point can affect project outcome.
 - b and c only
18. Risk tracking and control consists of:
- Identifying any new risks that may arise during the project
 - Describing your risk management approach
 - Developing risk responses to the new risks
 - a and c only

19. The most troublesome Payment clause for a subcontractor is:

- a. Pay-when-paid
- b. Additional insured
- c. Pay-before-paid
- d. Pay-if-paid

20. What is the correct interpretation of the figure below?



- a. The project is ahead of schedule and over budget.
- b. The project is on target.
- c. The project is behind schedule and over budget.
- d. The project is behind schedule and under budget.